ANNUAL REPORT

COAST AND GEODETIC SURVEY

FISCAL YEAR 1991

U.S. Department of Commerce
Robert A. Mosbacher, Secretary

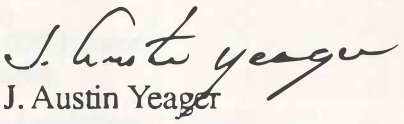
National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

National Ocean Service
John J. Carey, Acting Assistant Administrator

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

MESSAGE FROM THE DIRECTOR

On May 6, 1991, the Office of Charting and Geodetic Services became the Coast and Geodetic Survey (C&GS), a respected name in the mapping, charting, and geodetic communities since the 1870's. This annual report summarizes the major accomplishments of C&GS during FY 91. 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, 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

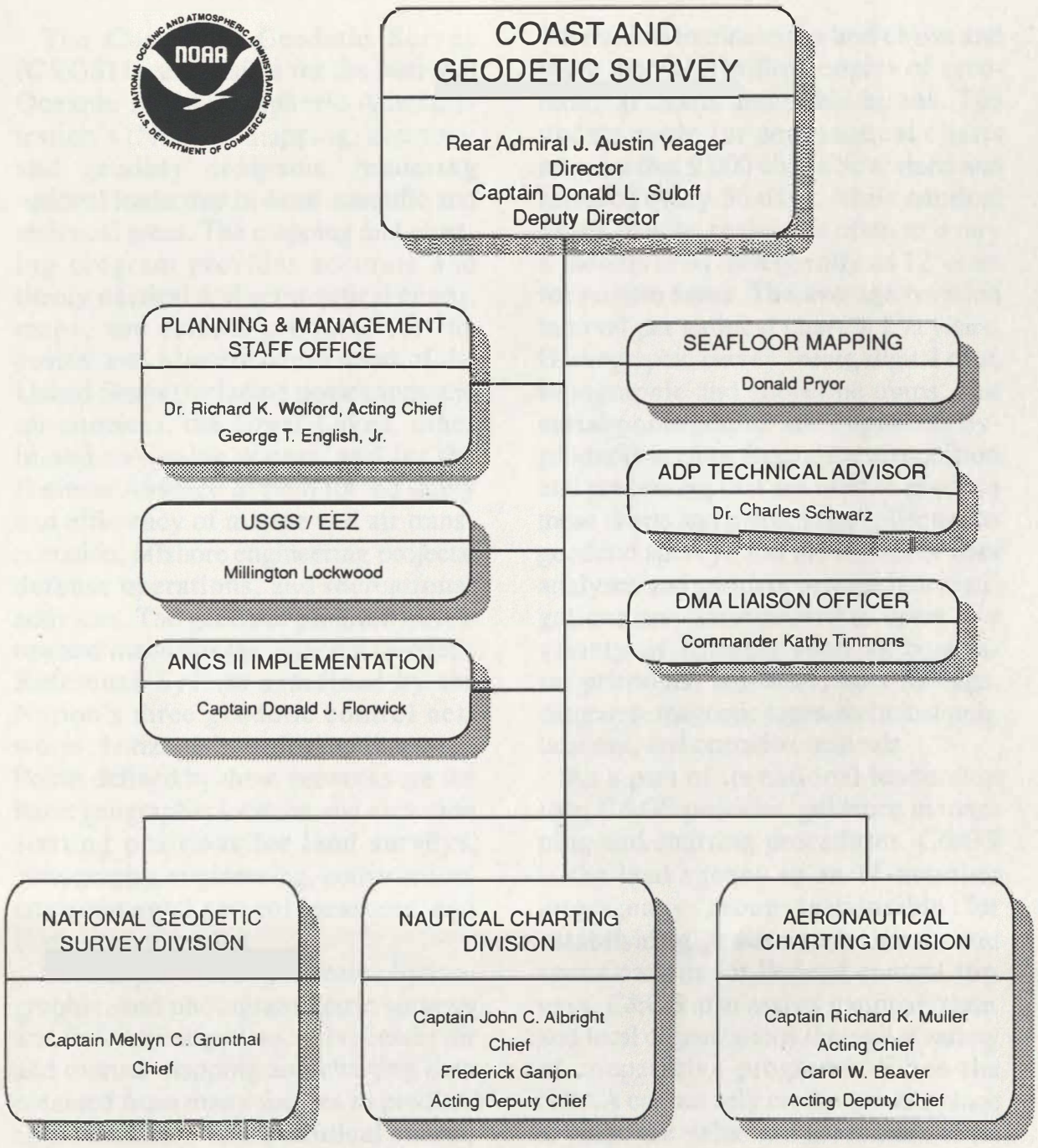
GLOSSARY OF FREQUENTLY USED ACRONYMS

AAS	Advanced Automation System
ACAS	Aeronautical Chart Automation Section
ACB	Aeronautical Chart Branch
ACD	Aeronautical Charting Division
ACT	Advanced Correlation Technology
ADAM	Airport Datum Monumentation Program
ADS	Automated Distribution System
AI	Artificial Intelligence
ANCS II	Automated Nautical Charting System II
ARS	Automated Reproduction System
ARTCC	Air Route Traffic Control Center
ATCSCC	Air Traffic Control System Command Center
CD-ROM	Compact Disk-Read Only Memory
CGDB	Chart Graphics Data Base
C&GS	Coast and Geodetic Survey
CIGNET	Cooperative International GPS Network
COE	U.S. Army Corps of Engineers
DACS	Digital Aeronautical Chart Supplement
DAS	Data Acquisition System
DB	Distribution Branch
DBMS	Data Base Management System
DBRITE	Digital Bright Radar Indicator Tower Equipment
DGPS	Differential Global Positioning System
DLG	Digital Line Graph
DMA	Defense Mapping Agency
DMAHTC	DMA Hydrographic/Topographic Center
DOC	Department of Commerce
DOD	Department of Defense
DOI	Department of the Interior
DPS	Data Processing System
ECDIS	Electronic Chart Display and Information Systems
EEZ	Exclusive Economic Zone
FAA	Federal Aviation Administration
FGDC	Federal Geographic Data Committee
FGCC	Federal Geodetic Control Committee
GIS	Geographic Information System
GISL-NIST	GIS Standards Laboratory of the National Institute of Standards and Technology
GPS	Global Positioning System
HARN	High Accuracy Reference Network
HDAPS	Hydrographic Data Acquisition and Processing System
HYDEX	Hydrographic Surveys Information Extract
IDPF	Integrated Digital Photogrammetric Facility
IFR	Instrument Flight Rules

IGLD	International Great Lakes Datum
IHO	International Hydrographic Organization
JOMAR	Joint Office for Mapping and Research
KB-GIS	Knowledge-Based Geographic Information System
LAN	Local Area Network
MCB	Mapping and Charting Branch
MGIS	Microcomputer Geographic Information System
MIS	Management Information System
MSAW	Minimum Safe Altitude Warning (System)
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
NAVSTAR	Navigation Satellite Timing and Ranging
NGC	Next Generation Cartography
NCD	Nautical Charting Division
NCRDL	Nautical Charting Research and Development Laboratory
NGIB	National Geodetic Information Branch
NGRS	National Geodetic Reference System
NGS	National Geodetic Survey
NGSIDB	National Geodetic Survey Integrated Data Base
NGVD 29	National Geodetic Vertical Datum of 1929
NIDB	Navigation Information Data Base
NIST	National Institute of Standards and Technology
OC	Obstruction Charting
ORCA	Ocean Resources Conservation and Assessment
ORD-CIA	Office of Research and Development of the Central Intelligence Agency
PC	Personal Computer
PCDB	Production Control Data Base
PROM	Programmable Read Only Memory
RB	Reproduction Branch
RDBMS	Relational Data Base Management System
RPLS	Rapid Precision Leveling System
RVM	Radar Video Map
SA	Selective Availability
SBIR	Small Business Innovation Research
SDTS	Spatial Data Transfer Standard
SURDEX	Survey Boundary Index System
TAC	Terminal Area Chart
TDP	Time-Dependent Positioning
TDWR	Terminal Doppler Weather Radar
TPP	Terminal Procedures Publication
URF	University (of Maryland) Research Foundation
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
VFR	Visual Flight Rules
WORM	Write Once, Read Many (Disks)

CONTENTS

ACCOMPLISHMENTS OF THE AERONAUTICAL CHARTING DIVISION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Carol W. Beaver
Acting Deputy Chief

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 ter-ritories), 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 asdefined 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 FY91, C&GS issued 1.8 million marine maps and charts and more than 11.1million 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 the NOAA cannot rely on the market place 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

Geodetic State Advisory 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. FY91 accomplishments are cited in separate chapters, each devoted to one of the three C&GS Divisions—National Geodetic Survey, Nautical Charting, and Aeronautical Charting.

ACCOMPLISHMENTS OF THE NATIONAL GEODETIC SURVEY

NATIONAL GEODETIC REFERENCE SYSTEM

The primary mission of the National Geodetic Survey (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 FY91 is described below.

HORIZONTAL GEODETIC NETWORK

Processing of horizontal data into the North American Datum of 1983 (NAD83) continued with new Global Positioning System (GPS) projects and classically observed projects. In FY91, 158 projects containing 12,463 stations were processed. In addition to SUN workstations, a Hewlett-Packard and a Solbourne workstation are now used for processing horizontal geodetic adjustments. Results of the computations are loaded into the NGS Integrated Data Base (NGSIDB) within 1 week of completion. The priority on processing is (1) NGS GPS projects, (2) other agencies' GPS projects, and (3) classically observed projects.

Cooperative efforts to provide horizontal control were conducted in Michigan, Minnesota, Montana, South Carolina, and Washington, D.C. A special effort was undertaken to advise the Maryland-Delaware Boundary Project on the observations and results of their contracted survey. NGS continued to provide the Federal Aviation Administration (FAA) with horizontal control at airport facilities. New to the effort are those airports which are under consideration for LORAN approach procedures. During FY91, final coordinates were computed for 239 airports. Since the beginning of the project, coordinates have been computed for 1,311 airports.

POST-NAD83 REGIONAL ADJUSTMENTS

As GPS technology expanded, many states have determined that it is cost effective to upgrade the accuracy of the horizontal component of the NGRS within their respective state. NGS developed an implementation policy to address upgrading the accuracy of the NGRS on a statewide basis. This policy has been fully implemented in Florida, Tennessee, and Oregon. Plans and accomplishments are summarized in Figure 1.

Two primary milestones exist in a statewide upgrade. The first milestone is the completion of the statewide GPS survey and the adjustment of these GPS stations. The second is the adjustment of all the remaining observations in the state which include the historical classical data, lower order GPS data, and connections across state borders. The results of the GPS and classical data readjustments for the States of Tennessee, Florida, and Oregon have been loaded into the NGSIDB.

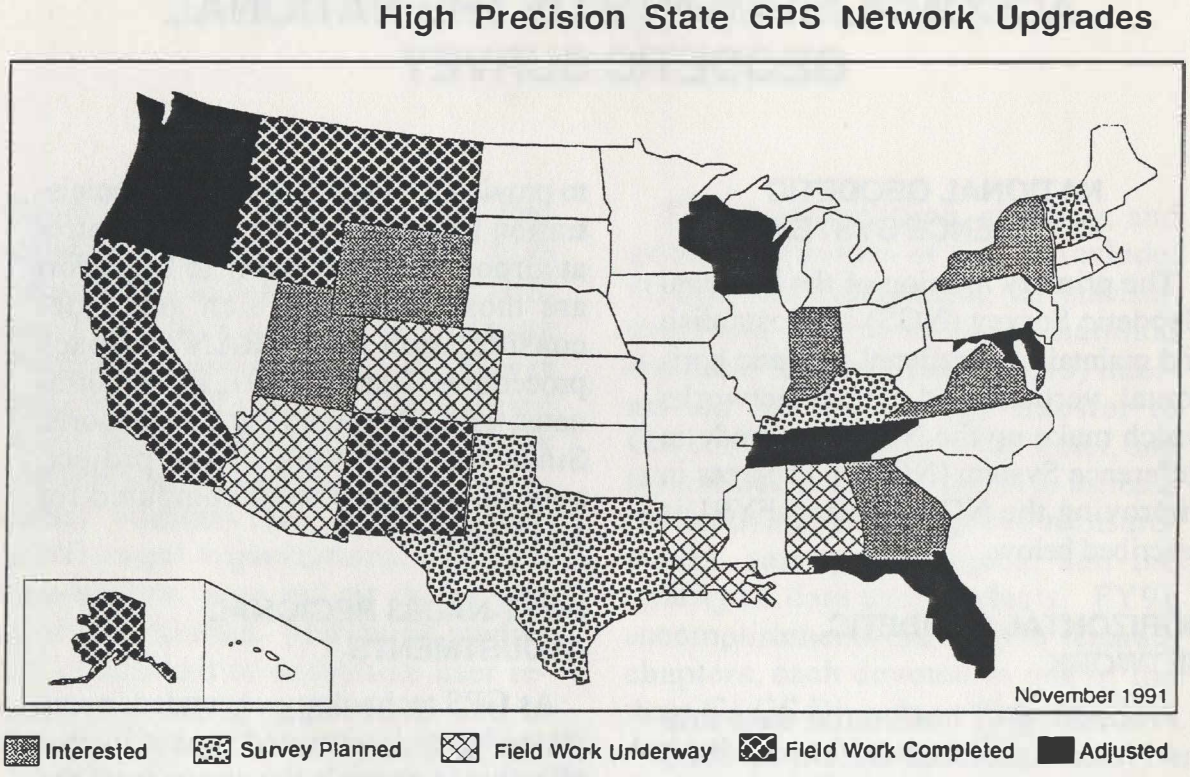


FIGURE 1. Map showing participation by states requesting NGS support in establishment of high precision networks based on GPS surveys.

VERTICAL GEODETIC NETWORK

Implementation of the North American Vertical Datum of 1988 (NAVD88) project, which redefined and readjusted the geodetic heights of the 585,000 bench marks in the NGRS, continues to be one of the major tasks of NGS. The project is part of an international effort, requiring close cooperation with NGS' counterpart agencies in Canada and Mexico: the Geodetic Survey Division, Canada Centre for Surveying; and Instituto Nacional de Estadistica e Informatica. This cooperation culminated in a 5-day technical exchange meeting in October 1990 in Aguascalientes, Mexico.

The U.S. portion of the project included the remonumentation and reobservation of an 81,500-kilometer subset of the vertical control portion of the NGRS. This subset, designated Basic Net A, provided the framework for the development of improved height values for the 585,000 bench marks. Leveling was accomplished to first-order, class II accuracy, according to Federal Geodetic Control Committee (FGCC) publication, *Standards and Specifications for Geodetic Control Networks*.

During FY91, international cooperation was enhanced by technical exchange meetings, exchange of leveling data, and continued joint investigation of several technical and research efforts involving NAVD88. Completion of the primary phase of the new adjustment was accomplished in December 1990. The resulting heights will be published in 1991-92.

All 105 U.S. geographic blocks of leveling data were processed through the Helmert blocking (final quality assurance) phase of the project. The highest level solution of the U.S. vertical network has been completed. A back solution of this network was performed and data outliers in the Helmert blocks were removed. The set of Canadian-reduced normal equations was combined with the set of U.S.-reduced normal equations. The special border junction point data that were inconsistent between Canada and the United States were resolved. Heights from the NAVD-88 General Adjustment were loaded into the NGS data base in July 1991. NGS has now begun the next phase of the NAVD88 project. This will incorporate the remaining 20 percent of the network to include "posted" and crustal motion points. This phase is expected to take 2 years.

The vertical control portion of the NGRS was strengthened by field survey projects in support of the NAVD88 readjustment program, cooperative leveling projects, and leveling by state, county, and private organizations. These surveys were accomplished primarily by NGS field units, U.S. Geological Survey (USGS), Maryland Department of Transportation, New Jersey Geodetic Survey, North Carolina Geodetic Survey, South Carolina Geodetic Survey, Imperial County in California, Florida Department of Natural Resources, Minnesota Department of Transportation, Louisiana Department of Transportation, Towill, Inc., and Woolpert Consultants. The Towill leveling data accounted for a 312-kilometer vertical control network for the Superconducting Super Collider Laboratory in Texas.

During FY91, NGS leveling units completed 3,500 kilometers of first-order geodetic leveling in the conter-minous United States. Surveys involving 8,100 kilometers of new leveling lines (both NGS and non-NGS) were processed for inclusion in NAVD88. In addition, 20,500 kilometers of Mexican first-order leveling were combined with the U.S. NAVD88 data.

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

- Vertical connections to the GPS statewide, high-accuracy reference network (HARN) stations in Maryland (Maryland Department of Transportation).
- Vertical connections to the statewide HARN stations in Delaware (Delaware Department of Transportation).
- Establishment of heights for bench marks used to determine deflection of the vertical by combining leveling and GPS data, Cape Canaveral, Florida (Naval Surface Warfare Center).
- Leveling to monitor vertical deformation in the Long Valley Caldera and Coalinga areas, California (USGS' Office of Earthquakes, Volcanoes, and Engineering).

The FGCC Vertical Subcommittee and the American Congress on Surveying and Mapping Ad Hoc Committee on NAVD88 continued to meet periodically to determine and document the impact of NAVD88 on users. Both committees recommended that NGS perform a minimum constraint, least squares adjustment of appropriate leveling data for NAVD88, and that the datum be shifted vertically to minimize recompilation of national mapping products.

NAVD88 satisfies these recommendations. The missions of both com-mittees have now been changed to concentrate on the implementation aspects of NAVD88.

The International Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, which is responsible for readjusting the International Great Lakes Datum of 1955 (IGLD55), recognized that "NAVD88, which uses geopotential elevations (numbers), will greatly enhance the single hydraulic vertical control methodology previously used in development of IGLD55." Draft recommendations by the Coordinating Committee state that the readjusted IGLD should parallel NAVD88 and that it use the same data involved in NAVD-88. The Coordinating Committee agreed with the minimum-constraint, least squares adjustment concept for IGLD and requested that IGLD heights be referenced to local mean sea level at Pointe-au-Pere (Father Point)/ Rimouski, Quebec.

In order to minimize the effects on USGS' national mapping products, as requested by users and to satisfy the Coordinating Committee requirements mentioned above, NGS selected the new International Great Lakes Datum (IGLD) local mean sea level height value at the primary water level station at Father Point/Rimouski as the minimum constraint (datum point) for NAVD88. This minimized the impact on national mapping products, thus NAVD-88 will effectively replace both the National Geodetic Vertical Datum of 1929 (NGVD29) and IGLD55.

The Vertical Network Branch, in cooperation with FGCC, also coordinated a test survey and evaluated the results of the WILD NA2000 digital leveling system. The system measures, calculates, and records leveling data electronically using bar-code leveling rods. A report, documenting the results of the test, has been prepared. Monitored by the Nautical Charting Research and Development Laboratory (NCRDL), work continues on the Rapid Precision Leveling System (RPLS) Project which will be discussed in the section on Accomplishments of the Nautical Charting Division. Various technical aspects of RPLS, which promises to minimize or eliminate atmospheric refraction errors in leveling, have been considered. Work has resumed on RPLS at NGS' Instrumentation and Equipment Section facility near Corbin, Virginia.

Preliminary results of the latest vertical control surveys of Orleans Parish, Louisiana, were presented by NGS personnel at a September 1991 meeting of the multiagency Geocadastre Steering Committee in New Orleans. The committee, chaired jointly by NGS and the Orleans Parish Regional Planning Commission, monitors and seeks to preserve the NGRS in the region. NGS results indicate significant continuing differential subsidence of about 1centimeter per year for the Orleans Parish area.

GRAVIMETRIC NETWORK

New gravity data were added to the NGS data base for the computation of the new high-resolution, U.S. geoid (GEOID90), including approximately 53,000 new gravity observations from the Defense Mapping Agency (DMA). The entire Canadian gravity data base was acquired and matched against NGS' existing data. Approximately 118,000 of these were new U.S. observations. The NGS gravity data base presently

contains 2.3 million observed gravity records. Efforts are now underway to improve the coverage, density, and accuracy of the gravity data base in preparation for the computation of a new North American geoid (GEOID95).

Regional geoid surfaces were computed for the Superconducting Super Collider Laboratory in Dallas, Texas, and analyzed by the University of Maine. These analyses confirmed the value of geodetic leveling and regional gravimetric geoids for the quality control of high-precision GPS surveys.

A multiyear, ad hoc NGS working group was formed to search for digitized terrain data and observed gravity data from other government agencies and private industry. The objective of the working group is to provide sufficiently dense geophysical data for the computation of the high-resolution national and North American continental geoids mentioned above. In addition to the data mentioned previously, the digitized topographic elevation data of Mexico were obtained as part of these activities.

GPS SURVEYS AND APPLICATIONS

NGS continued the application of GPS technology to geodetic surveying, including the development of software packages, transfer of technology to other government agencies and the private sector, and determination of precise orbits for the surveying community. The application of GPS technology, using signals from the Navigation Satellite Timing and Ranging (NAVSTAR) system being established by the Department of Defense (DOD), continued to be an efficient, economical, and accurate survey system.

NGS completed GPS surveys with 10 Trimble Navigation model 4000SST and 11 Trimble Navigation model 4000ST GPS satellite survey systems. The survey systems were used to observe GPS satellite surveys in the vicinities of Kayak Island to Cape Fairweather and FAA Radar Sites, Alaska; New Madrid Seismic Zone, Missouri; Yellowstone Park and Hebgen Lake subsidence areas, Montana; Greenwood and Laurens County areas, South Carolina; and the Alaska, California, Colorado, Delaware, Idaho, Maryland, Montana, and Washington statewide network upgrades. GPS surveys were also observed for the Department of Transportation in Idaho, the Census Bureau, the National Crustal Motion Network project in Alaska and California, and 3 projects in support of the Airport Datum Monumentation Program, and 8projects in support of the LORAN-C airport survey program in 23 states for FAA.

Besides NGS-observed GPS surveys, 64 GPS survey projects were received from other agencies including US 29 Survey, Northeast Alabama Project, US 43 Survey, US 82 Survey, US 280 Survey, Huntsville Survey, Annison Bypass Survey, Central Connection Survey, and Northwest Connection Project, Alabama; Noreado Network Survey, Arizona; Furson Bay Aids To Navigation and Moss Landing Harbor Survey, California; Telluride Airport Tie, Colorado; CSX Rail to Trail - Mabel to Polk City, SR87 - Santa Rosa County, SR40 & 46 - Lake and Volusia Counties, SR79 - Bay County, SR54 - Pasco County, and Navigation Aids - Egmont Channel, Florida; Albany-Dougherty Counties Survey, Georgia; Lexington Densification Survey, Kentucky; White Cote to

West Blanche Bay and St. Mary Parish Survey, Louisiana; WSSC Automated Mapping Study 1, Maryland; Lake Michigan Mapping Project, Whitefish Point and Sault Ste. Marie Project, I-94 Jackson County Survey, I-96 Livingston County Survey, I-75 Oakland County Survey, and M-43 Ingham County Survey, Michigan; Statewide

B-Order Upgrade and City of Las Cruces, New Mexico; Wallkill River Basin-Sussex County and Somerset County Survey, New Jersey; USCG Montauk Bay Survey, New York; Gaston County Project, Charlotte GPS Survey, NCSU Centennial Campus Project, Sea Grass Survey, and NCSU Hoffman Forest Survey, North Carolina; City of Cleveland Survey, Geauga EMMS Project, Summit County Project, Delaware County Survey, and ODOT District 1 Lima -US 30 & I-75, Ohio; Winchester Bay to Cape Ferrelo Project and Coos Bay Aids to Navigation, Oregon; Richland County Project, Charles County Survey, Southwest Spartanburg Survey, and North Spartanburg County Survey, South Carolina; Memphis B-order Survey, Tennessee; Matagorda Bay and Approaches Survey and City of Corpus Christi Survey, Texas; James City County Densification, VADOT Truslow Road Survey, City of Danville Survey, York River - Mobjack Bay Survey, City of Lynchburg Survey, Town of Culpeper Survey, Spotsylvania County Survey, and James and Appomattox Rivers - Richmond to Petersburg Survey, Virginia; Seattle Harbor Survey, Washington; and Statewide Network Upgrade, Wisconsin.

The projects above were completed in support of varied requirements including extension and densification of the NGRS, monitoring of vertical and horizontal displacements associated with tectonic movements, monitoring crustal motion network stations and connecting Federal Aviation Administration (FAA) airports to the NGRS, state and county geodetic network and control survey upgrades, and state highway surveys. NGS observed the following projects between October 1990 and September 1991 using GPS surveying techniques:

Number of projects	25
Number of receivers per project	5/10
Total stations occupied	2,488

No tests or demonstrations of new GPS satellite surveying systems were scheduled during the fiscal year. A total of 14 tests have been conducted since 1983 by the FGCC on the FGCC test network located near Washington, D.C. Initial contacts were made by three manufacturers for tests to be conducted in early FY92.

Use and enhancement of NGS' GPS orbit computation software continued. Tracking data for 16 GPS satellites were routinely received from 20 Cooperative International GPS Network (CIGNET) tracking stations throughout the world. See the map shown on Figure 2. The CIGNET data were prepared for (1) archival purposes, (2) distribution, and (3) for computation of precise GPS orbits with the NGS orbit software package PAGEII. Distribution of precise GPS orbits by DMA for the civilian GPS user community continued. Computation of precise GPS orbits by NGS began in April 1990. NGS released its first accurate orbital data on September 25, 1991. The orbital data, called precise ephemeris data sets, give the location of each of the 16 GPS satellites of the NAVSTAR system currently in orbit for

FIGURE 2. Map of the world showing location of GPS satellite tracking stations. Since other nations cooperate in this program, the network is called the cooperative International GPS Network (CIGNET). These stations provide the data needed by NGS to determine GPS satellite ephemerides for the civilian community.

three 7-day periods beginning July 21, 1991. Additional 7-day orbital data sets will be released on a weekly basis. The 6-month lead time was planned to ensure the software was working properly, personnel were thoroughly trained, and verification procedures were in place.

Other GPS satellite survey developments are as follows:

- Operational kinematic GPS field units completed observations in support of the FAA Airport Datum Monumentation Program (ADAM) program in Illinois, Missouri, and Wisconsin. A similar observation program was used to support the FAA LORAN-C airport program in 22 states.
- The operational use of the GPS vector reduction package, OMNI, continued at the NGS headquarters in Rockville, Maryland, and on two of the NGS GPS field units. A version of the package with multitasking capabilities and utilizing windowing techniques was completed. The software package has been used successfully with data in formats from four different GPS receiver manufacturers, both in single manufacturer and mixed manufacturer combinations within the same observing session.
- All NGS GPS field units are now experienced in conducting least squares adjustments of field-reduced vector data, and this analysis is now being carried out on a routine basis. All orbit tracking data and computation results, office vector computations, field computa- tions, and raw GPS observations were routinely archived on optical WORM (Write Once, Read Many) disks. This significantly

reduced the cost of storing the data, reducing the space required, and extending the projected usable life span of the storage media when compared with nine-track tapes.

THE NATIONAL GEOID, GEOID90

Precise geoid heights are becoming more important because they relate the ellipsoidal heights obtained from GPS satellite measurements to the orthometric heights obtained 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 recognition of the evolution of surveying techniques, NGS recently computed a high-resolution geoid height model for the conterminous United States called GEOID90. The geoid model displayed in Figure 3 was computed using nearly 1.5 million pieces of gravity data held by NGS, terrain data from NOAA's National Geophysical Data Center in Boulder, Colorado, and values from The Ohio State University geopotential model, OSU89B. The result is a grid with 3-mile spacing in latitude and longitude. The geoid heights are referred to the Geodetic Reference System 1980 (GRS80) ellipsoid, and range from a low of -53 meters in the Atlantic Ocean to a high of -5 meters in the Rocky Mountains. At this resolution, known geologic features, such as the Mid-Continent Gravity High near Lake Superior and the Wichita Arbuckle System north of Texas are clearly evident.

GEOID90 is a digital product and is distributed on computer diskettes through NGS' National Geodetic Information Branch. The GEOID90 model has received wide acceptance and has been incorporated into the software of several corporations developing GPS surveying technology. The accuracy of the GEOID90 model is estimated at approximately 10 centimeters (one-sigma), although in some locations of the country, long wavelength errors up to a 2 parts-per-million level may occur. It is anticipated that the greater use of GPS will lead to demand for geoid models of increased accuracy. NGS is conducting research on techniques for achieving this goal.

DEFLECTIONS OF THE VERTICAL

The increasing use of the GPS satellite system for geodetic control surveying has led to an unforseen requirement. Among the many advantages of GPS surveying is the freedom in placement of control points without any concern for intervisibility. However, surveyors using traditional techniques usually require two nearby points of known orientation to provide an initial alignment of their surveys. That orientation is supplied by means of a supplemental point known as an azimuth mark. Currently, it is more economical to establish azimuth marks by means of astronomic measurements. Therefore, the greater use of GPS has fostered an increasing requirement to convert astronomic azimuths into geodetic azimuths. This conversion requires the Laplace correction, which is computed by means of the deflections of the vertical (geoid slopes) of the Earth.

NGS computed a high-resolution deflection of the vertical model for the

FIGURE 3. Map of the United States depicting the geoid heights determined from the GEOID90 model which has been 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.

conterminous United States, known as DEFLEC90. DEFLEC90, a digital product distributed on computer diskettes, consists of gridded deflection values with a 3-mile spacing in latitude and longitude. A computer program is provided with DEFLEC90 to facilitate the inter-polation of Laplace corrections and deflections of the vertical at discrete points. DEFLEC90 was computed from the same gravity grid used to compute the GEOID90 geoid height model, ensuring compatibility.

CRUSTAL MOVEMENT ACTIVITIES

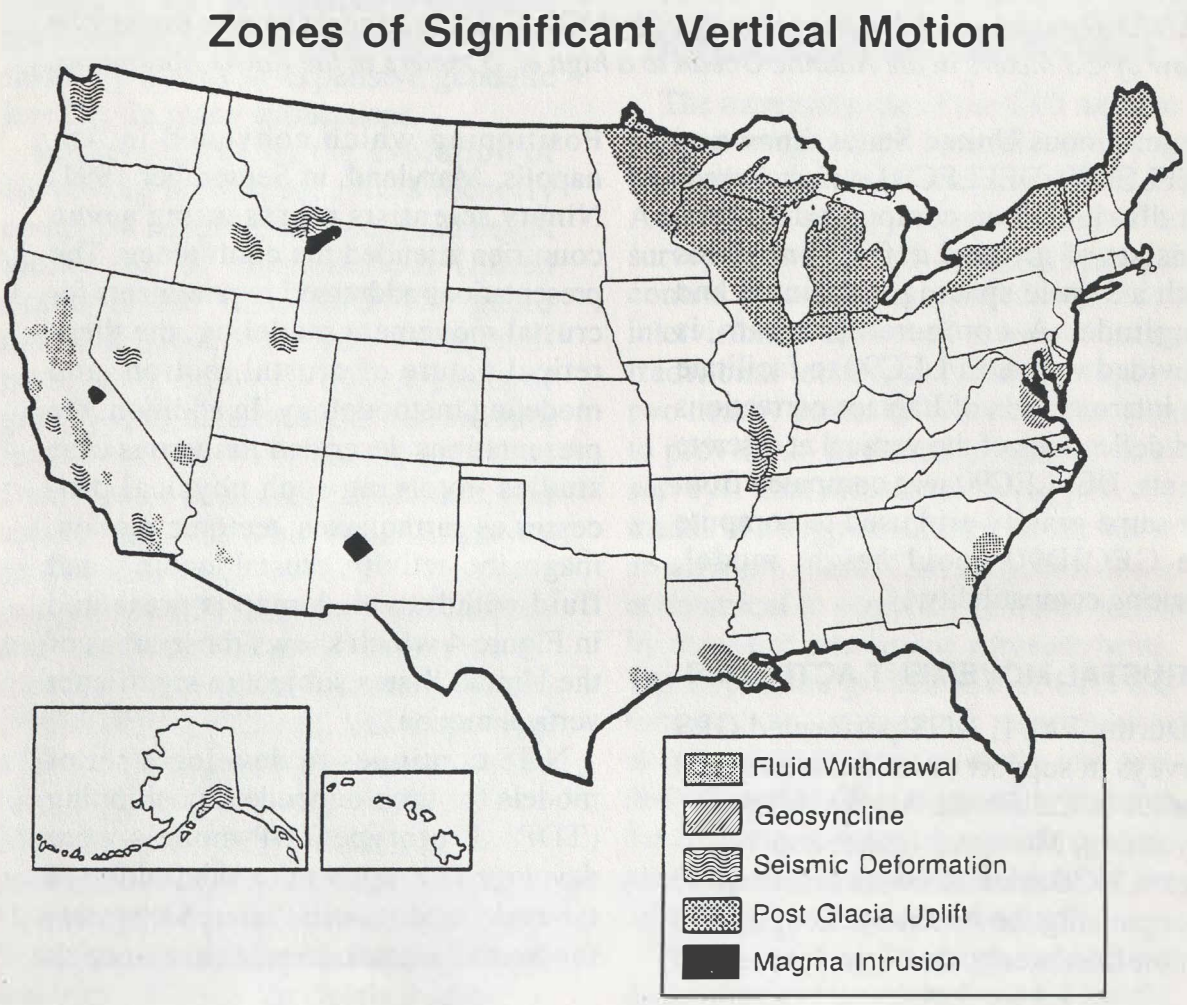
During FY91, NGS performed GPS surveys in support of crustal movement studies in California, Alaska, Missouri, Wyoming, Montana, Idaho, and Washington. NGS scientists were instrumental in organizing the American Geophysical Union Conference on Time-Dependent Positioning which convened in Annapolis, Maryland, in September 1991. Ninety scientists representing seven countries attended the conference. The presentations addressed requirements for crustal movement modeling, the theoretical nature of crustal motion, and modeling methodology. In addition, the presentations described numerous case studies involving such physical processes as earthquakes, tectonic motion, magmatic activity, crustal loading, and fluid withdrawal. A map is presented in Figure 4 which shows those areas of the United States subject to significant vertical motion.

NGS continues to develop a set of models for time-dependent positioning (TDP). Prototype TDP models were developed to support the redefinition of the horizontal geodetic reference system for North America. In particular, models

for horizontal crustal motion were developed for 19 tectonically active regions in the United States. Sixteen of these regions combine to span California. The other three regions span areas in Nevada, Alaska, and Hawaii. Model parameters were estimated from more than a century of triangulation/trilateration data including about 8 years of the precise electro-optical distance measurements observed under the auspices of the USGS Crustal Strain Project. These models were employed to "homogenize" the 150-year span of geodetic data archived by C&GS. That is, each triangulation/trilateration observation contained in these 19 regions was updated to approximate in value that which would have been observed on December 31, 1983. Thus, derived horizontal positions for the new North American reference system correspond to positions for this date.

More recently, the 16 models for horizontal motion in California have been superseded by a single, unified model. The new model incorporates 11 more years of data than that used for the 16

FIGURE 4. Map of the United States showing zones of significant vertical motion caused by various physical processes.



original models, including 7 years of regularly repeated very long baseline interferometry observations at 19 sites. Predicted velocities for the California model are thought to be accurate at the 5 millimeters/year level.

Models for vertical crustal motion are also being developed to define a dynamic geodetic reference system in that dimension. NGS has identified 22 regions in the United States where significant vertical motion has occurred as shown in the figure. Models have already been developed for three of these regions: Washington State; Yellowstone Hebgen Lake; and Houston, Texas. Moreover, models for three additional regions are presently under development: Prince Williams Sound, Alaska; the Great Lakes region; and New Orleans, Louisiana. Parameters for vertical models are estimated primarily from leveling data and tide gage data archived by C&GS.

TECHNOLOGY TRANSFER

Transfer of technology to state, county, private surveyors, and engineers continues to be an important activity within NGS. NGS presented 13 horizontal workshops to over 1,000 state, local, and private users of the NGRS. The presentation of the workshops on State Plane Coordinates, Datum Transformation, Geographic Information Systems (GIS), and Planning and Adjustments have been evaluated by the participants themselves to be of great value. A new workshop on Project Planning and Adjustments was developed and presented to a variety of audiences including local surveyors, government land specialists, and state highway officials. These complex ideas are presented in such a way that effectively explains many difficult concepts in working with the new GPS technology.

In May 1991, a 2-day Vertical Control Workshop was presented in Anchorage, Alaska. This was followed by nearly 2 weeks of practical training of three surveying units provided by the Alaska Department of Transportation and Public Facilities during which actual first-order field leveling was performed. In September 1991, the first in a series of NAVD88 implementation seminars, which will be presented for the next several years, was presented in Tallahassee, Florida.

NGS headquarters office personnel again trained NGS field personnel as well as employees of other Federal agencies in the use of microcomputers and GPS vector computational procedures. A 2-week training session in GPS technology was conducted for employees of the Bureau of Land Management (BLM) and the Forest Service. Under provisions of a formal Memorandum of Understanding, NGS is assisting BLM offices in their implementation of GPS for cadastral survey applications. In addition, NGS presented a week-long seminar on GPS technology to members of the Mexican Surveying Agency at Aguacaliente, Mexico, and participated in the Civil GPS Service Information Committee.

Technology transfer was also supported by participation in panel discussions, technical papers, speeches, and the training of national and international scientists and surveyors visiting NGS. NGS continues to be an international focal point for GPS field work, dev-elopment, and information. NGS is committed to the continued development of GPS as the primary surveying system for both the public and private sectors.

Work on the development of *Multipurpose Land Information Systems: The Guidebook* continued. The first release (Chapters1 through 3) was published in February 1990. The second release (Chapters 4 through 7) was published in October 1990. The third release (Chapters 8, 9, 10, and 16) will be published early in FY92.

The NOAA state geodetic advisory program is a cooperative 50/50 cost-sharing program between Federal and state governments. C&GS assists the states with their geodesy 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 (Figure 5) summarizes the status of the number of states currently participating.

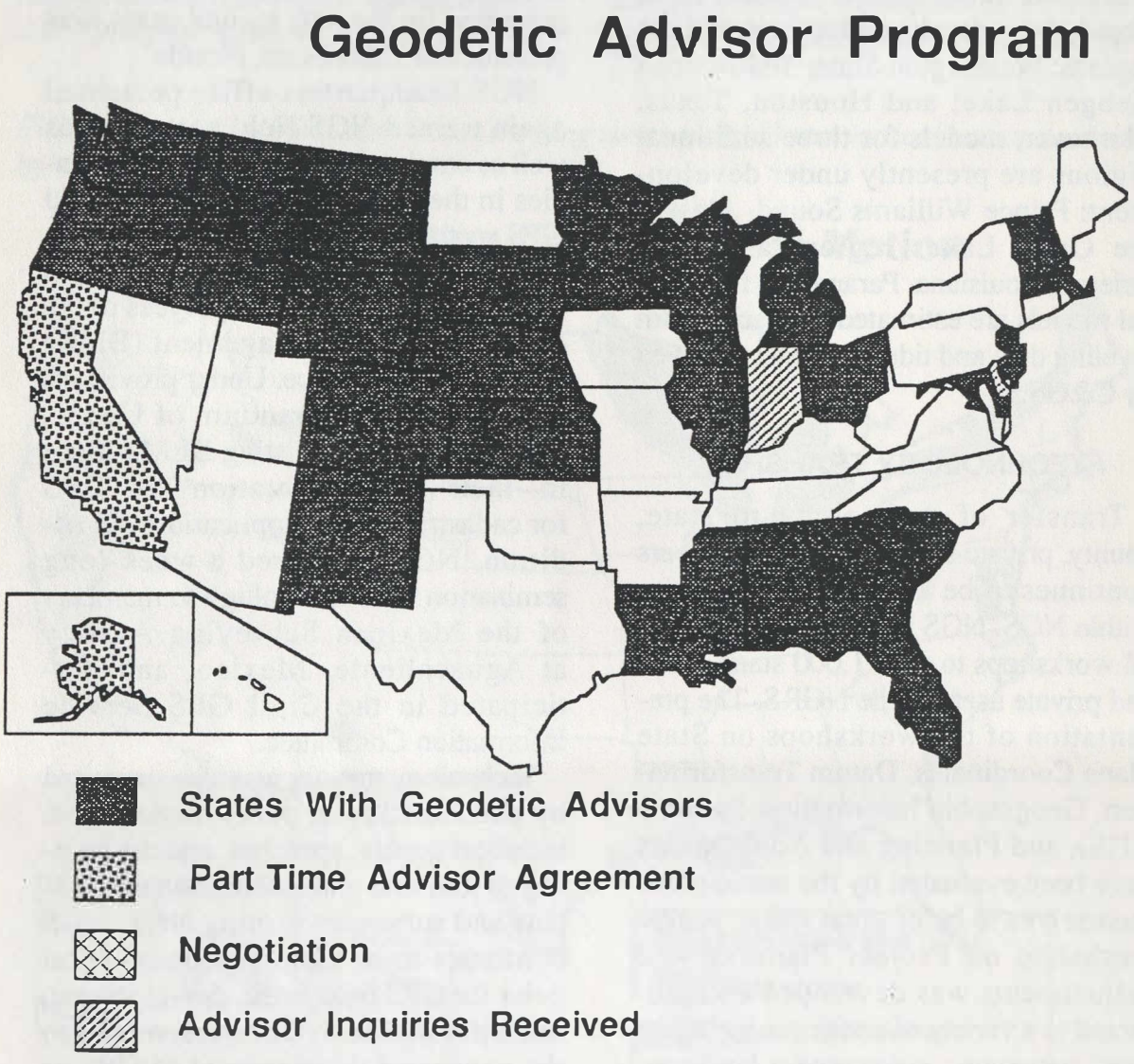


FIGURE 5. Map of the United States showing state participation by the states in the NGS State Geodetic Advisory Program.

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. The NGIB also conducts a marketing program to increase user awareness and understanding of these products and to improve NGS' responsiveness to its users. Major accomplishments during FY91 are as follows:

- Distributed the second set of chapters of the *Land Information System Guidebook.*
- Distributed Lambert and transverse Mercator projection tables for the State Plane Coordinate System of 1983.
- Distributed the final NAD 83 report.
- Distributed new software products to convert coordinate data from NAD 27 to NAD 83.
- Distributed geodetic data for 28 states and the District of Columbia for use with VICES, a computer-based tool that allows users to retrieve and display control point and map name information.
- Conducted cost studies to ensure that the prices for all NGS information products are consistent with agency pricing guidelines.
- Provided numerous publications, historical records, and the results of research investigations in order to fulfill diverse requests from universities, individuals, government agencies, and businesses throughout the United States and from other countries.

In addition, the NGIB undertook the following steps to improve the quality and availability of geodetic data:

- Consolidated data distribution from two locations to one.
- Automated approximately 60,000 station recovery notes under a contract with Management Technology, Inc. The contract began in October 1990 and was completed August 1991 and eliminated the entire file of backlog recoveries in paper form. In the future, recoveries will be automated by state geodetic advisors or others in-house as they are received to avoid future backlogs.
- Implemented improved station description processing procedures.
- Implemented the Description Integration System, a way to unify all description tables in the NGSIDB.
- Submitted a proposal for a unified data sheet to replace separate data sheets for horizontal and vertical control points. The proposal was subsequently reviewed and approved, and software for the new NGS Data Sheet was designed and written.

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 Hawaii and in the Gulf of Mexico for the Exclusive Economic Zone (EEZ) program; hydrographic surveys were conducted in Alaska, California, Michigan, Texas, Louisiana, Alabama, Florida, and Rhode Island. C&GS continued the installation of new hydrographic data acquisition and processing systems aboard NOAA ships. Automated indexing and archiving systems for hydrographic surveys continued to be developed. Significant progress was made in positioning ships and field parties using the Differential Global Positioning System (DGPS). 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, final edit of the Nautical Chart Manual was begun, and support for the national Electronic Chart Display and Information Systems (ECDIS) Project was continued.

MAPPING THE EXCLUSIVE ECONOMIC ZONE

On March 10, 1983, a significant step was taken concerning the exploration and management of both living and nonliving marine resources when the President proclaimed the U.S. territorial EEZ. This area encompasses 3.4 million square nautical miles of the ocean and seafloor within 200 nautical miles of the U.S. coastline. It includes not only the waters of the continental United States, but also its possessions and trust territories. NCD has established a major program to determine the characteristics and resources within the EEZ by using modern survey techniques to provide high-resolution bathymetric maps of areas rich in resource and scientific potential.

The Joint Office for Mapping and Research (JOMAR) consisting of representatives from C&GS and the U.S. Geological Survey (USGS) coordinates the EEZ mapping and research activities of both agencies. USGS provides copies of imagery data acquired on relatively small-scale surveys that NCD uses for planning and evaluation. NCD, in turn, provides USGS with large-scale detailed bathymetry to support geological interpretation of the seafloor.

Multibeam swath sonar systems are installed on four NOAA ships. The SURVEYOR, DISCOVERER, and MT. MITCHELL are equipped with the Sea

Beam system and can survey areas where the depths range from 600 to 11,000 meters. The WHITING, equipped with Hydrochart II, surveys between 150 and 1,000 meters of water depth. Thus, all of the continental shelf, slope, and upper rise may be surveyed including the deeper areas of the U.S. EEZ such as the Aleutian and Puerto Rico trenches. More than 105,000 square nautical miles of the EEZ have been surveyed. These surveys include coastal Alaska, Hawaii, California, Oregon, and Washington in the Pacific; Mississippi and Louisiana in the Gulf of Mexico; and Virginia in the Atlantic. The early 1989 installation of an intermediate depth swath survey system on the WHITING has allowed delineation of the upper reaches of the economically important Gulf Coast Salt Dome Province. These multibeam surveys provide 100 percent coverage of the seafloor, yielding details never revealed before in the U.S. continental shelf and slope areas.

Use of the commercially available STARFIX navigation system by the MT. MITCHELL and WHITING in the Gulf of Mexico has resulted in a significant increase in survey productivity. GPS navigation was successfully used in the differential mode by the DISCOVERER in Hawaii. Deployment of the full GPS satellite constellation by the DOD will be critical to the completion of EEZ surveys. The installation of the MicroVAX II data acquisition and shipboard processing systems on the MT. MITCHELL and WHITING has resulted in significant improvements in both shipboard ability to monitor data quality and processing efficiency. The parallel development of a MicroVAX II-based verification and map processing system at C&GS headquarters has streamlined the map production system and has the promise of generating new products and efficiency within the Ocean Mapping Section of NCD's Mapping and Charting Branch (MCB). To date, data for 13 map areas in the Gulf of Mexico have been acquired, verified, and processed resulting in a finished map product that completely utilized the MicroVAX II systems.

In 1989, DOD reevaluated its position relative to the classification of all multibeam data within the U.S. EEZ as a potential security threat. DOD withdrew objection to publication of multibeam data within 97percent of the total area of the EEZ. Since October 1989, C&GS has published 32 1:100,000-scale maps. The orderly dissemination of digital data began in FY91.

A cooperative project with the NOS Office of Ocean Resources Conservation and Assessment recently has been initiated to develop gridded digital bathymetric data on the continental shelf to support marine GIS and bathymetric map production.

HYDROGRAPHIC SURVEYS

The Hydrographic Surveys Branch (HSB) planned and conducted hydrographic surveys during the year using four ships and two mobile field parties in the following areas: Togiak Bay, Alaska; Dutch Harbor, Alaska; Icy Strait, Alaska; Cross Sound, Alaska; Skagway, Alaska; Sacramento River, California; southern New England coast, Rhode Island; approaches to Cameron, Louisiana, and Sabine, Texas; approaches to Corpus Christi, Texas; approaches to Mobile, Alabama; approaches to Pensacola, Florida; Corpus Christi and Aransas

Bays, Texas; and Matagorda and Lavaca Bays, Texas. Also, a special survey was accomplished in southern Lake Michigan, in support of JOMAR.

HYDROGRAPHIC SURVEY BOUNDARY INDEX AND HYDROGRAPHIC SURVEYS 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 75 percent of the C&GS hydrographic survey inventory. New software presently under development will permit the digitization of the remaining 25 percent (offshore survey inventory) during 1992.

The Hydrographic Surveys 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 1991. HYDEX incorporates information about each registered hydrographic survey commencing with registry number H-05000 (circa 1929).

DIGITAL ARCHIVE

The HSB continued working with NCD's NCRDL during 1991, resulting in the transfer of 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.

The HSB has acquired a GIS workstation along with a magneto-optical disk drive. This will facilitate a more economical transfer of all digital hydrographic survey data to optical disk media to meet the growing need for this information. Continued transfer of digital data is in abeyance pending software development. The GIS will allow simultaneous retrieval and display of HYDEX, SURDEX, and digital data.

HYDROGRAPHIC DATA ACQUISITION AND PROCESSING SYSTEM

All NOAA field units conducting hydrographic surveys had Hydrographic Data Acquisition and Processing System (HDAPS) capability during FY91. 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: ships, 29-foot Jensen launches, and 22-foot 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 MS-DOS compatible computers. The major enhancement to the DAS systems in FY91 was the integration of DGPS as the primary navigation system. DGPS was used by both the Atlantic Hydrographic Party 2 in Michigan and the RUDE in northeastern Long

Island Sound. The Atlantic Hydrographic Party 2 established its own local differential network, whereas the RUDE received its differential correctors from the USCG beacon on Montauk Point, Long Island. HDAPS Range-Azimuth capabilities have also been enhanced.

The DPS units underwent numerous revisions and enhancements during FY91. Development has focused on improving data processing capabilities while maintaining "user friendliness." Enhancements have been made to the side scan sonar contact file, sounding edit functions, position recomputation functions, and plotting routines. On-screen plotting of survey parameters such as plotter sheet boundaries and horizontal control stations has also been implemented. In addition, a program has been developed that assigns each sounding in a survey an "excess level," based on depth which signifies that the sounding should be plotted on the final field sheet. Less significant soundings may be plotted on a secondary plot, preventing clutter on the final plot. The net result is that the final plot contains the most significant soundings and enough supporting soundings to present a legible, accurate representation of the bottom topography.

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 the Photogrammetry Branch (PB) to provide new coastline data and information needed for the production of nautical and aeronautical products. Program activities include aerial photographic surveys, coastal mapping, shoreline surveys, location of aids to navigation, nautical chart revisions, airport obstruction surveys, chart construction, submerged aquatic vegetation mapping, and marine sanctuary boundary demarcation.

During the year, 2 air photo missions supplied 92 rolls (16,500 frames) of aerial photography to meet photogrammetric surveying and mapping requirements. Airport photography was secured throughout the conterminous United States. Aerial photographic coverage that is required for new shoreline mapping was carried out in California, Washington, Texas, Virginia, Michigan, Illinois, Indiana, Ohio, South Carolina, Georgia, and North Carolina. In addition, 31 major harbors along the west coast were photographed. Geodetic ground control required for mapping these harbors will be established after the fact to locate photo-identifiable points. Such an undertaking would not have been feasible before the introduction of GPS technology into the aerial photographic mission.

Total surveying and mapping accomplishments include completing 168 airport surveys, 22 special airport NAVAID surveys, 142 LORAN surveys; publishing 123 Airport Obstruction Charts, 127 LORAN surveys, 21 special surveys, and 126 Airport Obstruction Data Sheets; and completing 7 shoreline mapping projects consisting of 78 maps. The shoreline mapping projects (registered maps) provide coverage in the following areas: North Carolina (9), South Carolina (15), Maryland (1), Alaska (23), Texas (13), Washington (2), and Michigan (5).

As part of the field operations required to support coastal mapping, approximately 155 horizontal control stations were established (23 by conventional surveying techniques and 132 by GPS), an additional 86 network stations were recovered and positioned, and 15 horizontal control projects were submitted to NGS for final adjustment.

Other important accomplishments during FY91 included the following:

- The PB continued work on a new Coastal Mapping Program Operations Manual. This manual will consist of a series of stand-alone sections, each dealing with some aspect of the program which can be readily updated as required by advancements in technology. Section 6, Aerotriangulation, was accepted at the Division level and implemented. The first coastal mapping project has been quality assured using the specifications contained in Section 3, approved in FY 90.
- Airport survey parties were converted to a completely digital electronic surveying system. Additional efficiencies will be realized when this system is used in conjunction with the recently procured GPS receivers and analytical plotters. Digital levels were introduced for the first time, again in order to maximize survey efficiency.
- Work has begun on a flight management system which should bring greater efficiency to the conduct of aerial photographic operations. The system is based on very precise near real-time GPS pseudo-ranging, a CD-ROM digital map file, and modern electronic camera technology. A 20-percent savings is anticipated for the overall flight mission. These savings will be directed to responding to other C&GS coastal mapping requirements.

DIGITIZATION OF PHOTOGRAPHIC DATA BASES

Since the 1930's, photogrammetric surveys have been conducted in support of coastal mapping and airport obstruction surveys. In 1989, the PB began loading a photographic data base which currently defines the geographic position of more than 382,500 photograph centers. This represents approximately 90percent of all archived photography. This year, the data base activities have expanded to include the loading of the corner coordinates of all topographic survey sheets in the archive. To date, 1,300 sheets have been added to the data base. The information is available to the entire Division via the C&GS Local Area Network (LAN). The photograph positions were digitized from the original master flight line diagrams and were stored in the data base. In the near future, the photo centers will be positioned in real-time by the GPS receiver installed on the aircraft. The photo center positions will then be printed on the border of the negative as the film is being advanced by the camera and loaded into the data base from computer-generated files.

MODERNIZATION OF PHOTOGRAMMETRIC INSTRUMENTATION

Photogrammetric operations have begun to reap the benefits of new technology. GPS has been integrated into an operational mode for geodetic positioning of survey markers as well as the positioning of camera exposure stations in the highly dynamic environment

of jet-powered aircraft. Analytical photogrammetric aerotriangulation and compilation have all but replaced conventional analog stereoplotter technology. The improvements in efficiency as a result of the new technology have allowed C&GS to participate and share its technology in cooperative programs with other NOAA offices that require high-accuracy mapping. The metric quality of mapping products has improved because the new instrumentation facilitates the overall accomplishment of the variety of tasks related to map production. The development of a truly seamless digital data base has become a reality.

In FY90, GPS receivers were deployed to C&GS coastal mapping field parties. For the past 18 months, paneled geodetic control has been established according to geometric requirements of the planned flight lines. In the past, the flight line design was compromised to take advantage of as much existing geodetic control as possible. The use of GPS has increased the overall accuracy of the photogrammetric mapping, strengthened the national network of geodetic control, and resulted in a greater efficiency for the geodetic survey operations. In speeding up the ground control surveys, C&GS accomplished 50 percent more projects than were originally planned in FY91.

Five analytical stereoplotters were accepted from the manufacturer and certified for map compilation as of October 1, 1990. Stereoplotter operators have been trained and began operations in a totally digital environment beginning on October 1, 1990. Three instruments are installed in the field Photogrammetry Section in Norfolk, Virginia. Two other units are installed in Compilation Section A in C&GS headquarters in Rockville, Maryland. The Norfolk-based instruments perform conventional compilation tasks. The Rockville-based units perform aerotriangulation and special compilation missions.

GPS-controlled photogrammetry took on a new meaning this year. Not only is the targeted control positioned by GPS methods, but also the exposure station of the camera. With the added *a priori* information for the exposure station, the required amount of paneled ground control will be significantly reduced. As a result, the PB has become more responsive to the mapping needs of NOAA. The need for long-range planning for ground control and premarking of ground control will be reduced. Periodic coverage of the entire coastline at a 5- to 10-year cycle can now become a reality. The implementation of this technology is expected to be phased in over the next 2 years as the GPS constellation of satellites is put into full operation.

Two major tests were conducted this year in cooperation with the State of North Carolina. The first test demonstrated the capability of calibrating the airborne photogrammetric systems operated by C&GS and North Carolina. The second test demonstrated the practical application of GPS-controlled photogrammetry for the accomplishment of large civil works projects. C&GS also participated in joint technology transfers with three universities, six state governments, the Environmental Protection Agency, the Canadian government, and several private companies. C&GS continues to explore the use of contracting with private industry for the acquisition of metric aerial photography.

NEW CHARTING PRODUCTS

Five new charts were issued during FY91. These included three "Official Use Only" charts covering Navy homeports near Corpus Christi, Texas, and in Mobile Bay, Alabama. The other two charts cover New Bedford Harbor, Massachusetts, and the lower portion of Cook Inlet, including Kachemak Bay, Alaska. Three nautical charts previously under the authority of the DMA were issued by C&GS for the first time. These were two charts covering the Mariana Islands, one showing LORAN-C, and the other showing OMEGA, plus a chart covering Bahia Laolao, Saipan and Sunharon Roads, Tinian.

NCD now maintains a suite of 992 nautical charts; 393 were published as new editions during FY91. A total of 169 charts depict the territorial sea limit and the contiguous zone (12-mile limit), 56 show the EEZ (200-mile limit), 28 show the Natural Resources Boundary (3-league limit), 283 depict LORAN-C, and 25 contain the OMEGA electronic positioning system.

Implementation of the NAD83 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 840 (approximately 85 percent of the total) charts have been converted to NAD83.

A program is under development to provide listings containing information on marinas and their facilities for individual charts. The program is designed to pull selected fields from the full facilities data base. The data base is expected to simplify maintenance of facility standards. The program will allow queries by geographic position, state, or chart. This information will be made available for public sale.

NAUTICAL CHART MANUAL

Editing text of the primary chapters of the final draft of the new Nautical Chart Manual (seventh edition) continued. The final edit was begun, and graphic artwork to accompany the text has been prepared. This draft of the new edition consists of new text and an additional 250 pages of appendices. This is the first revision of the manual since the 1963 edition which consisted of 213 pages, including appendices. The new edition contains 11 chapters that define critical nautical charting production stages, including sounding selection; selection and delineation of depth contours; depiction of roads, urban areas and land contours; and detailed procedures for charting aids to navigation. The historical background of C&GS, NOAA's area of nautical charting responsibility, the legal requirement which the mariner must follow in using the charts in U.S. ports, and NOAA's international charting relationships are some of the subjects covered. An extensive glossary of terms commonly encountered in the compilation of nautical charts has been compiled from 40 authoritative national and international references.

CHART AUTOMATION AND DIGITAL DATA

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

PRODUCT AUTOMATION

C&GS is currently operating in a transitional mode between the traditional methods of "manual" cartography and a developing automated system. Algorithms to produce supplemental chart graphics such as tide tables, tide boxes, and channel and facility tabulations have been implemented into the chart production system. Computer-assisted techniques support the production of new nautical chart editions, new and reconstructed charts, and EEZ bathymetric maps. With the use of personal computers, the MCB is enhancing its ability to process data collected on the Intergraph Digitizing System and SCITEX Raster Plotter System. Color separation reproducibles for new and reconstructed charts are created through automation. The MCB now has the capability to provide computer-assisted revisions to supplement the negative engraving aspect of the production process.

Electronic navigational chart equivalents to approximately

50analog nautical charts are also being produced. This task is scheduled to be completed by mid-1993. The primary thrust of this effort is to support C&GS participation in the U.S. Electronic Chart Test and Demonstration Project. This project is a multiagency effort to provide sound, practical comments regarding the suite of proposed standards on ECDIS. Data collected for ECDIS will be loaded into the Automated Nautical Charting System II (ANCS II) data base. A secondary purpose of this project is to provide a solid foundation from which estimates may be made for the ANCS II data collection.

MICROCOMPUTER APPLICATIONS

The use of microcomputer-based applications increased during the past year with the continued development and planning of new capabilities. Use of NCD's microcomputer LAN continued to grow in FY91, with additional users and network nodes added in NCD staff offices, HSB, PB, and the MCB. The staff offices of the Aeronautical Charting Division, parts of NGS, and the Pacific Marine Center are connected to the LAN via remote call-in systems. The LAN interconnects 100 microcomputers in two buildings on seven separate floors providing shared access to data bases, software, and peripherals for more than 250 users.

Microcomputer-based software was used to maintain all channel tabulation and facility data for small-craft charts by providing input directly to the SCITEX plotter system. Plotters and laser printers are used to produce general copies of graphic files that are submitted for publication in the DMA Hydrographic/Topographic Center's (DMAHTC) Notice to Mariners. Information about all source material used in nautical charting is kept in a digital data base shared through the LAN. A "critical" production data base was developed to track aids to navigation from DMA and U.S. Coast Guard (USCG) publications in order to decrease compilation time. This capability will be networked during FY92. All these efforts have decreased the amount of time necessary to disseminate this information to the mariner.

Large data bases such as U.S. Power Squadrons membership, Discrete Independent Point File (DIPFILE), and Chart History and Program Parameters (CHAPP) files, and other tracking records are maintained on local micro-

computers for increased efficiency and shared access to LAN.

The Microcomputer Geographic Information System (MGIS) developed by NCRDL was installed at additional sites in the MCB, PB, and HSB providing common graphic interfaces to aids to navigation, shoreline, and topographic and hydrographic survey indices.

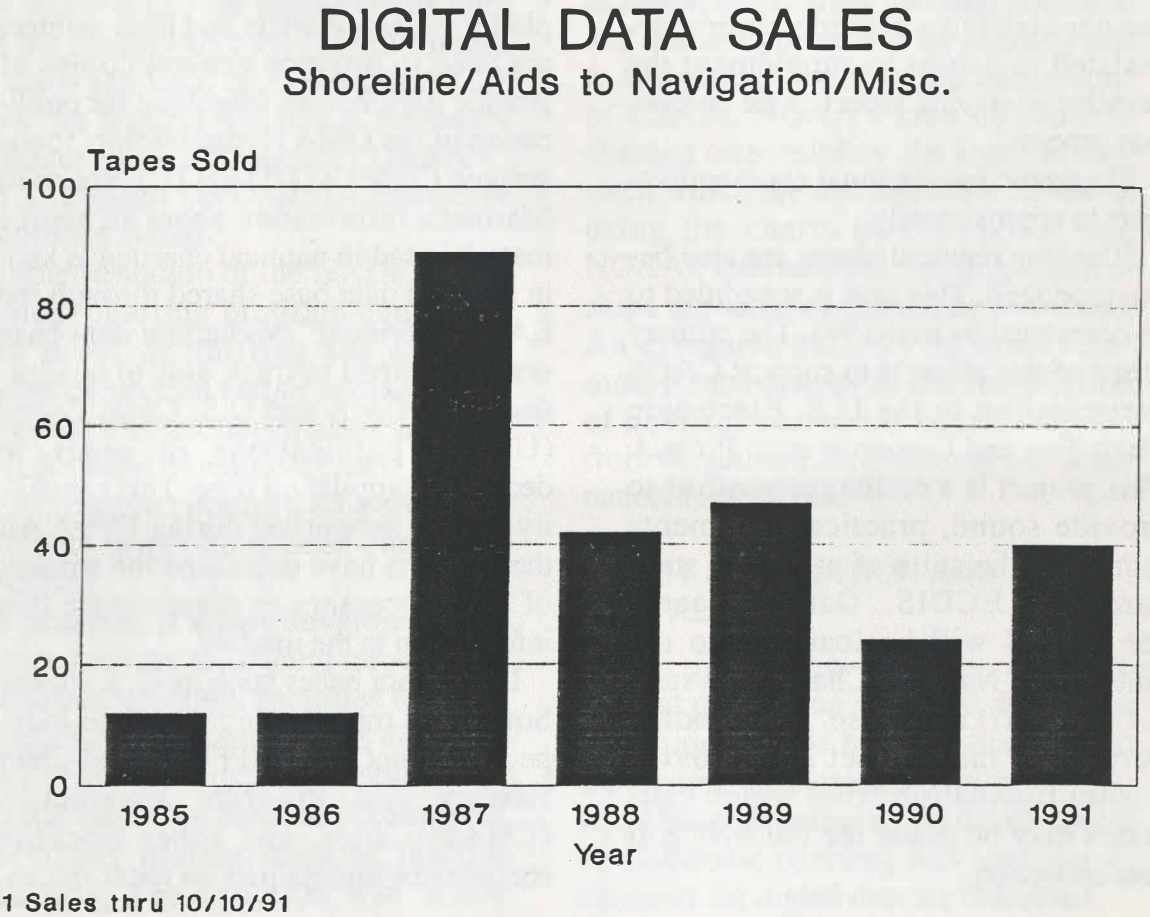
DIGITAL PRODUCT SALES

NCD continues to provide a variety of digital products for sale to government agencies, private companies, and the general public. These can be divided into two categories: digital data and LORAN-C overlays.

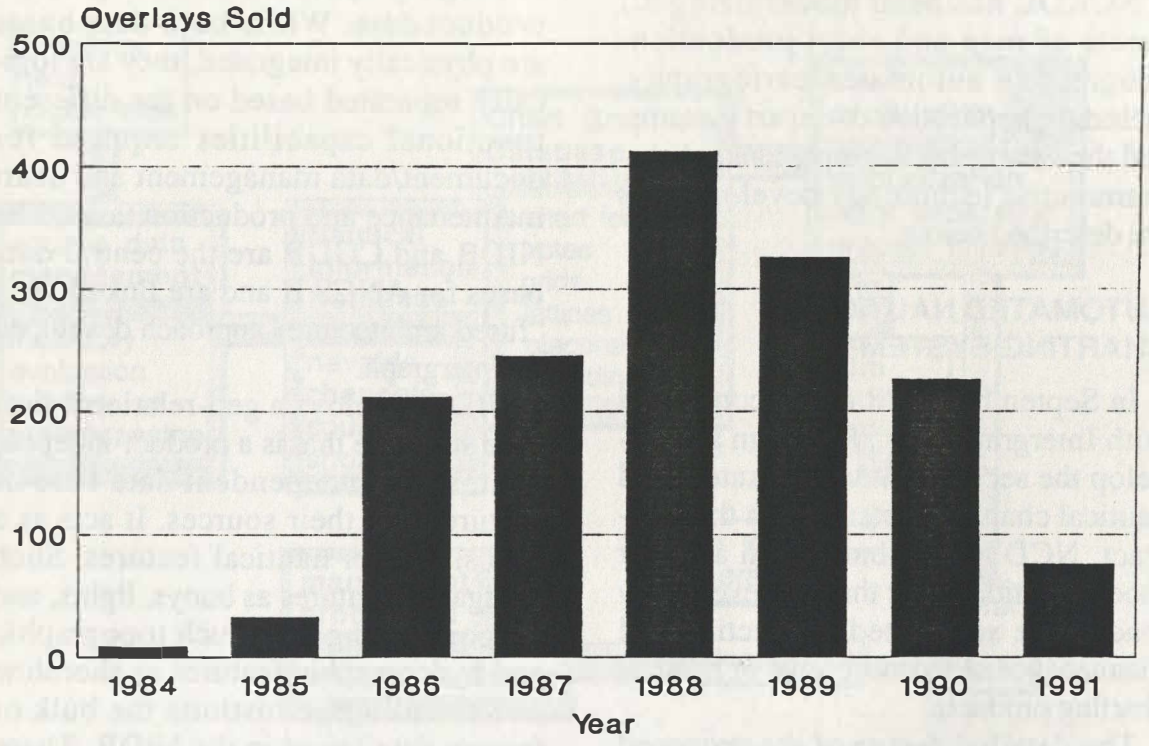
DIGITAL DATA

These products respond to the needs of electronic chart users, manufacturers, academia, and individuals that require accurate charting data in digital form. Although C&GS has made only a minimal effort to market these data, the sale of shoreline and other digital data products has increased as shown in Figure 6. Feedback from customers indicates they would

FIGURE 6. Chart depicting the growth in sales of digital shoreline and Aids to Navigation data since 1985. Increase in price imposed by NOAA in 1991 may reduce demand in the future.



LORAN-C OVERLAY SALES



1991 Sales thru 10/10/91

FIGURE 7. Chart depicting the early growth in sales of LORAN-C overlays and the subsequent decrease attributed to the price increase imposed by NOAA in 1991.

like to buy more products tailored to their needs if NCD would make them available.

On July 25, 1991, new pricing guidelines for digital data products went into effect. The price of shoreline and aids to navigation has more than tripled. These prices will have a definite impact on future sales of these 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.

LORAN-C OVERLAYS

Since 1984, C&GS has provided LORAN-C overlays for bathymetric maps. These overlays are used by commercial and sport fishermen to accurately locate themselves over particular bottom features that may harbor fish. In addition, an increasing number of users are from academic and state institutions, using these overlays for various scientific studies.

The increase in price of these overlays beginning in FY90 and continuing more recently on July 25, 1991, has had an adverse affect on LORAN-C overlay sales. This is summarizrd in Figure 7.

RESEARCH AND DEVELOPMENT

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.

AUTOMATED NAUTICAL CHARTING SYSTEM II

In September 1988, NCD contracted with Intergraph, Inc., to design and develop the second generation automated nautical charting system. With this contract, NCD has embarked on a major modernization effort that will eventually lead to the automated production and maintenance of its entire suite of nautical charting products.

The detailed design of the proposed system is currently in its final stages, and software development has commenced. The design is being accomplished by an onsite Intergraph design team working with the NCD project team. Details of the design are documented in version 4 of the *System Design Specifications,* volume 3, Operations Concepts. The following describes the general characteristics of the system.

ANCSII will consist of three primary data bases and five major functional areas. The three data bases are the Navigation Information Data Base (NIDB), the Chart Graphics Data Base (CGDB) and the Production Control Data Base (PCDB). The five functional areas are: Manage Source, Produce Charts, Produce Manuscripts, Manage Archives, and Manage System.

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 product 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. The NIDB and CGDB are the central data bases for ANCS II and are linked via a "fused architecture" approach developed by Intergraph.

NIDB employs a geo-relational data base structure that is a product-independent, scale-independent data base of features and their sources. It acts as a repository for nautical features. Such navigation features as buoys, lights, and beacons, along with such topographic and hydrographic features as shoreline and soundings, constitute the bulk of feature data found in the NIDB. These types of features are extracted and routinely processed from a wide variety of internal and external sources at C&GS. Features are logically grouped into feature themes and classes and stored in the NIDB. Attributes will be stored in a relational data base and geometry is stored in Intergraph's IGDS file structure. Attributes and geometry are linked via a pointer. The NIDB also supports a variety of document cataloging functions which are used by the system software to track and link feature data to source data. The NIDB also incorporates a temporal design strategy which is required for providing on-line, audit-trail functions and history capability required by potential liability issues. The temporal design is used in two ways: (1) it records all changes to temporal features, and (2) it allows information about the history of a feature or geographic area contained in the data base to be reviewed at anytime.

AUTOMATED NAUTICAL CHARTING SYSTEM II - WORKFLOW

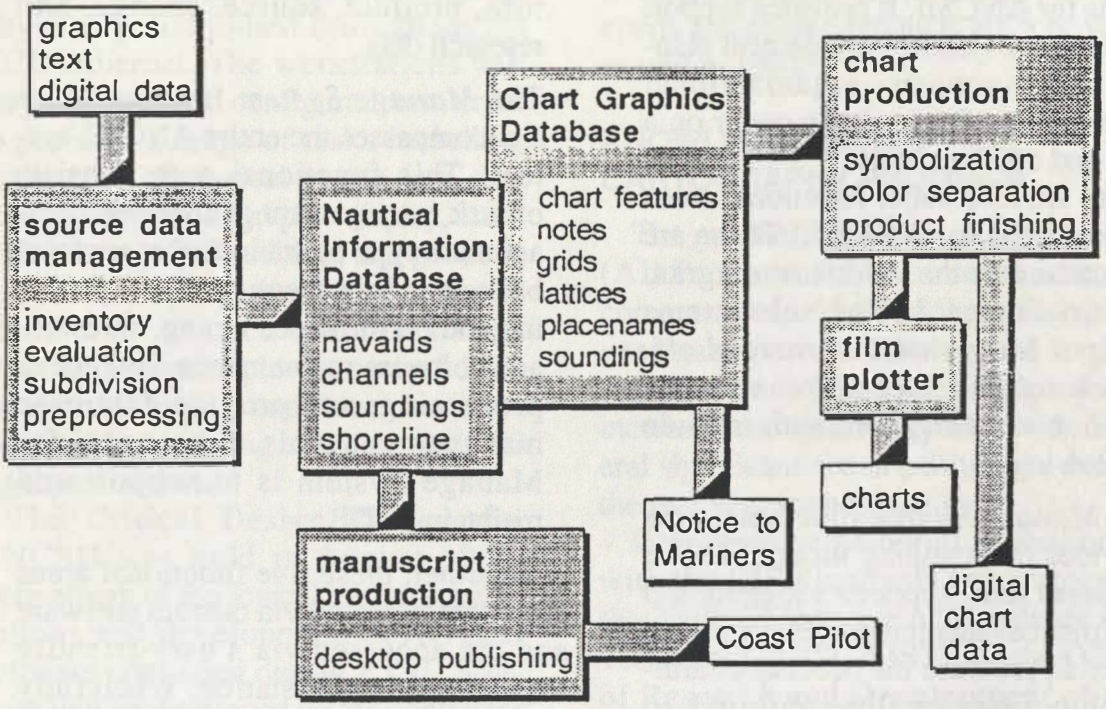


FIGURE 8. Diagram of the next generation Automated Nautical Charting System (ANCS II) and the data pathway through the various subsystems.

The NIDB also supports a wide variety of simple and complex spacial queries using either a query by example form (QBE) or from a structured queried language (SQL) command line.

The CGDB is a product- and scale-dependent data base that consists of a set of discrete product data bases. Each chart product has its own graphic data base which includes product-specific graphics that reference NIDB attributes. It contains highly symbolized vector representations of all chart features extracted from the NIDB. It also contains grids, graticules, legends, notes, and magnetic data required for each nautical chart product. NIDB feature changes will be linked to each product that it potentially effects. Capabilities are being developed to support application of features through the scales, cartographic generalization, and timely submission of Local Notice to Mariners and chartlets. In addition, these capabilities will provide nautical cartographers with the tools needed for product maintenance and production in a way that is consistent and systematic and will ensure that product quality, accuracy, and NOS standards are met.

The third data base, the PCDB, supports a wide variety of the system management functions required for scheduling, monitoring system activities, generating various system and management information system reports, maintenance of hardware and software configurations, documentation listings,

and problems and repairs. The PCDB supports all task management subsystems for ANCSII. It provides support for intelligent system management planning and supports organizational resource allocation tasks to occur on a timely and efficient basis.

There are five major functional areas or subsystems for ANCS II. These are incorporated in the workflow diagram given in Figure 8. The subsystems consist of Intergraph commercial off-the-shelf software and custom software written by Intergraph and include the following:

- The *Manage Source* functional area provides for scanning input of vector and raster data, supports a logging and document evaluation process of source material, provides the necessary cartographic functionality required to update both the NIDB and CGDB, supports temporal tracking function, and provides an interactive cartographic generalization and text processing. It provides automated sounding selection and depth contour capabilities for processing C&GS digital hydrographic surveys for the NIDB and CGDB using TIGRIS Mariner.
- The *Produce Charts* functional are a supports all product generation tasks, supports development of new and reconstructed nautical products, such as metrication for the suite of nautical charts, and supports development of electronic charts.
- The *Produce Manuscripts* functional area supports the creation and processing of C&GS Notice To Mariners submissions and provides a desktop publishing platform for maintenance and production of the Coast Pilot series using the SGML standard.
- The *Manage Archives* functional area provides separate archives for feature, product, source, change, and research data.
- The *Manage System* functional are a encompasses the entire ANCSII system. This functional area consists of task management and system management type operations that perform backup and recovery, system monitoring and performance tuning, hardware and software maintenance, and queue processing, and provide data base management tools. A key goal for Manage System is to support and maintain PCDB.

Together, these five functional areas are interconnected via custom software and are accessed via a user-friendly menu at each workstation. When fully developed, ANCS II will provide the necessary functional capabilities required for C&GS to meet its long-term mission in automated digital production.

ANCSII software will include a suite of Intergraph COTS products that include TIGRIS Mariner, selected mapping capabilities from Intergraph's MGE package, and Microstation software, as well as custom software needed to meet C&GS requirements. Graphic product generation will be performed by the Intergraph Microstation family of software. Textual products such as Coast Pilot books will be generated with Intergraph's desktop publishing software. Data base maintenance will require custom software and a commercial Relational Data Base Management System (RDBMS) for management of attribute information. Graphics files and the RDBMS are linked with another commercial software component developed by Intergraph.

When completed, the ANCSII will employ up to 40 RISC-based color graphic workstations which will be physically distributed throughout the NCD Ethernet. The workstations will vary in power and configuration in order to perform a range of tasks including digitization of nautical source data, data base manipulation, graphic display, interactive cartographic editing, and geodetic computations. Additional hardware will include an Anatech scanner and an Optronics scanner plotter, optical disks for chart archiving, and three data servers capable of storing approximately 30 gigabytes of data.

The Critical Design Review for ANCSII was held in August 1990. Refinement of the logical design specifications and development of ANCSII software continued during FY91. Software will be developed by the contractor in five incremental stages and delivered to C&GS for review and "hands on" experience in order to provide feedback to the contractor. The PhaseI delivery of software was demonstrated in March 1991 and delivered to C&GS in June 1991 for review. PhaseII of the software development is scheduled to be delivered during the first quarter of FY92.

Data collection for the creation of a test data base has commenced and will be completed during FY92. The test data base will contain nautical feature data for an area of 50 C&GS charts to be used for testing the system during a 6-month trial production. A "functional test" of the system will be conducted in mid-1993 and a "system acceptance test" is planned for the end of 1993 in order to test performance. Additional hardware and system software procurements may be executed by C&GS after system acceptance. Production implementation of ANCSII within NCD and eventual expansion to include the suite of approximately 1,000 C&GS nautical charts and related products are scheduled to start in 1994.

KNOWLEDGE-BASED CARTOGRAPHY PROGRAM

The goals of the Artificial Intelligence (AI) Program are to increase internal competence in AI technology and to investigate new technology in expert systems and related techniques for increased cartographic productivity. Several significant accomplishments during the past year are noteworthy.

Interagency collaboration continued with the GIS Standards Laboratory of the National Institute of Standards and Technology (GISL-NIST) and the Office of Research and Development of the Central Intelligence Agency (ORD-CIA). The objective is to share ideas and pool resources toward the development of advanced prototypes by applying AI and related technologies to problems of mutual interest.

Work continued toward development of the CartoAssociate cartographic expert system prototype. This project is being carried out as a collaborative effort with ORD-CIA to develop an embedded expert system capability which can be included in larger systems such as ANCSII. The embedded system will assist cartographers in performing specific decision-making processes, such as symbol selection, conflict detection and resolution, generalization when changing scales, and text placement. Much of the work is being performed in-house with ORD-CIA sponsored contractual assistance for object-oriented programming and related tasks.

Major progress was made in the development of a model for detecting and resolving conflicts among critical C&GS chart features, including complex features such as channels having associated buoys, soundings, range lights, shipwrecks, rocks, piles, text labels, and so forth. The embedded expert system graphic compilations are performed directly from a test object data base of C&GS chart feature and attribute data.

The CartoAssociate prototype was demonstrated onsite at a GISL-NIST technology integration workshop which highlighted this project and included technical papers and other live demonstrations on related topics from industry, academia, and other agencies. It was also demonstrated to numerous visitors from NCRDL, DMA, the Naval Oceanographic Office, and the Defense Hydrographic Initiative's technical working group. To support the CartoAssociate effort, progress was made in developing an in-house version of a custom inference engine (rule interpreter), written in the C language, to provide faster inferencing from the cartographic knowledge base. The goal is to develop a highly efficient and portable engine that can be embedded directly into the object data base management system and programming environment as a compiled primitive, thereby improving efficiency and performance by at least an order of magnitude. The portability factor will become important when the system is eventually moved to the ANCSII platform.

A competitively won Pioneer Fund grant continued progress on the CartoAssociate's object data model and the development of its attendant object data base of real C&GS chart feature data. NCRDL is very proud of winning this grant within a field of over 70 competing project proposals considered by the Department of Commerce (DOC). This project will be carried out throughout FY92.

By winning another competitive DOC award, in this case a Small Business Innovation Research (SBIR) proposal, work could progress on the Knowledge-Based GIS (KB-GIS) project which includes data fusion and scale change capabilities. An earlier FY90 prototype achieved correct feature generalization and portrayal for shorelines, channels, waterfronts, and harbors when changing scales from 1:25,000 to 1:100,000 representations from a single chart feature object data base.

The KB-GIS work will continue through FY92 to develop advanced capabilities allowing multiple data bases of diverse kinds of spatial data to be cartographically modeled by an object-oriented expert system. Eventually, the final system will become a major part of the CartoAssociate's embedded ANCSII capability for automatic feature generalization and scale change.

These prototypes are being developed on engineering workstations under an object-oriented software development and data base environment. The workstations are linked via an Ethernet network to a host data server configuration running an advanced object-oriented data base management system. Much progress was made this past year in integrating the interfaces between the implementation languages, the expert system shell, and the graphics display software tools. All software development

is being performed under the UNIX operating system using the X-Window, Smalltalk-80, and C languages over standard TCP/IP network protocols.

SIDE SCAN SONAR FOR MAPPING OBSTRUCTIONS

A high-speed, high-resolution side scan sonar system was developed under an SBIR contract with Klein Associates of Salem, New Hampshire. It is designated as the Multiple Beam Focused Sonar (MBFS). Joint tests of the MBFS prototype were conducted in the United Kingdom in the summer of 1991 by the Navies of the United States, United Kingdom, Canada, Australia, and New Zealand. It was conclusively shown that MBFS was a reliable high-speed, high-resolution acoustic sensor. It was also concluded that improvement was required in the MBFS's real-time display of the multibeam data such that the interplay between sonar range scale, vessel speed, beam steering, and display media could be optimized towards maximum, real-time visual impact on an operator.

MICROCOMPUTER GEOGRAPHIC INFORMATION SYSTEM

The MGIS has been built for managing surveys and related information such as location of horizontal control points, sediment data, and location of tide stations. It is now being deployed at multiple sites, and 18 such systems are now used by C&GS in daily operations. The software was built by integrating AutoCad graphics, dBaseIII Plus, and other commercial microcomputer software packages. The MGIS runs on an IBM family of microcomputers. Twenty-nine data bases have been brought on line.

SWATH SURVEY SYSTEM ALIGNMENT METHODS

An automated technique for determining the roll, pitch, and heading biases between the Swath Survey System's acoustic array and the shipboard attitude sensors was developed under a SBIR contract with TAU Corporation of Los Gatos, California. The present manual technique is lengthy and prone to errors due to subjectivity assessments made during contour matching on multiple aspect surveys of a given location. The new specialized algorithms and associated workstations were delivered in the summer of 1991. They are being tested on existing data sets.

REMOTE ACOUSTIC SENSING OF SOUND VELOCITY PROFILES

Advanced inversion theory has been developed which predicts the ability to measure a sound velocity profile remotely using acoustic volume reverberation. A detailed mathematical representation has been published, and analyses of existing acoustic volume backscatter data acquired for other reasons support the solution form. New data specific to this topic are required to complete the feasibility demonstration. No further action is contemplated on this project in the near future.

RAPID PRECISION LEVELING SYSTEM

A multiyear, multinational project is underway to develop a first-order leveling system that achieves the same accuracy as motorized differential leveling systems, but with much greater economy. The primary economy results from lengthening lines of sight by eliminating atmospheric refraction effects

and through the use of laser electronic distance measuring devices. Contract monitoring is being done by NCD, and the construction of a prototype system is being accomplished under the direction of NGS by its Instrument and Equipment Section in Corbin, Virginia.

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 wave form detections techniques. 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.

DIGITAL SPATIAL DATA STANDARDS

The International Hydrographic Organization's (IHO) Committee on Exchange of Digital Data published the first release of its exchange standard entitled, "IHO SP-57: IHO Transfer Standard for Digital Hydrographic Data (DX90)." Formal adoption of this significant effort is expected at the XIVth IHO Conference in Monaco in May 1992.

The Spatial Data Transfer Standard (SDTS) Technical Review Board, in conjunction with NIST, is completing the work of making SDTS an approved Federal Information Processing Standard (FIPS). It is expected that SDTS will be promulgated as a FIPS in early 1992. NCD is participating in the recently reorganized and reauthorized Federal Geographic Data Committee (FGDC). FGDC's efforts are focused on government-wide agreements and standards in digital spatial data.

IMPLEMENTATION OF THE DIFFERENTIAL GLOBAL POSITIONING SYSTEM

NCD has made significant progress this year to incorporate the DGPS technique for vessel positioning in hydrographic and bathymetric operations. Previously, due to intermittent coverage of the GPS, it was used only to calibrate ship-to-shore survey positioning systems. In 1991, the GPS constellation increased to the point where there was sufficient coverage to allow DGPS to be used as the primary positioning system in survey operations.

The DGPS technique is a positional accuracy improvement technique that can be implemented with inexpensive, commercially available GPS equipment. A static GPS receiver, at a known location, determines range correctors for each GPS satellite in view. The time-referenced range correctors and the correction's rate of change are transmitted to the user for incorporation in the position computation. The user's DGPS position computation is performed real-time with the predicted range corrections defined by each satellite's range correction and rate of change.

The DGPS technique results in (1) improved positional accuracy,

(2) a longer coverage window, and (3) greater immunity from satellite failures and the limitation of the Selective Availability (SA) mode imposed by DOD on the NAVSTAR GPS. The accuracy of a GPS position is a function of the accuracy of the satellite range measurements and the satellite locations (the geometry of the satellite ranges). A longer coverage window is realized because the positional error is significantly reduced and "poorer" satellite geometry can, therefore, be tolerated without exceeding the positional accuracy required by the survey. Greater immunity to satellite failures is realized since the reference GPS "knows" its location, and the satellite data are corrected based on this known location. The DOD policy to purposefully degrade the accuracy available to the general user of GPS (SA) is implemented by inducing range errors. Since the DGPS technique removes range errors, the effects of SA are not realized by the DGPS user.

A test was conducted on the NOAA Ship MT.MITCHELL in April 1991 to determine the feasibility of using a DGPS service with a satellite-based data link. The test, which compared the performance of two satellite-based DGPS services to the STARFIX positioning system, showed that DGPS could be used to perform bathymetric surveys of the EEZ. The test indicated that the DGPS positional accuracy was comparable to STARFIX and that downtime, due to unfavorable GPS satellite coverage, was acceptable. Based on the results of this test, a contract was mawarded to COMSAT for a similar DGPS service to support the NOAA Ship DISCOVERER's survey activities in Hawaii. While there were a few problems initially, the DGPS-based surveys performed in Hawaii were deemed a success.

Cooperation with USCG promises to yield a DGPS service with similar performance at greatly reduced costs. In a cooperative effort between NOAA and USCG, DGPS services will be established at selected USCG radio beacon stations using existing C&GS GPS equipment. Areas where NOAA has long-term mapping and charting activities, such as the Gulf of Mexico, will be selected for these installations. Both agencies and the mariner will gain from this effort. The USCG will use the knowledge gained during this activity to determine the final hardware/software configuration of the DGPS radio navigation system they will begin installing in 1994. C&GS will have a high-accuracy positioning system, with coverage beyond the limits of the EEZ, for very little outlay of capital. These positioning systems will be available to anyone possessing the necessary commercial off-the-shelf shipboard equipment from numerous manufacturers.

The usefulness of this radio beacon-based DGPS system for nautical charting surveys was demonstrated in late spring 1991 by the NOAA Ship RUDE. After verifying the accuracy of the USCG DGPS service provided by the Montauk Point, New York, radio beacon, the RUDE began using it as the survey positioning system. Changeover to DGPS as the RUDE progressed through the survey area allowed operations to continue without the need for shore survey activities.

To evaluate the utility of DGPS for the hydrographic field parties, a self-contained DGPS system comprised of

the GPS receivers and a VHF radio data link was procured. This system was used to perform a hydrographic survey which was requested by USGS near Benton Harbor, Michigan. The survey, performed by a 22-foot launch, had a noticeably higher production rate than other similar surveys due to the reduced logistics required for shoreline survey control.

Based on the success realized by each implementation of DGPS, a program to procure and install the appropriate DGPS system for each hydrographic and bathymetric field unit has been developed with the Office of NOAA Corps Operations. Subject to realization of funding, all field units will be given a DGPS capability during the FY92 field season. To improve the efficiency of utilizing DGPS in survey operations, field procedures and survey software will be refined. Evaluation and testing of new hardware and software for the purpose of improving NCD's utilization of DGPS will continue.

KINEMATIC GLOBAL POSITIONING SYSTEM IN PHOTOGRAMMETRY

Development of an operational capability for GPS-controlled photogrammetry is still being pursued. NCRDL scientists work closely with the Photogrammetry Branch. C&GS has acquired GPS data on portions of three more operational projects, and these data will be used in place of the available ground control. The C&GS GPS-controlled photogrammetry system has been recalibrated since inclusion of the new Wild RC-20 aerial camera, and the PB is developing a real-time navigation capability to improve the reliability of data acquisition.

C&GS is very active in transferring this technology and assisting others to develop a similar capability. As mentioned previously in the section on modernization of photogrammetric instrumentation, the North Carolina Department of Transportation acquired a GPS data set at a mountainous highway project with the help of C&GS personnel. The have reported very good results. The U.S. Army Corps of Engineers (COE) completed a demonstration project at Ft. Lewis, Washington. C&GS personnel monitored the data acquisition and data reduction phases. COE is planning to continue development of GPS-controlled photogrammetry using private sector contractors and C&GS advice. USGS acquired a large data set in the Phoenix, Arizona, area to use in evaluating the potential of GPS-controlled photogrammetry for its National Aerial Photo Program. They have sought software, advice, and assistance from C&GS in processing these data. Furthermore, C&GS personnel have conducted workshops at both of the last two annual meetings of the American Society of Photogrammetry and Remote Sensing. These workshops were attended by more than 90 individuals with nearly half from the private sector and many from foreign countries.

C&GS is continuing to improve the software to process GPS-controlled photogrammetric data and are distributing it to other agencies at both the Federal and state level and to the private sector.

INTEGRATED DIGITAL PHOTOGRAMMETRIC FACILITY

The Integrated Digital Photogrammetric Facility (IDPF) is being developed

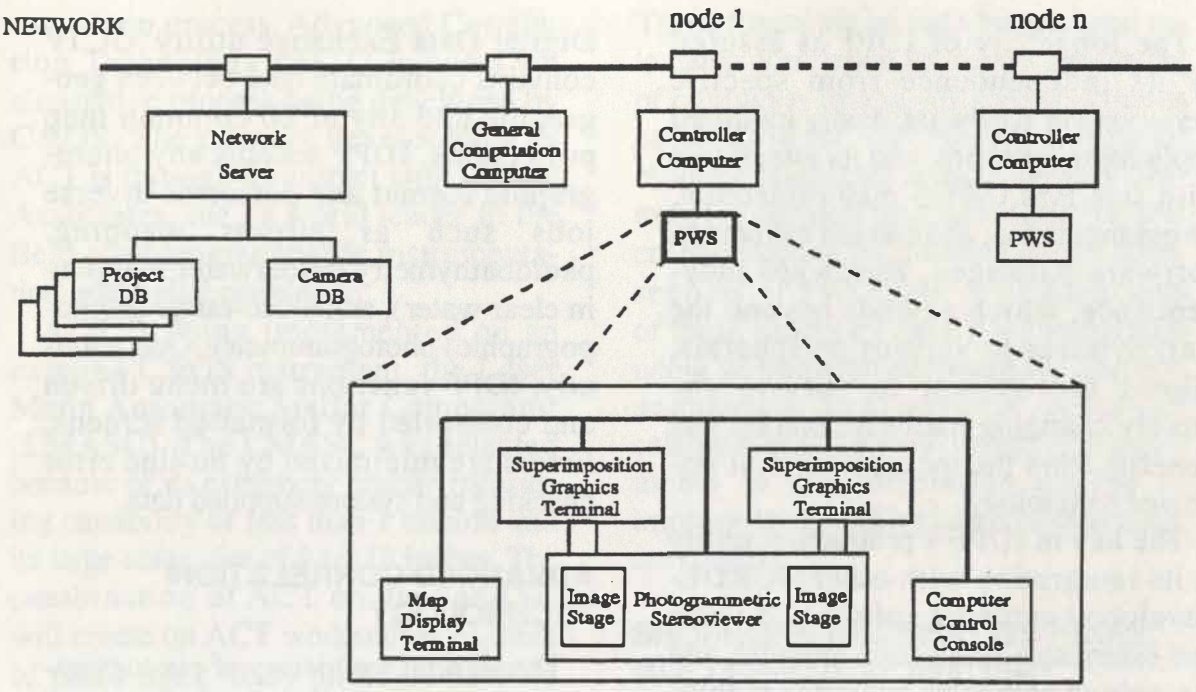


FIGURE 9. Diagram of a photogrammetric workstation in one node of the IDPF network.

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. IDPF couples advanced photogrammetric technology with computer graphics and a relational data base management system. Begun in 1984, IDPF development led to an operational system in 1987. The system's capabilities, then limited toaerotriangu-lation, were expanded to a complete compilation package in 1989. The final developmental phase will be completed in mid-1992. The various IDPF data bases will run under a digital RDBMS with many additional application programs.

The present IDPF configuration consists of five stereoviewers and their peripherals, forming photogrammetric workstations linked as networked nodes sharing a common data base. See Figures 9 and 10. The three data bases are (1) the project data base, (2) camera calibration data base, and (3) the OC data base.

In support of FAA tasks on the IDPF, the Airport OC data base has now been interfaced with programs such as the data base editor, obstruction data sheet report generator, and related graphics. A computer program was developed to model the 3-dimensional approach surfaces over any airport. This software will be integrated into the IDPF and the OC data base for on-line obstruction penetration analysis.

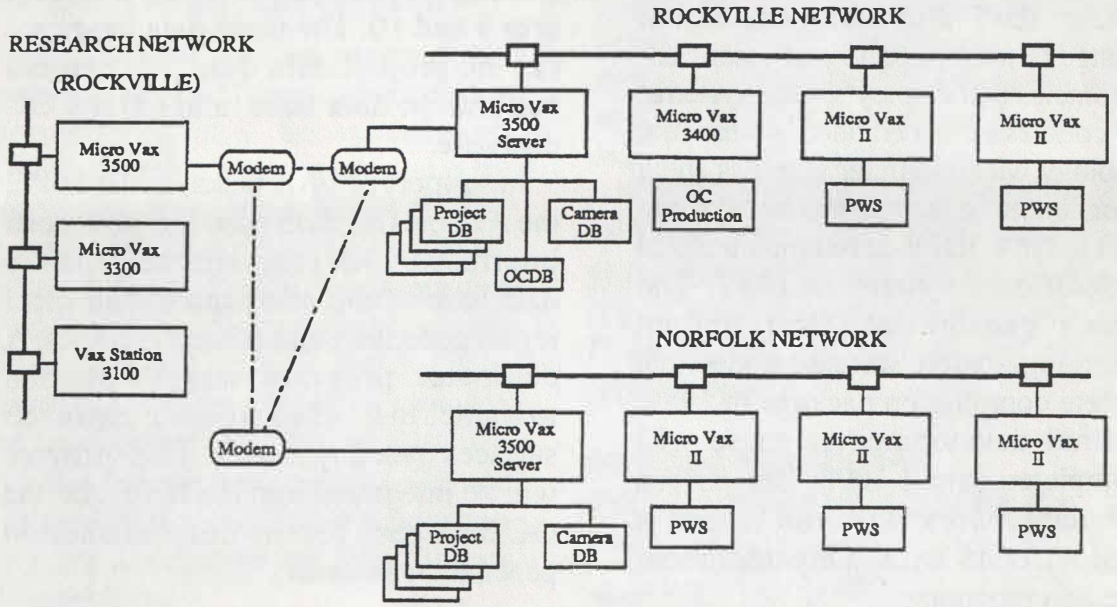
The longevity of IDPF is assured by its independence from specific stereoviewer hardware, easily modified application software, and its integration with standard C&GS map projection, aerotriangulation, and camera calibration software packages. Hardware independence, which extends beyond the stereoviewer to various peripherals, allows the system to survive the rapidly changing hardware market and benefits 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 the unique computer operational environment. Integrated mapping software includes the General Integrated Analytical Triangulation Program, the General Cartographic Transformation Package (GCTP), the C&GS 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.

ADVANCED CORRELATION TECHNOLOGY

Throughout the history of photogrammetry, the extraction of data has been accomplished through the use of trained human eyes. However, technological advances in digital image sensors, coupled with high performance microcomputers and sophisticated correlation algorithms, have created an alternative

FIGURE 10. Diagram of the complete IDPF showing the relationships between the Norfolk, Virginia, and Rockville, Maryland, production units and the Rockville Research Network.



extraction process. Advanced Correlation Technology (ACT) is one such alternative process being developed by C&GS. The primary development of ACT is through a contract with Helava Associates, Inc., a world leader in the field of photogrammetric instrumentation and digital correlation.

ACT is being implemented on an existing C&GS instrument, the Laser Mann Automatic Stellar Comparator (LMASC). The LMASC 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 will create on ACT workstation capable of performing many photogrammetric applications utilizing correlation techniques. The implementation of ACT has required considerable software development by C&GS in addition to the correlation software provided by the contractor. The integration of the correlation software into a photogrammetric applications package is being directed by C&GS.

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

Currently, the correlation 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. Enhancements to the correlation engine to improve the speed and ease of operation are ongoing.

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 has been developed through the SBIR program. An SBIR project goal is to develop a semiautomated process of delineating shoreline from digital data sets. Initially, the SBIR vendor proposed Landsat multispectral data; however, these data suffer some accuracy limitations due to the pixel size. Discussions with the vendor during the first phase of the SBIR contract have broadened the data sets to include any multispectral data set, including scanned aerial photographs. Aerial photography is of interest because of its availability and superior accuracy. The broad base of data sets that can be supported is very attractive in that it allows for shifting to various multispec-

tral sensors, both satellite and airborne, as availability and accuracy match the demands of shoreline delineation.

The initial SBIR contract proved the feasibility of the approach. C&GS has successfully competed for a PhaseII SBIR contract. The PhaseII contract is a 2-year software development, targeted for existing microcomputer platforms and production operations. 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.

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). Charts and file maintenance, a continuous process, are required to support the regularly scheduled update cycle for the program. ACD also prints and distributes all nautical charts and maps compiled by the NCD.

The cartographic functions of the ACD are located in the Aeronautical Chart Branch (ACB). The activities of the ACB can be divided into four different categories:

- Visual products
- Instrument products
- Special products
- Data management for the above products

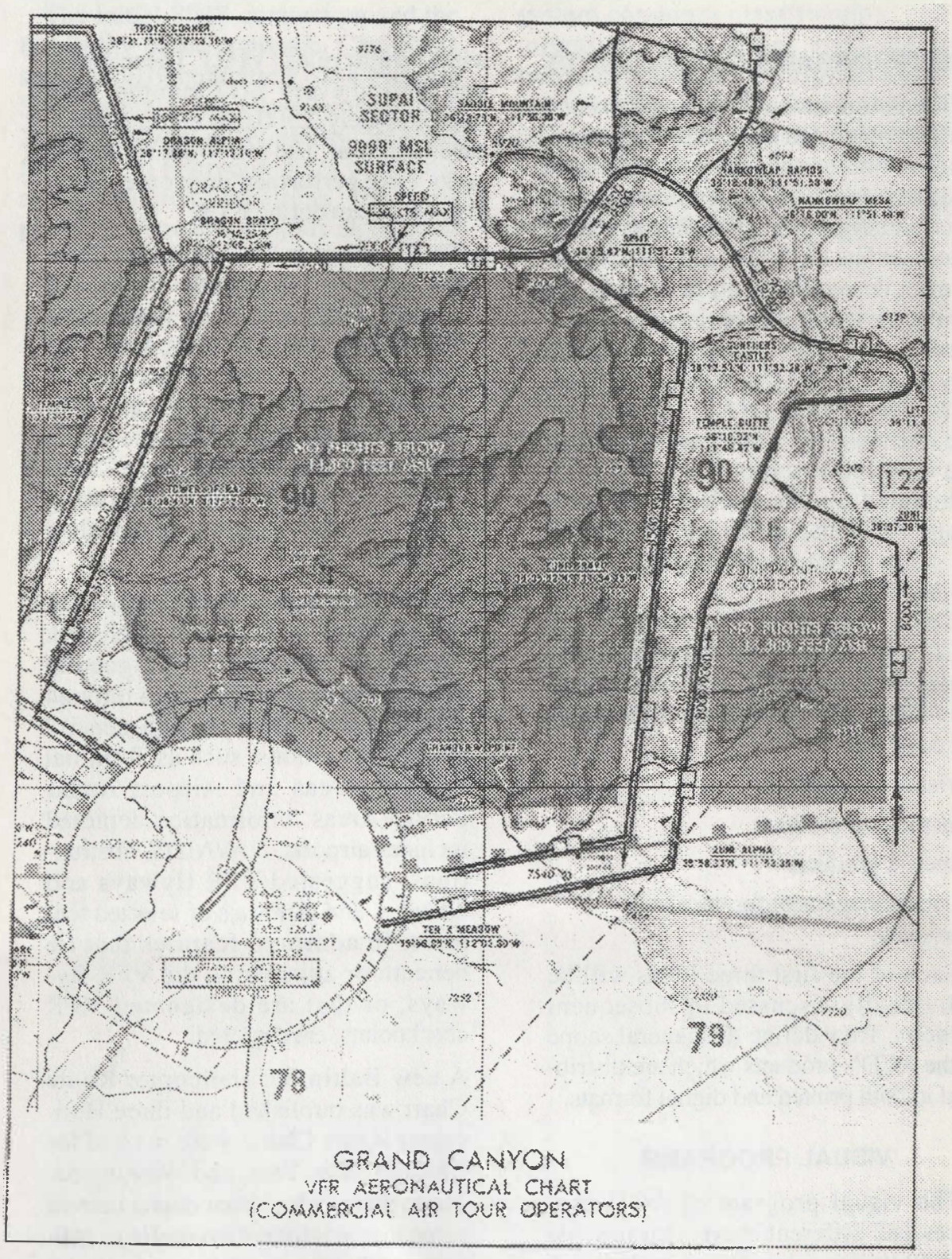
Each of the first three items will be individually discussed in subsequent sections. They define the general scope of the ACD's products which are distributed in both printed and digital formats.

VISUAL PROGRAMS

The visual program of ACD produces 182 different charts that provide information to pilots flying under 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 FY91.

- The Washington Terminal Area Chart was expanded to include the revised airspace designated as the Washington Tri-Area Terminal Control Area. The information depicted on this chart is shown in much more detail than the sectional charts because of its larger scale. The Terminal Area Charts (TAC) are used by pilots operating within or near the newly established control area.
- A new Baltimore-Washington VFR Flyway Planning Chart was published. This three-color chart is designed to assist pilots in planning flight through and/or around areas of high-density aircraft operations, such as Terminal Control Areas and Airport Radar ServiceAreas. Information depicted includes airports, NAVAIDS, obstructions, suggested VFR flyways and altitudes, and pictorials of selected features. In addition, features that lie beneath or adjacent to the VFR flyways, or that are designated VFR checkpoints, are depicted.
- A new Baltimore Helicopter Route Chart was published and three Helicopter Route Charts were revised for Chicago, New York, and Washington. These three-color charts depict current aeronautical information useful to helicopter pilots navigating in areas with

FIGURE 11. A section of the Grand Canyon VFR aeronautical chart designed for commercial air tour operators in the area.



high concentrations of helicopter activity. Information depicted includes associated frequency and lighting capabilities, NAVAIDS, and obstructions. In addition, pictorial symbols, roads, and easily identified geographical features are portrayed.

- The new Grand Canyon VFR Aeronautical Chart was designed to be used with the Las Vegas Sectional Chart (see Figure 11). This new product includes a General Aviation Chart and a Commercial Air Tour Operators Chart. Special Flight Area Rule 50-2, free flight zones, corridors, altitude boundaries, sector frequencies, and altimeter changeover lines are depicted on both charts. In addition to those features, the Commercial Air Tour Operators Chart includes fixed wing VFR routes, helicopter VFR routes, and VFR holding areas and patterns.
- A new edition of the Aeronautical Chart User's Guide was published to include all specification and product changes. This is the 3rd edition and replaces the 2nd edition which was published in May 1989. The Aeronautical Chart User's Guide includes explanations of Instrument Flight Rules (IFR) and VFR terminology, a list of ACD aeronautical products, and explains chart symbology.

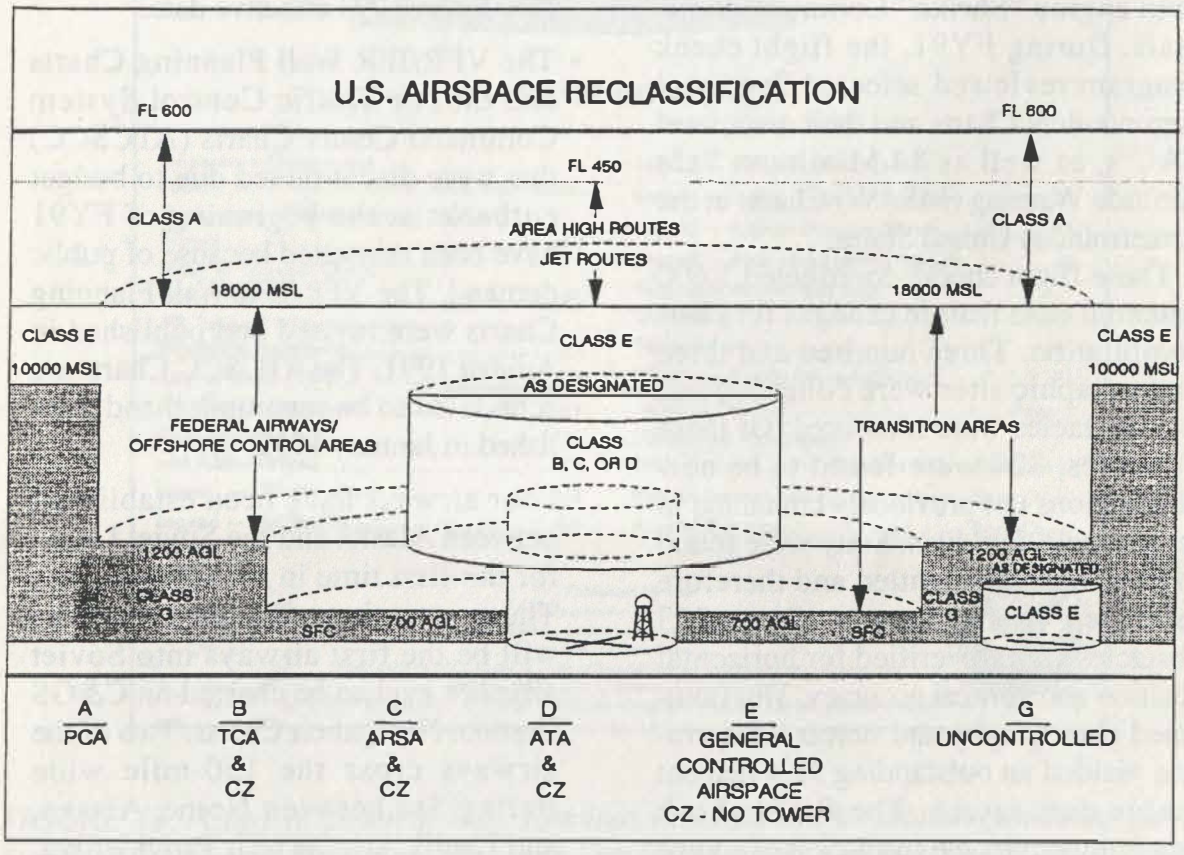


FIGURE 12. Diagram of the airspace reclassification prototype prepared by ACD to assist FAA in conforming with international standards.

- Special prints of the Cheyenne Sectional were produced for training of FAA procedures specialists at the Aeronautical Center in Oklahoma City.
- The Airspace Reclassification Prototype was produced to assist in FAA plans to reclassify all U.S. airspace to conform with international standards. This is shown by the diagram in Figure 12. The prototype incorporates recommendations identified in the National Airspace Review, which is currently being evaluated by an Interagency Air Cartographic Committee Task Group.

Visual aeronautical charts are flight checked once every 3years by a rotating crew of three NOAA commissioned officer pilots flying a government-owned twin engine "Shrike" Commander aircraft. During FY91, the flight check program reviewed selected Sectional Aeronautical Charts and their associated TAC's, as well as 84 Minimum Safe Altitude Warning (MSAW) Charts in the conterminous United States.

These flight checks contributed 1,600 potential base feature changes for chart compilation. Three hundred and three 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 PROGRAMS

The instrument program of ACD provides more than 8,900 charts and publications, which are used by pilots flying under FAA IFR. Nearly 80 percent of these publications must be revised every 56days. Approximately 7,800,000 copies of instrument charts and publications are distributed annually. Important acomplishments for the past year are discussed below.

- The conversion of the Enroute Low Altitude Chart series from two to four colors continues. The Alaska Low Altitude Chart series was produced by automated methods and printed in January 1990. The U.S. Low Altitude series is in preparation with a planned November 1993 effective date.
- The VFR/IFR Wall Planning Charts and the Air Traffic Control System Command Center Charts (ATCSCC) that were discontinued due to budget cutbacks at the beginning of FY91 have been reinstated because of public demand. The VFR/IFR Wall Planning Charts were revised and published in August 1991. The ATCSCC Charts are scheduled to be recompiled and published in January 1992.
- Four airways have been established between Alaska and the Soviet Union for the first time in aviation history. These new air traffic service routes will be the first airways into Soviet airspace ever to be charted on C&GS Enroute Navigation Charts. Two of the airways cross the 150-mile wide Bering Sea between Nome, Alaska, and Urelik Airport near Provideniya, Siberia. The other two airways originate at Gambel Airport, St. Lawrence Island, Alaska, and cross 200 miles of

UNITED STATES GOVERNMENT FLIGHT INFORMATION PUBLICATION

U.S. TERMINAL PROCEDURES

NORTHEAST (NE) VOL 3 OF 3

INSTRUMENT APPROACH PROCEDURES • STANDARD TERMINAL ARRIVALS

STANDARD INSTRUMENT DEPARTURES • AIRPORT DIAGRAMS

EFFECTIVE 0901Z 19 SEP 1991
TO 0901Z 14 NOV 1991

Consult NOTAMs for latest Information

CONSULT CHANGE NOTICE (CN) EFFECTIVE 17 OCT 1991 FOR INTERIM UPDATE

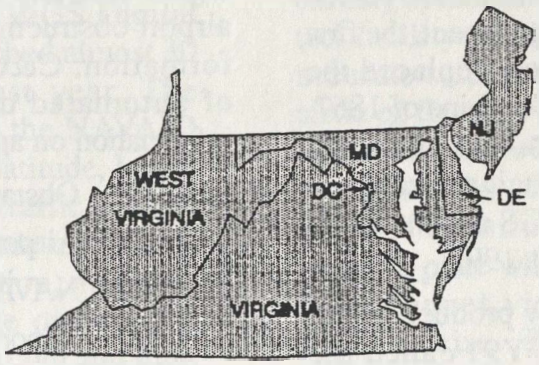


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FIGURE 13. Copy of cover of U.S. Terminal Procedures Publication combines the Standard Instrument Departure, Standard Terminal Arrival, and Instrument Approach Procedure Charts into one new product. This action by ACD provides the user with a more efficient and less costly product.

the Gulf of Anadyr to Leninka Airport, Anadyr, Siberia. This historic occurrence is the result of cultural exchange agreements signed by President George Bush and Soviet President Mikhail Gorbachev during the 1990 Summit Meeting in Washington, DC. Another outcome of these agreements is the new Maritime Boundary between these countries which is already depicted on C&GS aeronautical charts. This new boundary agreement, the first with the Soviet Union, replaced the U.S.-Russia Convention Line of 1867. The four new airways—which are not expected to carry much air traffic—were shown on C&GS aeronautical charts starting May 30, 1991.

- ACD published a new product during the first quarter of FY91 called the U.S. Terminal Procedures Publication (TPP). The TPP combined Standard Instrument Departure Charts, Standard Terminal Arrival Charts, and Instrument Approach Procedure Charts into one product. A representative cover of this new publication is shown in Figure 13. The consolidation of these separate books into one product will save each chart customer up to $450 per year. These savings are the result of in-house efficiencies and procurement of a single commercial contract that includes all drafting, photoservicing, film maintenance, printing, and distribution. In addition to cost savings, the TPP's have enhanced aviation safety because pilots no longer have to refer to several different books during the critical landing phase of flight. The new publication has a common effective date with other instrument products. The publications consist of 16 volumes and a Change Notice. At the same time, the Terminal Alaska book became the Alaska TPP with a cover similar to the TPP's.

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 bases are being developed for transition areas, special air traffic, and all remaining airspace files.

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. Following are some of the major accomplishments during FY91:

- Compilation of 219 FAA-sponsored MSAW 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 FAA, DOD, and C&GS charting requirements. The complete file is available to the public in digital form and in hard copy.
- Subscriptions for the C&GS Digital NAVAID's File has reached almost 30 subscribers in the past year. The NAVAID files contain 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 now available in both hard copy and digital formats. 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 midpoint containing changes that occur during the 56-day publication cycle.
- Digital Special Use Airspace Files are currently being prepared. This data base will give 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 some of the designations included in this airspace. Completion of this data base is projected for late 1992.
- Over 1,000 Radar Video Maps (RVM) were produced in FY91 for the 233 FAA facilities being served. 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 1,396 analog RVM's to digital files for loading to the PROM's. The first Digital Bright Radar Indicator Tower Equipment (DBRITE) was delivered in December 1990; to date, 519 maps have been delivered.
- Digital aeronautical data for a 50 nautical mile radius of the Oklahoma City, Oklahoma, and Memphis, Tennessee, airports were provided to the FAA. The data were extracted from RVM design files and will be evaluated to determine if these 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.

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. This is illustrated in Figure 14. The Aeronautical Information Data Base of ACAS is capable of supporting graphic overlay compilation, overlay production, and generalized support for all products. It is installed at the Rockville, Maryland, site of ACD.

In FY91, 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 Automatic Radar Terminal System Displays, DBRITE, and FAA's Advanced Automation System (AAS).

AAS is a major project of the ACD. It is the FAA's $3.5 billion 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. Figure 15 shows some of the major operational features. AAS will allow the area and tower air traffic control facilities to track seven times more aircraft than the current systems. It will allow aircraft to operate with fewer constraints, over more routes, and with greater fuel efficiency. Significant savings in manpower, rents, utilities, and energy costs will be possible with AAS. 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 is being designed by IBM for AAS, in part, around the data bases and digitized charts from 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.

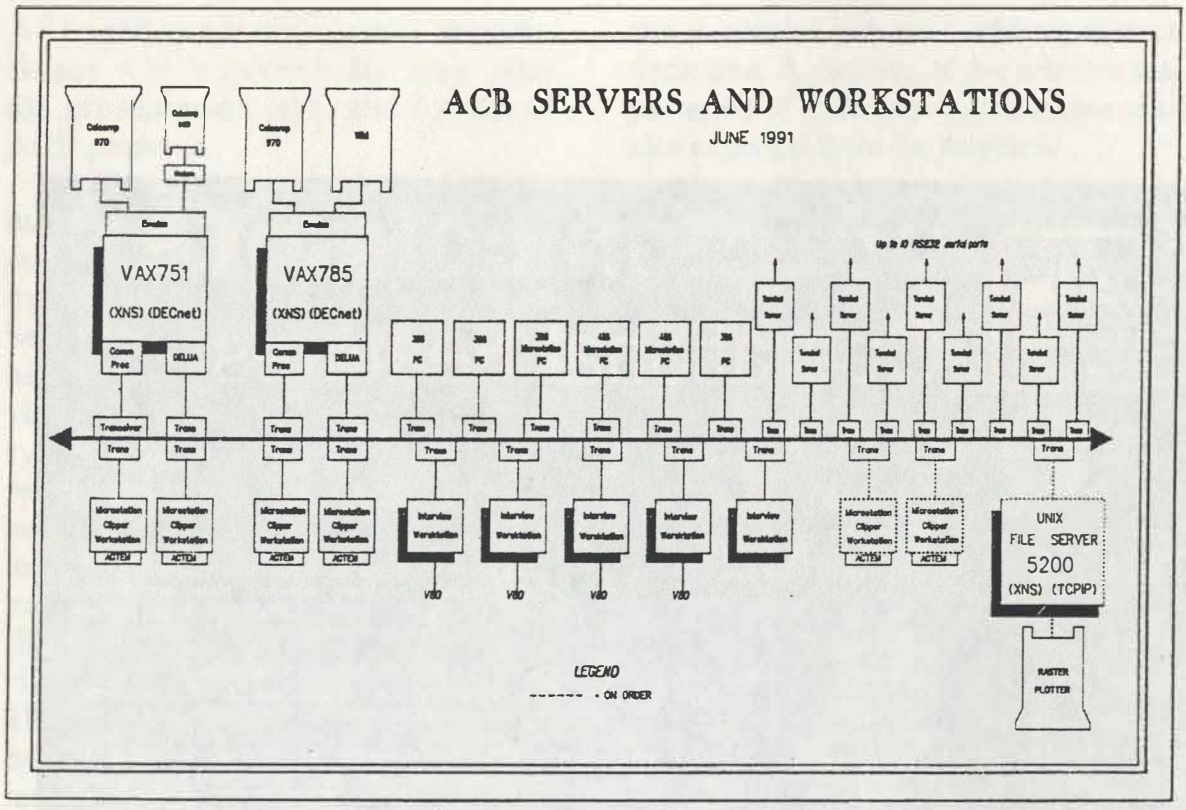

FIGURE 14. Diagram illustrating how ACD plans to use a central host computer to serve workstations in the major production units of the Aeronautical Chart Branch.

The current ACAS system configuration includes a LAN consisting of two minicomputers (VAX 751 and VAX 785); terminal servers linking alphanumeric terminals and microcomputers in all production and development areas; and peripherals that include PROM burners, graphic workstations, and electrostatic and vector plotters.

To accommodate the requirements in support of DBRITE and AAS, an additional UNIX computer with 2.8 gigabytes of mass storage and 64 megabytes of RAM were added to the LAN. Several 16 megabyte cartographic workstations and 386 microcomputers have also been added to the system. In total, the system can currently handle 100 workstations and is presently loaded with 80 workstations.

Development continues on upgrading and expanding ACAS' aeronautical data base management system. The system will take advantage of state-of-the-art technology for data manipulation and retrieval.

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 will be completed in early FY92, allows for technology transfer between

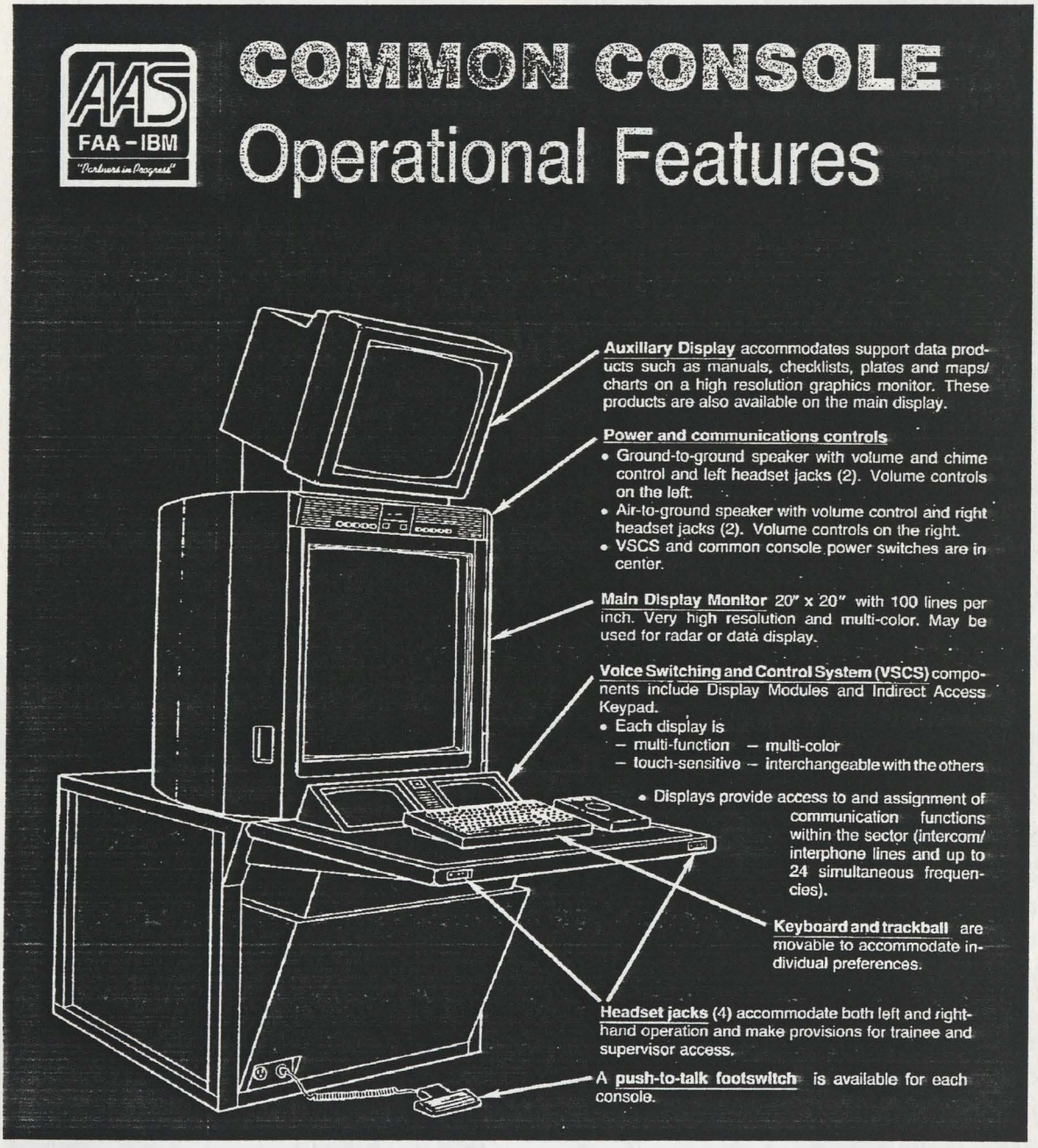

FIGURE 15. Summary of operational features being developed for the Advanced Automated System which the FAA plans to use to control air traffic into the 21st century.

ACD and academia on two distinct issues which potentially may alter the presentation style and format of ACD products.

The first issue examined was the potential for using 3-D charting of the NAS using the various aeronautical data bases maintained by ACD. This modeling will be 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 3-D mapping formats is whether they will contribute to lowering the pilot's workload and add to flight safety. The Embry-Riddle researchers are using pseudo 3-D charts to test the workload response of pilots in a simulation environment. This project has helped provide an indication for how ACD could plan its data base development to support 3-D 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, so 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 is also expected from the research.

NEXT GENERATION CARTOGRAPHY PROGRAM

ACD continues to explore new concepts and methodologies for improving the efficiency of chart compilation, reproduction, and distribution through its Next Generation (Aeronautical) Cartography Program (NGC). ACD is using the University Grant Program to investigate the benefits of state-of-the-art advancements in charting automation to prepare for anticipated aviation requirements well into the 21st century.

The NGC Research and Development Program is a technology demonstration project sponsored by ACD. The program includes the evaluation of high speed parallel processing, high-density optical disk storage, and advanced distributed GIS software.

A key thrust of the program is to support the need for electronic aeronautical chart data bases. Electronic aeronautical charts appear in a variety of areas, including the electronic data base requirements for the AAS which will be used to operate NAS and for various commercial applications.

Another element of the NGC program includes exploring the interest of commercial companies in meeting the public need for a legally recognized electronic data base for their next generation electronic map systems. Industrial input is being solicited concerning acceptable and desirable standards for possible ACD electronic products, particularly in the area of chart presentation style and format.

As part of this effort, two prototype Compact Disk-Read Only Memory (CD-ROM) products were developed. These products contained samples of digital aeronautical data files maintained by ACD. They were prepared to demonstrate the availability of machine-readable ACD airspace navigation data and to seek industry and government comments and input for future digital aeronautical data requirements.

Accomplishments of the NGC program prior to FY91 include the following:

- Development of a NOAA 2001 NGC System Concept.
- Development and continuation of commercial company relations and support for the NGC laboratory. The relationships resulted in the donation of equipment and software by avionics and computer related companies. ACD was able to use the donated equipment at no charge to the Government.
- Establishment of a laboratory at the University of Maryland Research Foundation (URF) facility in Greenbelt, Maryland, including a MicroVAX II/GPX processor with a 750 megabyte hard disk supported by two integral color graphics workstations; a commercial GIS software package, a raster digitizing camera; a vector-based digitizing table, and a 300 DPI color thermal plotter.
- Development of a set of guidelines and a baseline schema definition (including documentation) for the construction of a baseline data base. The schema was used to import digital source data into a GIS system for evaluation.
- Development of a GIS evaluation criteria report to provide a standard for the evaluation of any GIS software package.

ACD and URF completed their grant agreement during FY91 with all tasks described in the proposal completed on or ahead of schedule. The following is a list of accomplishments completed during FY91:

- Translated and incorporated USGS Digital Line Graph (DLG) topographic data files into the baseline data base to be manipulated by a GIS software package.
- Converted ACAS aeronautical data into the DLG standard format for importing ACAS data into a wide range of GIS systems.
- Developed symbology for data display commensurate with existing paper products.
- Combined ACAS aeronautical data with selected USGS digital topographic data files to create a prototype aeronautical chart. USGS DLG files were stored in layers of the baseline data base of a prototype TAC. The ACAS data were merged into the baseline data base with GIS software routines and specialized software and manual procedures. The resulting data base was used to display and plot combined ACAS and USGS data in an automated prototype aeronautical chart. See Figure 16.
- Incorporated attribute data into the baseline data base for the prototype TAC.
- Initiated the addition of terrain elevation data to the baseline data base for inclusion on the prototype TAC.
- Performed an intense technical evaluation of an off-the-shelf GIS application software package using the baseline data base developed, and prepared a report documenting the results

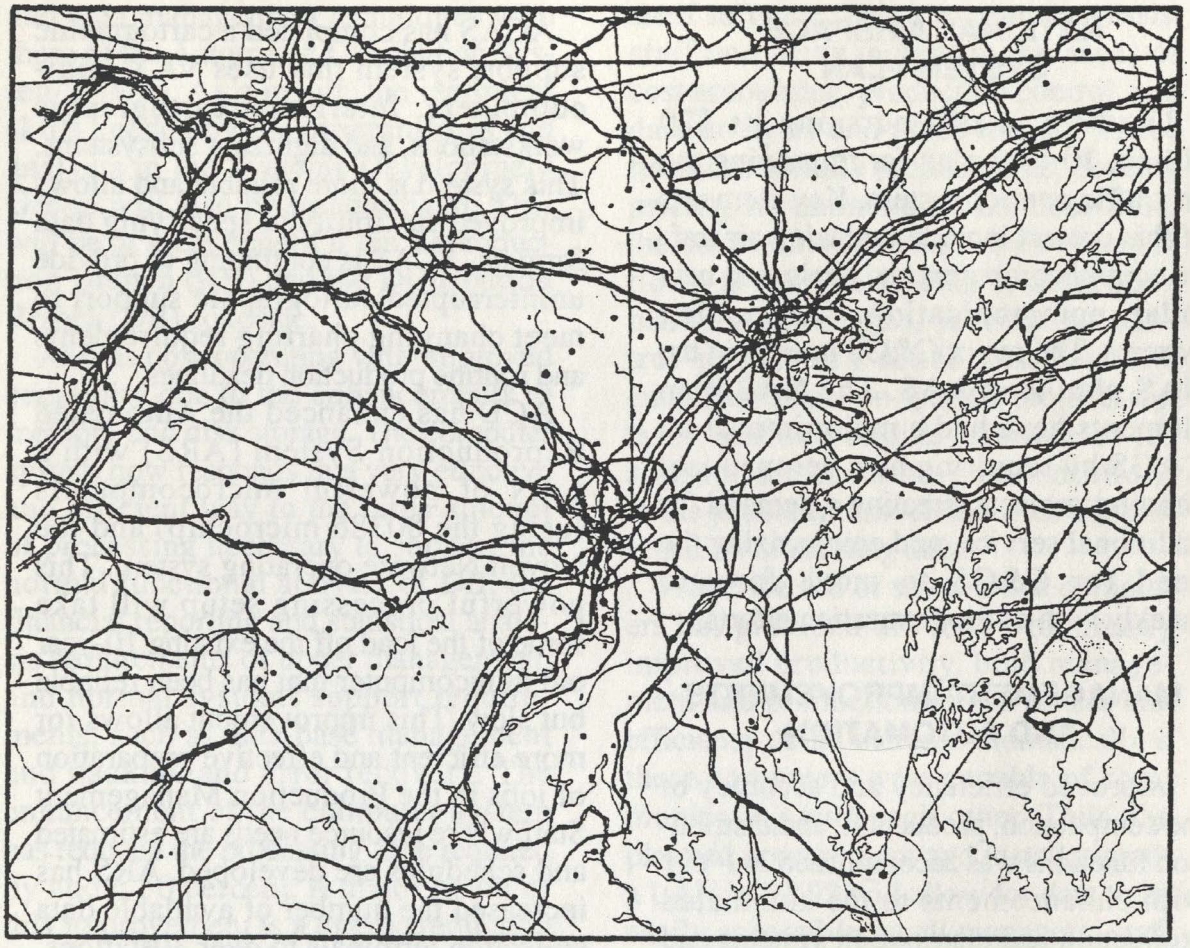

FIGURE 16. Copy of a plot for a digital prototype chart (Washington TAC) prepared from a data base that combines aeronautical data from ACD and topographic data from USGS.

of that evaluation. The evaluation report documented the potential applicability of the software for ACD's current and anticipated future production needs.

- Conducted a survey of available GIS software packages from the standpoint of applicability and support to the ACD program. Selected alternative GIS packages for future evaluation.

The University Grant Program allowed ACD to successfully generate a prototype data base containing all available digital data. The completed prototype contained approximately 80 percent of the data currently found on traditional paper aeronautical charts. The grant to URF was completed at the end of FY91, however, ACD plans to continue grants with other universities during FY92 to support this valuable research and development effort. The future of the program is being dictated by the availability of funding.

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 C&GS interest in the NAS plan is in AAS. The NAS Plan elements have had a major impact on C&GS 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, production, and distribution functions was accomplished in FY91 with enhancements to the automated production and distribution systems and the procurement of additional microcomputers in all branches of ACD. More powerful microcomputers and commercially available software are improving response time and user acceptance.

Development of a limited LAN that supports mini- to micro- and micro- to micro-computer data transfer will be implemented in the next few years as resources become available. The procurement of LAN's will increase user flexibility and data accessibility to large data bases. Research into the use of laser analog and digital disks for high density narrative and image storage and retrieval and the development of a microcomputer cartographic workstation are continuing.

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

ACD has enhanced the Automated Reproduction System (ARS) with a LAN of powerful microcomputers (using the 80386 microchip) and the Novell Netware operating system. This powerful processing setup will take some of the load off 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 Staff where resource needs are estimated and schedules are developed. ARS has increased the number of available data collection terminals to over 30stations. Parsec, an estimating package, was installed and is operational in all the personal computers in the Production Management Staff. The Parsec program will assist RP personnel with cost estimates. In addition, the RB 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 software to run on a Honeywell minicomputer. This conversion will require the existing code to be rewritten in the BASIC programming language 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 Automated Distribution System (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 if the Reproduction Branch (RB) and the Distribution Branch (DB) collocate.

ADS is now operating with improved capability due to the enhancements to memory and disk storage. 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 DB, the financial reporting and statistical analysis requirements of upper management, and normal systems support requirements, such as data base management and backup, and error recovery. The enhancement of the computer system has reduced the processing time required by about 50 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 occur 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, and manage 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 its 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, and 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 LAN in FY92 will allow for data to be easily accessible by all managers, staff personnel, and other users in any of ACD's many locations. 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 stand-alone computers on the ACD staff to the three ACD Branches.

The major functional areas that will be supported by the MIS include 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.

DISTRIBUTION FUNCTIONS

ACD's DB plans and directs the distribution of C&GS's aeronautical and nautical charts and related publications to government agencies, the public, and approximately 4,000 authorized sales agents. In FY93, the DB will start to distribute those charts and products that are available to the public from the DMA. This will be done both directly and through the established network of chart agents.

The DB 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 DB 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 DB duties to provide the flexibility required to meet goals and objectives. The DB is continuing to increase its customer service operation by training its personnel to be more skilled in 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 Government agencies. The DB has also installed new telecommunication equipment to enable customers to telefax orders for faster turnaround time.

The functions of the DB 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, subscriptions, accounts receivable, and inventory. The related computer programs are easily adaptable to changing functional requirements. The computer system was improved in FY91 with the procurement of additional random access memory and two additional disk drives. These enhancements tripled the memory size and doubled the disk storage space. This new hardware has improved the system response time to the users and has speeded up the processing and printing of voluminous output requirements such as labels, invoices, and account statements.

REPRODUCTION FUNCTIONS

The ACD RB plans and directs integrated printing production facilities for the photolithographic reproduction and finishing of charts and maps. The RB engages in and uses all of the processes for producing printed charts and maps from manuscripts; operates 60-inch, 5-color presses; develops production techniques and controls; and provides for maintenance of equipment. Through the increased use of automated tech-

niques and systems, the RB has improved its administrative efficiency and production control capabilities. The mission of the RB is to revise, construct, and reconstruct nautical and aeronautical navigational 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 RB consists of various production-oriented Sections, each performing an integral piece of the total operation. These sections include production management, negative engraving, layout, photography, lithography, typesetting, pressroom operations, and finishing operations.

During FY91, the Reproduction Branch acquired two new equipment systems that have expanded product capabilities in the Photo Unit and the Type Unit. The Photo Unit acquired 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 almost produce the full color spectrum. Proofs are now made on a white photographic paper. Testing is in progress to make proofs on a mylar base which will allow for the proof to be used as a chart overlay for applying compilation corrections.

The Type Unit has installed a new typesetting system which incorporates the flexibility of the Macintosh page make-up workstations for composition with the quality output of the Linotronic 300 imagesetter. This state-of-the-art system offers many advantages over the MultiSet III system previously used in the unit. Page make-up can now be 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 will result in cost savings for the DB's Photo Unit on appropriate products.

To support their mission, more than 100 employees interface with the 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 RB; and performs all processing functions necessary to generate management reports from the data base.

The hardware presently supporting the ARS has reached the end of its expected life cycle. It must be replaced 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 the BASIC programming language under the PICK operating system. ARS will then be consistent with the system that supports ADS. The Ultimate/Honeywell minicomputer that will be used is available as a result of the upgrade of the ADS system. After the software conversion process is completed in FY 92, the computer system will be replaced with new state-of-the-art equipment in FY93.

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 "fail-soft" 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.

Nautical chart deliveries were significantly increased during FY91. The RB reproduced 380 new editions of nautical navigation charts. Through the combined efforts of in-house and commercial engraving resources, a total of 406 charts were reproduced.

The Persian Gulf Crisis created such a huge demand for military maps that DMA could not print them fast enough. As a result, they requested emergency help in printing their maps. The RB responded immediately by reorganizing its work crews to establish a third shift and added three shifts on Saturdays to make press time available. By printing around the clock, six days per week, the RB was able to both increase production of critical-to-safety charts for NOAA and also support DMA's additional requirements.

MARKETING EFFORTS

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

The following tasks were accomplished in FY91 to support these goals:

- ACD continued its long-standing program of participation in aviation trade and airshows. Ten shows were attended in FY91. 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. ACD also provided funding and personnel staffing for several boat shows and nautical trade shows during the year.
- C&GS exhibited at nine technical shows in FY91. Nautical, aeronautical, and geodetic products were displayed at the exhibit booths, and knowledgeable personnel from the three Divisions within C&GS distributed catalogs and answered questions from show attendees.
- The sixth National Ocean Service Chart Agents' Workshop which had to be canceled in 1990 due to budget constraints has been rescheduled for the spring of 1992. Arrangements are being made to hold this workshop in Bethesda, Maryland. Tours of C&GS cartographic and distribution facilities will be offered to agents to familiarize them with C&GS's chart production and distribution environments.
- 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 ACD personnel to encourage aviation groups 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.

- ACD continues to provide promotional items to be distributed 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 fourth year of production and is becoming a useful source of information to C&GS' constituency. C&GS has received many requests from commercial companies wanting to be on the mailing list for this publication.
- The DB has continued to provide training in customer service and telephone techniques for its customer service representatives and other ACD personnel. This training emphasizes total customer satisfaction in all dealings with the public.
- ACD 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.
- Planning and development of several catalogs began in FY91 for the marketing of DMA products and publications. ACD will undertake the distribution of DMA aeronautical and nautical charts to the public in the fall of 1992.
- ACD is staying in touch with its users through its customer inquiry system. ACD calls a selection of aeronautical and nautical chart agents periodically to inquire about products, services, and problems. All problems in servicing and product delivery are routed to and resolved by the DB to improve service to chart agents. In addition, the Chart Agent Visitation Program continues to provide valuable information on customer service. Agents are visited by ACD personnel while traveling to trade shows, technical conferences, or on other official duties. Results from these visits allow ACD 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.
- In an effort to respond to public awareness of the need to protect the environment, ACD has embarked on aprogram to encourage NOAA chart users to recycle their expired charts and publications. This program also includes the preparation of articles for aviation magazines, written special notices to chart purchasers, and distribution of flyers and posters to chart agents throughout the country. See Figure 17.