ANNUAL REPORT

COAST AND GEODETIC SURVEY

National Oceanic and Atmospheric Administration
National Ocean Service
Silver Spring, MD 20910

December 1993

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FISCAL YEAR 1993

U.S. Department of Commerce
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National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary

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

MESSAGE FROM THE DIRECTOR

This annual report summarizes the major accomplishments of Coast and Geodetic Survey (C&GS) during FY 93. 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, photogrammetric, 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
ADS	Automated Distribution System
ANCS II	Automated Nautical Charting System II
ARS	Automated Reproduction System
ARTCC	Air Route Traffic Control Center
CD-ROM	Compact Disk-Read Only Memory
CGDB	Chart Graphics Data Base
C&GS	Coast and Geodetic Survey
CIA	Central Intelligence Agency
CIGNET	Cooperative International GPS Network
COE	U.S. Army Corps of Engineers
DACS	Digital Aeronautical Chart Supplement
DAS	Data Aquisition System
DBRITE	Digital Bright Radar Indicator Tower Equipment
DGPS	Differential Global Positioning System
DMA	Defense Mapping Agency
DNC	Digital Nautical Chart
DPS	Data Processing System
ECDIS	Electronic Chart Display and Information Systems
ESDIM	Earth System Data and Information Management System
FAA	Federal Aviation Administration
FDAD	Fully Digital ARTS (Automated Radar Terminal System) Display
FGCS	Federal Geodetic Control Subcommittee
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
GPS	Global Positioning System
HARN	High Accuracy Reference Network
HSB	Hydrographic Surveys Branch
HDAPS	Hydrographic Data Acquisition and Processing System
HSHRSSS	High Speed, High Resolution Side Scan Sonar
HYDICE	Hyperspectral Digital Imagery Collection Experiment

IACC	Interagency Air Cartographic Committee
IAPC	Instrument Approach Procedure Chart
IDPF	Integrated Digital Photogrammetric Facility
IFR	Instrument Flight Rules
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IMTA	International Map Trade Association
LAN	Local Area Network
MCGIS/CS	Marine Coastal GIS and Compilation System
MIS	Management Information System
MSAW	Minimum Safe Altitude Warning
MSS	Multispectral Scanner
NOS	National Ocean Service
NOAA	National Oceanic and Atmospheric Administration
NAD 27	North American Datum of 1927
NAD 83	North American Datum of 1983
NAS	National Airspace System
NAVD 88	North American Vertical Datum of 1988
NCD	Nautical Charting Division
NCRDL	Nautical Charting Research and Development Laboratory
NGIB	National Geodetic Information Branch
NGRS	National Geodetic Reference System
NGS	National Geodetic Survey
NGVD 29	National Geodetic Vertical Datum of 1929
NIDB	Navigation Information Data Base
NIST	National Institute for Standards and Technology
NSRS	National Spatial Reference System
NRL	Naval Research Laboratory
PB	Photogrammetry Branch
PCDB	Production Control Data Base
PROM	Programmable Read Only Memory
RDBMS	Relational Data Base Management System
RNC	Raster Nautical Chart
RVM	Radar Video Map
SBIR	Small Business Innovation Research
SDTS	Spatial Data Transfer Standard
TQM	Total Quality Management

USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
VFR	Visual Flight Rules

CONTENTS

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 the sciences of hydrography, photogrammetry, and cartography. The mapping and charting program provides accurate and timely nautical and aeronautical charts, maps, and related products for the coastal and adjacent ocean areas of the United States (including possessions and territories), the Great Lakes, other inland navigable waters, and for the National Airspace System for the safety and efficiency of marine and air transportation, offshore engineering projects, defense operations, and recreational activities. The geodetic program develops and maintains the National Geodetic Reference System (NGRS) as defined by the Nation's three geodetic control networks: horizontal, vertical, and gravity. Points defined by these networks are the basic geographic location and elevation starting positions for land surveys, local geographic information systems (GIS), 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 over 10,000 aeronautical charts. In FY 93, C&GS issued 1.5 million marine maps and charts and more than 12 million copies of aeronautical charts and publications. The update cycle for aeronautical charts requires that 9,000 charts be revised and reissued every 56 days, while nautical charts may be revised as often as every 6 months or as infrequently as 12 years for remote areas. The average revision interval per nautical chart is 2 1/2 years. Hydrographic survey sheets, digital data, topographic and shoreline maps, and aerial photographs are important by-products arising from data acquisition and processing that are used to produce these charts and maps. Data collected on geodetic surveys and the results of data analyses and geodetic research investigations are disseminated to users in a variety of formats such as computer printouts, software, data listings, diagrams, magnetic tapes, technical publications, and operations manuals.

As a part of its national leadership role, C&GS provides guidance in mapping and charting procedures. C&GS is the lead agency in an 11-member interagency group responsible for establishing geodetic standards and specifications for Federal control surveys. C&GS also assists national, state, and local organizations through a variety of cooperative programs. Since C&GS cannot rely on the 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 State Geodetic Advisor Program. Personal contacts are made between C&GS personnel and local users during field surveys. The Cooperative Charting Program involving the U.S. Power Squadrons and the U.S. Coast Guard Auxiliary provides valuable feedback information on nautical charts. Additional contacts are made through professional organizations, technical conventions, and boat and air shows. 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:

- data acquisition and processing,
- data base management,
- establishment and maintenance of national standards and specifications,
- information and technology transfer to Government and the private sector, and
- research and development to increase productivity and to improve measurements, survey techniques, and the quality of data and products.

FY 93 accomplishments are cited in separate chapters, each devoted to one of the three C&GS Divisions--National Geodetic Survey, Aeronautical Charting, and Nautical Charting.

ACCOMPLISHMENTS OF THE NATIONAL GEODETIC SURVEY

MISSION

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

TOTAL QUALITY MANAGEMENT (TQM) AND THE MISSION, VISION, AND GOALS OF NGS

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

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

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

HORIZONTAL GEODETIC NETWORK

Processing of horizontal data into North American Datum (NAD 83) was completed for 234 projects containing 9,802 stations. Horizontal control was provided at Federal Aviation Administration (FAA) airports in Arkansas, California, Idaho, Maryland, New Jersey, Nevada, Texas, Utah, Virginia, and Wyoming. NGS conducted five workshops on State Plane Coordinates and Datum Transformations, Project Planning and Network Adjustments, and Building an Accurate Geographic Information System (GIS)/ Land Information System (LIS). Other examples of these technology transfer activities are given in a separate section below.

POST-NAD 83 REGIONAL ADJUSTMENTS

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

HARN EXPANSION

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

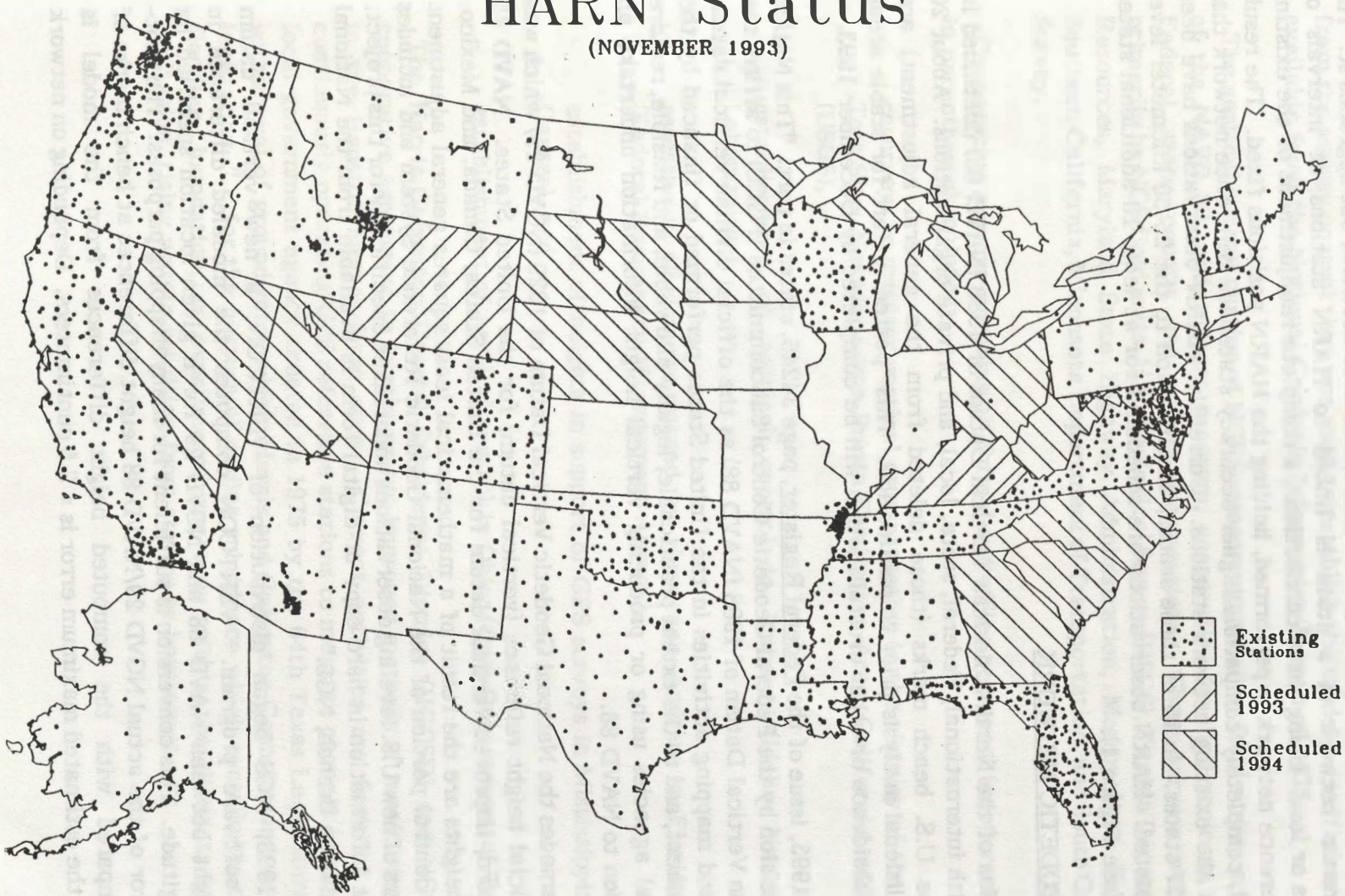

Figure 1. Map showing participation by states requesting NGS support in establishment of high accuracy reference networks based on GPS surveys. Dots show locations of existing stations.

HARN is independent of the existing horizontal reference network, but upgrades it. The existing reference network in a state is linked to HARN stations at intervals of 100 kilometers or less. Using these connections, a complete readjustment of the existing statewide reference network is performed, holding the HARN positions fixed. The result is an upgraded, completely compatible higher accuracy statewide reference network that includes all of the existing network stations. Currently, HARN observations have been completed in 27 states. In 15 of these states, densification to the 25-50 kilometer level has been completed. HARN observations are scheduled for at least 10 additional states during FY 94 (see Figure 1).

VERTICAL GEODETIC NETWORK

Implementation of the North American Vertical Datum of 1988 (NAVD 88) continued in cooperation with international, Federal, state, local, and private organizations. About 20 percent of the U.S. bench marks (those deleted from the general adjustment) are undergoing additional analysis prior to publication. This "posted" effort for stable areas not involving subsidence or other crustal motion will be completed by December 1993.

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

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

In February 1993, NGS began distribution of VERTCON, a new vertical datum transformation software program. VERTCON computes the modeled difference in orthometric height between NAVD 88 and NGVD 29 for a given location specified by latitude and longitude. This conversion is sufficient for many mapping purposes. The root-mean-square error of the actual NGVD 29/NAVD 88 height differences at bench marks of the NGRS compared with the computed height differences from the model is ± 1 centimeter; the estimated maximum error is ± 2.5 centimeters. Depending on network

design and terrain relief, larger differences may occur the farther a control point is located from the survey control that was used to establish the model's coefficients. VERTCON is available from the National Geodetic Information Branch of NGS.

The vertical control portion of NGRS was strengthened by field survey projects in support of the NAVD 88 readjustment program, cooperative leveling projects, and leveling by Federal, state, county, and private organizations. These surveys were accomplished primarily by NGS field units, U.S. Geological Survey (USGS), Florida Department of Natural Resources, Maryland State Highway Administration, Metropolitan Water District of Southern California, Minnesota Department of Transportation, and South Carolina Geodetic Survey.

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

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

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

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

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

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

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

GPS SURVEYS AND EPHEMERIDES

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

GPS-DERIVED ORTHOMETRIC HEIGHTS/GRAVITY OBSERVATIONS

California Department of Transportation (CALTRANS) and NGS undertook a cooperative project to estimate GPS-derived orthometric heights in San Diego County, California, to ± 5 centimeters. The project included NGS' analysis of existing GPS, gravity, and leveling data, determination of requirements for additional observational data of the three types listed above, training of CALTRANS personnel to observe the required data, and computation of an improved regional geoid model of the county using the proper combination of existing and new data. These activities will result in recommended procedures to improve CALTRANS' ability to determine more accurate GPS-derived orthometric heights to meet many of their vertical requirements for transportation improvement projects.

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

CRUSTAL MOTION

NGS cooperated with Federal, state, local, and academic institutions in conducting geodetic surveys for documenting displacements associated with the two magnitude 7+ earthquakes that occurred in California during 1992. A new model for the 1964 Prince William Sound, Alaska, earthquake was developed. Software was generated enabling the

geodetic community to apply NGS' crustal motion model for updating geodetic coordinates and observations in California.

GEOID93

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

KINEMATIC GPS GEODETIC SURVEYING RESEARCH

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

FEDERAL GPS BASE STATION ACTIVITIES

The FGCS interagency subcommittee of the Federal Geographic Data Committee (FGDC) convened a workshop on Federal GPS Reference (Base) Station activities, May 18-20, 1993, in Rockville, Maryland. The Fixed Reference Station Working Group of FGCS explored issues to determine how best to integrate GPS reference station activities of Federal agencies to avoid duplication, improve efficiencies, and reduce costs. The workshop, attended by 25 participants representing nine Federal agencies (Bureau of Land Management, Environmental Protection Agency, National Aeronautics and Space Administration, NOAA, National Park Service, U.S. Army Corps of Engineers, U.S. Coast Guard, U.S. Forest Service, and USGS), concentrated on four areas:

- user data requirements,
- reference station design,
- status of reference station implementation, and
- identification of barriers to reference station data exchange.

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

- pseudorange (meter-level accuracy) versus carrier phase (centimeter-level accuracy) observables,
- real time versus after-the-fact data access,
- fixed station versus moving platform applications, and
- level of reliability required.

Workshop participants agreed that specifications were needed for several classes of reference stations at varying levels of complexity. Factors that increase complexity are:

- data links for real-time data transmission,
- dual receiver back-up for very high reliability, and
- high data recording rates (0.5 to 1 second sampling versus 5 to 30 second sampling) for moving platform positioning.

Although agencies presently attempt to share reference station data at local, state, and regional levels, there are several technical and procedural barriers to data sharing. A significant technical barrier is the incompatibility of data from different types of GPS receivers, even when using the RINEX (Receiver INdependent EXchange) data format. This incompatibility can cause the determination of coordinates to be very difficult when using different types of GPS receivers during a survey.

Procedural barriers include the closed nature of some agency data bases and agency policies on data cost recovery. The agency representatives agreed to work through the FGCS' Fixed Reference Station Working Group to resolve the technical problems and through FGCS and FGDC to develop interagency agreements to eliminate procedural barriers.

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

TECHNOLOGY TRANSFER

Development of the publication Multipurpose Land Information Systems: The Guidebook continued with distribution of Chapters 12, 14, 15, and 21 during FY 93. Chapters 13 and 19 will be published by January 1994. This comprehensive guidebook is used to develop multipurpose land information systems by focusing on local government's role in developing the multipurpose cadastre.

The C&GS State Geodetic Advisor Program continued in 26 states, with inquiries about the program being received from the States of New York and Connecticut. The accompanying map (see Figure 2) summarizes the status of the current state participation.

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

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

NATIONAL GEODETIC INFORMATION BRANCH

The objective of the National Geodetic Information Branch (NGIB) of NGS is the distribution of 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. In addition to these technology transfer functions, the Branch also conducts a marketing program to increase user awareness and understanding of these products and to improve NGS' responsiveness to its users.

During FY 93, NGIB accomplished the following:

- Users were provided with a new vertical datum transformation software program VERTCON. VERTCON computes the modeled difference in orthometric height between NAVD 88 and NGVD 29 for a given location specified by latitude and longitude.

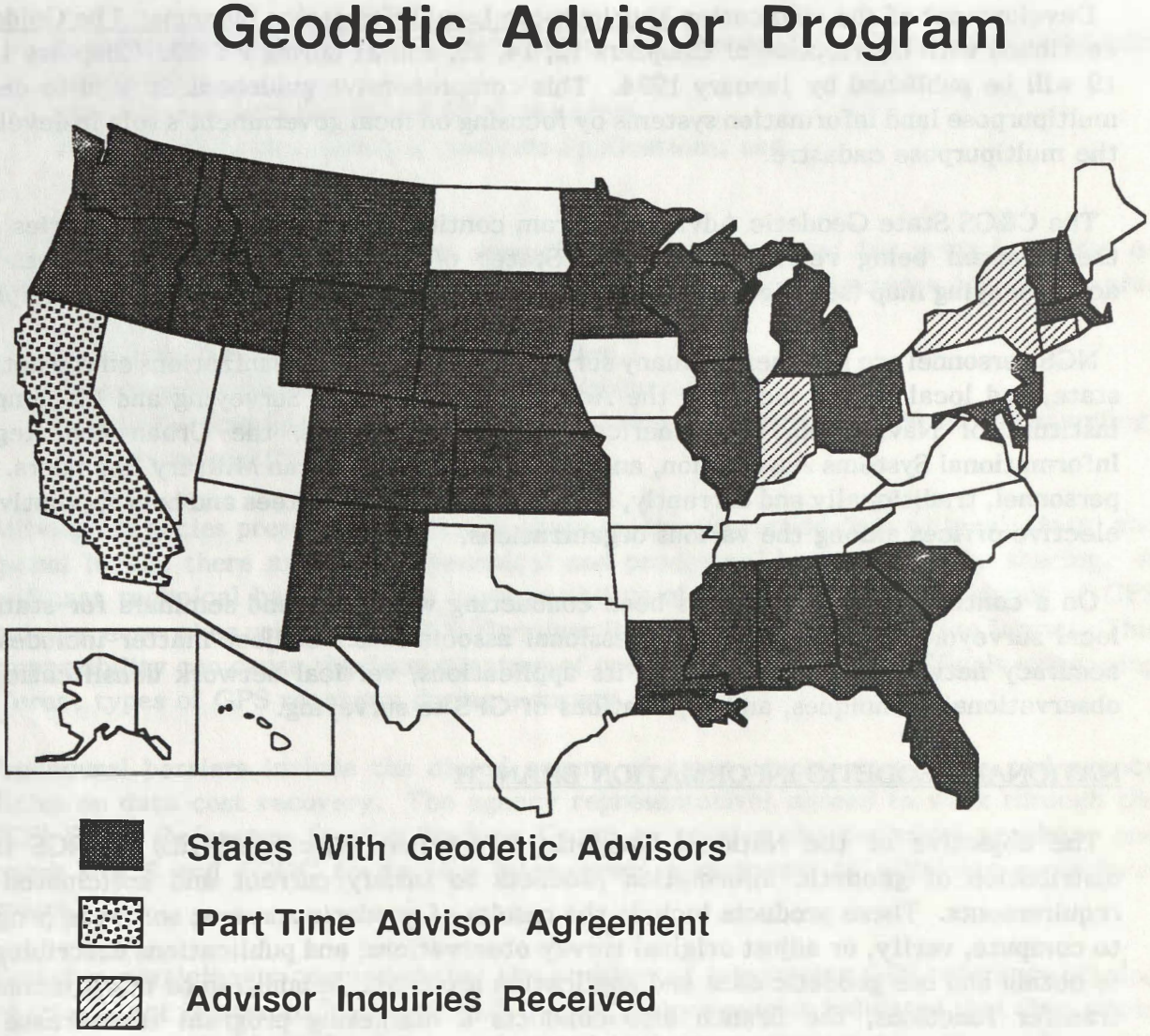

Figure 2. Map of the United States showing state participation in the NGS State Geodetic Advisor Program.

- A high-resolution geoid height model, GEOID93, was distributed to users for the conterminous United States. These geoid heights are referred to the Geodetic Reference System of 1980 (GRS 80) and are appropriate for use with GPS.

- Data were distributed for 31 new Calibration Base Lines, along with the NGS verification program, in support of cooperative interagency agreements.

- A high-resolution deflection of the vertical model, DEFLEC93, was distributed for the conterminous United States. These deflections of the vertical are referred to GRS 80 and are appropriate for use in Laplace corrections and deflection corrections.

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

- Chapters of the publication Mutipurpose Land Information Systems Guidebook, mentioned above, were distributed.

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

- Information on local geodetic control for environmental impact statements was provided for 44 proposed construction projects throughout the United States.

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

- Workshops were conducted on how to obtain, understand, and use NGS information products.

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

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

ACCOMPLISHMENTS OF THE AERONAUTICAL CHARTING DIVISION

INTRODUCTION

The Aeronautical Charting Division (ACD) role as a Government entity is to support the basic U.S. air navigation infrastructure. The mission of ACD is to provide accurate, high-quality air navigation information to users of the National Airspace System (NAS). To accomplish its mission, 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 NAS. The continuous maintenance of charts and files is required to support the regularly scheduled update cycle for the program. This Division also prints and distributes all of NOAA's nautical charts and maps. On October 1, 1992, ACD became the distributor for the Defense Mapping Agency (DMA) public sale aeronautical and nautical charts and related products. ACD is organized into three branches: The Aeronautical Chart Branch (ACB), the Reproduction Branch, and the Distribution Branch. ACD's accomplishments for FY 93 are as follows:

AERONAUTICAL CHART BRANCH (ACB)

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

- visual products,
- instrument products,
- special products, and
- chart automation.

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

VISUAL PROGRAM

Under the visual program, ACD produces 182 different charts that provide information to pilots flying under Federal Aviation Administration (FAA) Visual Flight Rules (VFR). The majority of these charts are revised every 6-12 months, with approximately 2,500,000 copies distributed each year.

Additional accomplishments of the visual program during FY 93 were as follows:

- The initial phase of the FAA Airspace Reclassification Project was effective on October 15, 1992. This phase of the project required over 3,000 new and revised

Federal rules to be applied to all VFR charts within a 1-year period. The changes were made as new chart editions were issued and all U.S. airspace was officially changed on September 16, 1993.

- The following Interagency Air Cartographic Committee (IACC) requirements were implemented in FY 93:
  - charting of noncontinuous navigational aids,
  - revisions to the charting of the availability of transcribed weather broadcasts,
  - inclusion of automated weather observing systems (AWOS), and
  - inclusion of hazardous inflight weather advisory services.

Visual aeronautical charts are flight checked once every 3 years by a rotating crew of three NOAA commissioned officer pilots flying a Government-owned twin engine "Shrike" Commander aircraft. During FY 93, the flight check program reviewed selected Sectional Aeronautical Charts and their associated Terminal Area Charts, as well as 147 Minimum Safe Altitude Warning (MSAW) sites in the conterminous United States.

These flight checks contributed 1,964 potential base feature changes for chart compilation. In addition, 384 photographic sites were compiled and 947 obstacles were measured. Of these 947 obstacles, 324 contained new obstructions not previously listed in the obstacle data files. Sixty were found to have been dismantled and therefore relabeled in the current file, and 563 obstacles were reverified for horizontal position and vertical accuracy. This combined photography and stereoplot operation yielded an outstanding 92.4 percent usable data return. The flight check program permits the resolution of source data inconsistencies and provides pilot input to the compilation and design of visual aeronautical chart products.

INSTRUMENT PROGRAM

Under the instrument program, ACD provides more than 8,900 charts and publications which are used by pilots flying under FAA Instrument Flight Rules (IFR). Nearly 80 percent of these publications must be revised every 56 days. Approximately 7,800,000 copies of instrument charts and publications are distributed annually. The following are the accomplishments in the instrument program:

- All 42 IFR Enroute Charts were converted to the newly developed enroute four-color specifications. The project was completed in three phases. The first phase, consisting of the Enroute High Altitude Charts, was carried out using standard manual cartographic compilation and drafting practices. The second phase, consisting of the Alaska Low Altitude Charts, was accomplished using computer-

assisted cartographic techniques to compile the charts. Drafting was manual. The third and final phase, consisting of the U.S. Enroute Low Altitude Charts, was fully automated. Data files were constructed, compiled, and drafted using VAX workstations. The charts for the final phase were printed in September 1993.

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

- The Terminal Procedures are produced in 17 volumes every 56 days, depicting over 8,000 instrument charts for arrival, landing, and take-off at over 2,500 airports in the United States. This was a 2 percent increase over last year's production.

- Under the direction of the IACC Task Group 30, a prototype reformatted Airport Diagram to a 10"x 10" configuration was compiled. The chart depicts standard taxi routes which clearly identify taxiways from where they start to where they end. Supplemental information is shown in text form.

- The Instrument Approach Procedure Charts (IAPC) will be hole-punched and shrink wrapped for distribution starting with the April 28, 1994, effective charting cycle date. Previously, the IAPC indices were prepared through a computer program that created a composition tape that was sent to the Government Printing Office to make negative images. The alternate, take-off, and radar minimums were sent to ACD's Reproduction Branch for creation of negatives. The advances in the use of personal computers in the production of these items has enabled ACD's Instrument Approach Procedure Section to gain 3 days in the production process, thereby allowing ACB to reduce costs and exercise total control over the data.

SPECIAL PRODUCTS AND SERVICES

The special products and services program provides Controller Charts, Obstruction Charts, Radar Video Maps (RVM's), 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:

65,000	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
2,100	Transition Areas

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 in the special products and services program during FY 93:

- Compilation of 236 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.

- Subscriptions for the NOS Digital NAVAID 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 a composite of information used in conjunction with aeronautical charts. It is currently available only on 3.5-inch or 5.25-inch floppy diskettes. The diskettes contain all nine sections of the DACS. This product provides ground coordinates to air traffic controllers, aviation system developers, and the general aviation community. All nine DACS sections are produced every 56 days. In addition, section three includes a change notice (issued at the 28-day midpoint) which contains changes that occur during the 56-day publication cycle.

- Over 1,400 RVM's were produced in FY 93 for the 213 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.

- ACD operates an automatic mapping system that is used to produce digital RVM's. The Digital Bright Radar Indicator Tower Equipment (DBRITE) program enables video maps to be generated and displayed digitally. During FY 93, 148 new maps were constructed and 530 maps revised for 267 facilities.

- ACD provides FAA facilities with maps to support the Terminal Doppler Weather Radar (TDWR) System. This system is one part of a vast new weather watching system designed to streamline travel and has the capabilities of producing "nowcasts." Nowcasts are extremely accurate localized 1-hour forecasts of violent storms and other items of intense interest to pilots including icing conditions, heavy snow, wind shear, turbulence, winds aloft, and fog. The TDWR system is particularly valuable to air traffic controllers in detecting wind shear. These are dangerous sudden wind shifts that have been blamed for more than 650 deaths in the last 25 years. Plans have been made to deploy radar systems at major airports throughout the country. During FY 93, 24 new maps were constructed and 92 existing maps were revised for 19 FAA facilities.

- ACD is in the process of preparing 12 maps for the new Denver International Airport to be used as Final Monitor Aids. These maps were designed specifically to monitor aircraft that make simultaneous approaches to the airport's four parallel north/south runways and two east/west runways. The maps are produced at a scale of 1:24,000 to provide maximum accuracy. Map data are sent to Denver in digital format and processed into a graphic for use by the controllers.

- During FY 93, ACD has completed its Digital Special Use Airspace Files data base. This data base provides ground coordinates necessary for graphic portrayal of regulatory and nonregulatory airspace. Alert areas, prohibited areas, restricted areas, airport radar service areas, transition areas, and control zones are the designations included in this airspace.

CHART AUTOMATION

The goal of the ACD's Aeronautical Chart Automation Section (ACAS) is to produce and implement an overall system containing a central host computer interfaced with graphic work stations 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 ACD plan envisions the modular implementation of a comprehensive system in support of all major aeronautical charting products.

ACB SERVERS AND WORKSTATIONS

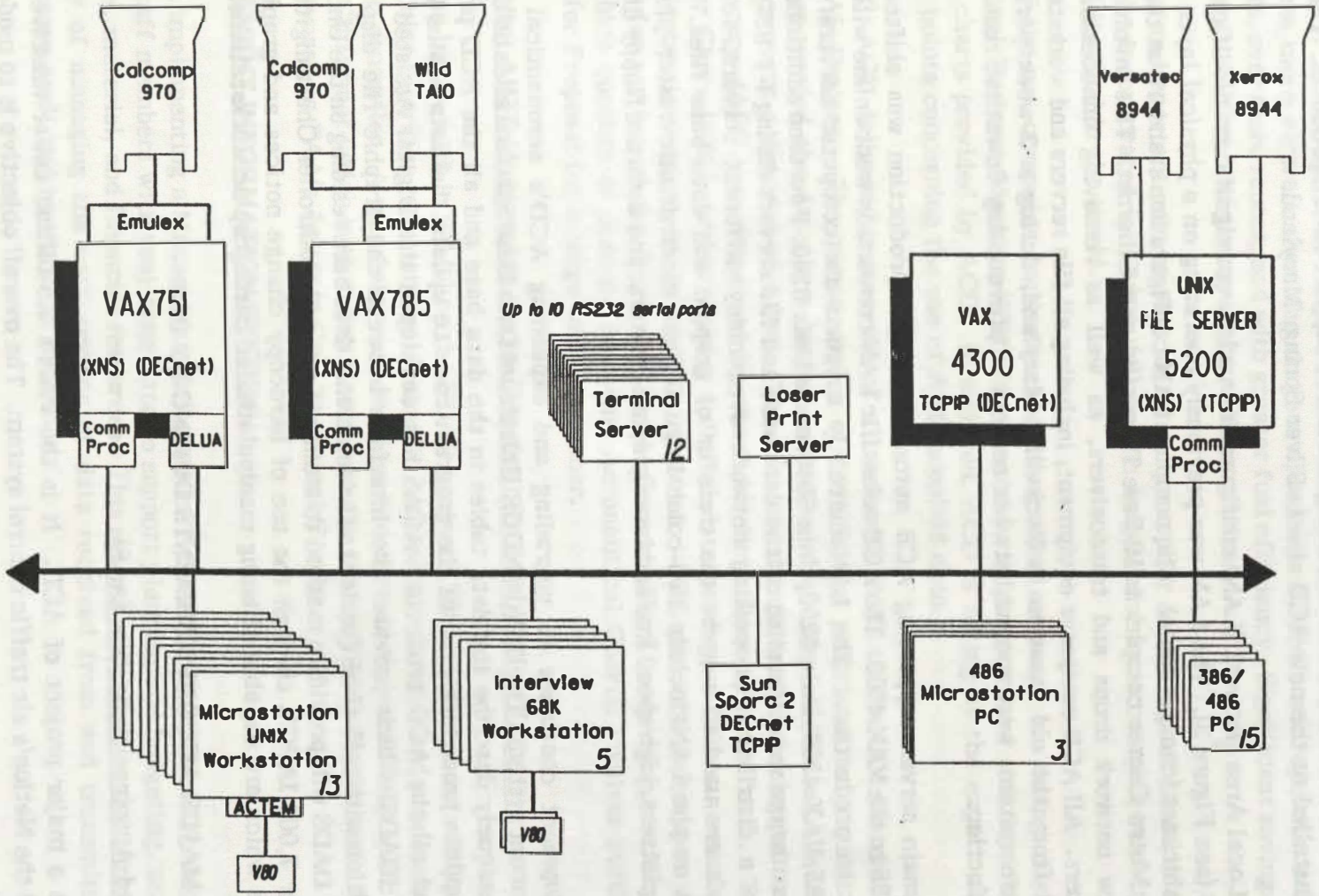

Figure 3. Diagram of the Aeronautical Chart Automation Section's (ACAS) local area network configuration.

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

The Local Area Network (LAN) configuration underwent significant modifications during FY 93 (see Figure 3). The LAN was previously operating on a physical layer of Ethernet 802.3 thicknet (coaxial cable). The complex LAN configuration standard at the new Silver Spring Metro Center complex is 10 Base T-twisted pair Ethernet. This involved installing all new network drops and transceivers, as well as removing unnecessary Ethernet repeaters. All ACB computer equipment, including all file servers and workstations, were moved from the old location in Rockville, Maryland, during a 2-week period in July. Software systems were moved between servers to prevent any downtime resulting in loss of production.

The main server supporting ACB automated chart production was shifted from the VAX 785 to the VAX 4300. The ACB scientific LAN conversion went online with very little impact to production. The LAN currently supports six computer servers: VAX 751, VAX 785, VAX 4300, Unix 5200, Unix 6040, and a Unix 6240. Fourteen additional gigabytes of mass storage were installed on the data base and file servers during FY 93. In order to achieve a distributed processing network over many different servers, four network protocols are used to support the transfer of graphic and data base files. Peripheral devices on the LAN include two-color large format electrostatic raster plotters, four vector plotters, high speed line and laser graphic printers, and assorted floppy disk and tape drives.

Development continues on upgrading and expanding ACD's aeronautical data base management system. The DEVCONDOR Relational Data Base System relies on dictionaries which uniquely describe the data tables in the data base and all the ACD products. A single update procedure creates the program code to update the data tables in the data base and all the ACD products. ACAS has developed the Digital Assisted Data Base System (DADS) which provides the interface between the graphic file displayed on a workstation with real-time queries to the relational data base residing on the Unix 5200 file server. DADS will provide a method to maintain over 40 Controller Chart digital products and over 7,000 IAPC's through the use of hardcopy change notices and graphic change overlays which are capable of being manipulated on cartographic workstations.

OTHER MAJOR ACCOMPLISHMENTS DURING FY 93

Advanced Automation System (AAS)

AAS is a major project of ACD. It is the FAA's 3.5-billion dollar massive effort to overhaul the Nation's air traffic control system. The overall objective is to modernize and

improve the systems to accommodate the spiraling demands for aviation services into the 21st century. AAS will allow the area and tower air traffic control facilities to track seven times more aircraft than the current systems. Aircraft will operate with fewer constraints, over more routes, and with greater fuel efficiency. Significant savings in staff hours, rents, utilities, and energy costs will be realized.

ACD has an important role to play as the sole supplier of the digital chart information that will be incorporated into what will be the largest and most complex real-time data system of its kind in the world.

State-of-the-art computer hardware and integrated software are being designed by International Business Machine (IBM) for the AAS, in part, around the data bases and digitized charts provided by ACD. In addition, ACD is acting as the expert advisor on technical points concerning the use of ACD supplied data.

In FY 93, ACD delivered prototypes of a landscape IAPC to the IBM Federal Systems Group AAS Project. The paper copies of IAPC's are portrayed in portrait format. Controllers needed the data in a larger format so that they could read the data on a console screen at a distance of 4 feet. The data are then turned and enlarged to 11"x13". The landscape IAPC was requested by the AAS Core Requirement Team. The Super Controller Chart (SCC) product is also a digital data product. This is a seamless, edge fitting electronic product to be used on consoles. SCC product prototypes were also delivered for testing on the Common Console Screen. Work to develop the Visual Super Chart, which consists of scanned Sectional Aeronautical Charts, involves putting out a Request for Proposal for a large format scanner.

Fully Digital ARTS (Automated Radar Terminal System) Display (FDAD)

ACD also began work in FY 93 on the FDAD project. The FDAD system will provide the man/machine interface between the air traffic control search radar and processors and the air traffic controller. A translator was developed to convert digital RVM graphic files into a SIF ASCII format which is then translated into the binary FDAD file format. Test maps were delivered to FAA's Atlantic City Technical Center.

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 operational 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. The procurement and installation of a LAN in FY 93 makes data easily accessible by all managers, staff personnel, and other users in Silver Spring and Riverdale in Maryland, and the Herbert C. Hoover Building in Washington, D.C.

After relocating to Silver Spring, Maryland, in July 1993, a large number of ACD personnel were connected to the NOAA LAN. Communications between NOAA components and ACD have improved with information being quickly and easily passed over the LAN. ACD plans to connect all microcomputers to the LAN as funding permits in order to establish resource sharing and reduce costs. The MIS can then bring together and correlate the cost, revenue, and production data currently residing on diverse computer systems. It can also eliminate redundant data entry, decrease the possibility for erroneous data, and allow for a more timely dissemination of summarized information. The new LAN will link the microcomputers in the ACD staff to those in the three Branches.

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

REPRODUCTION BRANCH

The Reproduction Branch, located in the Herbert C. Hoover Building in downtown Washington, provides the prepress services, printing, and finishing for all NOAA charts and maps. The Branch consists of production-oriented elements, each performing an integral piece of the total operation. These include production management, negative engraving, quality assurance, photography, lithography, typesetting, platemaking, pressroom, and finishing operations.

Several 60" multicolor lithographic presses are used to print the nautical and aeronautical maps and charts and some DMA maps. These presses are also the emergency back-up in

case of default by the IFR Enroute Charts printing contractor. The FAA requires a guarantee from NOAA through this backup that aeronautical charts publication dates will never be missed.

The aeronautical charts (except IFR Enroute Charts and book-bound products) are all printed by the Branch during a 2-week period every 28 days to meet strict publication dates. Between these periods, all nautical charts/maps and supplemental work are printed. The printing schedules are exceedingly tight so that the printed products are as current as possible. All equipment has backup arrangements to handle emergencies and ensure against missed publication dates. Approximately 50 percent of the different products in ACD's suite of charts are printed under contract. All of the Enroute Charts and all of the book-bound products are printed under contract.

The Branch uses a Carlson color proofing system with a Kreonite processor that allows for closer approximation of the colors achieved on the presses. Proofs are now being made on a mylar base that allows the proof to be used as a chart overlay for applying compilation corrections.

The Branch's typesetting system combines the flexibility of the Apple MacIntosh page makeup workstations for composition with the quality output of the Linotronic 300 image setter. Page makeup is performed directly on the system, integrating textual and graphic data online. The output from the Linotronic 300 can be either film (positive or negative) or paper, which results in cost savings for both film and paper supplies. A new catalog of fonts available on the new system was produced in FY 93. The catalog was distributed to the aeronautical and nautical chart compilation units who now order type produced on the new system. A method was developed and implemented to transfer the "Dates of Latest Editions" information and chart agent lists from the Automated Distribution System (ADS) system to the new typesetting system by floppy disk. The direct transfer meant that the information did not have to be maintained in two locations, cutting back on typesetting costs and proofreading time.

During FY 93, two used Gerber Photo Plotters were installed at the Reproduction Branch. One was obtained from AT&T and the other from USGS. This equipment (both operated simultaneously by one person) fulfills RVM and other ACD plotting requirements and serves as backup for any plotting contracts.

As part of the ACD's quality management program, approximately 90 employees interface with the Automated Reproduction System (ARS) through the automated production control, work-in-progress, time accounting, cost accounting, and job status reporting systems. ARS provides the collection, editing, and correction of cost accounting, employee time, material usage, and job control information; supports the initiation and scheduling of jobs through

the Branch; and performs all processing functions necessary to generate management reports from the data base.

The hardware presently supporting ARS has been in service for 11 years and reached the end of its expected life cycle 4 years ago. It is being replaced by an Ultimate/Honeywell minicomputer in order to continue to supply adequate support to production managers and cost control analysts in a timely and reliable manner. Planned actions to reduce costs and improve services include the conversion of the existing applications software to the proprietary PRINTPRO software.

This proprietary program is used in many printing plants in the private sector. It is expected that such a standard software package will allow the Government to operate at a greater level of efficiency than with the present internally developed system. PRINTPRO was developed in BASIC under the PICK operating system. Implementation of PRINTPRO on the Ultimate/Honeywell computer will produce a system that is consistent with that supporting the ADS. The software conversion process is expected to be completed in FY 94. After 1 or 2 years of operation to ensure user and management satisfaction, the computer hardware will be upgraded with new state-of-the-art equipment. This equipment is expected to be very powerful, and relatively inexpensive, microprocessors.

The new system will provide online 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 local data storage at the user terminals, and online data validation and correction by the users.

DISTRIBUTION FUNCTIONS

The ACD Distribution Branch plans and directs the distribution of NOAA's aeronautical and nautical charts and related publications to Government agencies, the public, and approximately 4,000 authorized sales agents. In FY 93, the Branch began to distribute those charts and products that are available to the public from DMA. Approximately 6,000 different DMA aeronautical and nautical charts and products are available for public sale. The magnitude of this effort required new contractual arrangements for the distribution of these products, and sales have been greater than when distributed by DMA. Orders for NOAA and DMA public sale products are processed directly from ACD and through the established network of chart sales agents.

The Branch also selects and monitors sales agents, determines quantity requirements for charts and related publications, initiates print orders, and performs bookkeeping,

accounting, and maintenance of mailing lists pertaining to the receipt and issuance of charts and publications. Critical missions of the Branch include the timely distribution of date-sensitive charts and publications, and the maintenance and production of current information about inventory and revenue. The successful operation of these functions depends on contractual support that presently includes warehousing, order filling, and shipping.

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

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

The Branch has also developed a program with the U.S. Postal Service to increase the efficiency of distributing products. A manifest system is being used to determine the cost of postage. This system replaced the previously used weighing/stamping method. ACD is charged for the postage indicated on the manifest. Using the manifest system, a formula based on the predetermined weights of each product (including packaging) and the destination of the product determines the cost for shipping. This eliminates the need for weighing and stamping each filled order. This system and a change in the distribution contractor combined to allow a major cost savings by a combined shipping of Airport Facility Directories and Terminal Procedure Publication products.

The Branch is continuing to increase its customer service operation by training its personnel to be more skilled at handling all types of situations and to increase expertise in providing technical information on all NOAA products and publications available from other Federal agencies. The Branch has also installed additional telecommunication equipment to enable customers to telefax orders when faster turnaround time is required.

The functions of the Distribution Branch are being supported by a commercially available online software package that was procured to provide standardization and customization of the operational environment. The ADS supports the processing of orders for charting products, customer credit verification, invoices and monthly statements, back orders and standing orders, accounts receivable, subscriptions, and inventory. The related computer

programs are easily adaptable to changing functional requirements. The computer system was expanded in FY 93 with 16 additional user terminals. These enhancements allow increased staffing. This new hardware decreased system response time to the users thus speeding up the processing and printing of voluminous output requirements for labels, invoices, pick lists, and account statements.

MARKETING EFFORTS

The long-term goals of the C&GS Marketing Program support the efforts of NOAA 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 FY 93 to support these goals:

- ACD continued its long-standing program of participation at aviation trade shows, air shows, and pilot fly-ins. In FY 93, three events were jointly funded with FAA. The exhibit at these events was staffed by both FAA and ACD personnel. ACD also attended two local air shows, two local fly-ins, and combined attendance at two additional aviation events with the flight school visitation program.

- C&GS exhibited at seven technical shows in FY 93, as well as at several local functions to promote public awareness of the services provided by C&GS. Nautical, aeronautical, and geodetic products were displayed at the exhibit booths, and knowledgeable personnel from the three C&GS Divisions provided informational materials to show attendees and answered technical questions.

- The seventh Workshop for NOS Chart Agents was conducted at the San Diego Marriott Hotel, San Diego, California, on September 15, 1993. This 1-day workshop, which was held in conjunction with the International Map Trade Association (IMTA) Annual Conference and Trade Show, was attended by over 45 chart agents from around the country and the world. Dr. W. Stanley Wilson, the NOAA Assistant Administrator for Ocean Services and Coastal Zone Management, was the guest luncheon speaker and addressed the National Performance Review and its emphasis on customer service. He also addressed future plans within NOS and how they will affect our customers.

  The program included presentations on nautical and aeronautical products and services, proposed policy, and product changes. The issues associated with the distribution of DMA products by ACD and how they will affect the chart agents were discussed. As at previous workshops, there was a closed-door session where the chart agents discussed their concerns among themselves, followed by a chart

agents' forum where the agents voiced these concerns and addressed their questions to the ACD personnel present.

The next workshop is planned for the fall of 1994 and again will be held in conjunction with the IMTA Annual Conference in Portland, Maine.

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

- During FY 93, personnel from ACD visited and discussed charting matters with certified flight instructors at airports throughout the country. The objectives were to educate flight instructors on the vast amount of changes which occur to charts during a chart cycle and to emphasize the importance of using charts that reflect up-to-date aeronautical information to enhance safe navigation. The presentations also provide an overview of the chartmaking process. The objective of this part of the presentations is to give the instructors an appreciation for the painstaking efforts employed in producing aeronautical charts. The flight instructors are encouraged to educate their students on the importance of using up-to-date charts and to include discussions on this topic as part of the flight school's curriculum.

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

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

- The C&GS publication entitled "C&GS Update" is a quarterly four- to six-page information bulletin now in its sixth year of issue. It relates the latest C&GS technology developments as well as program activities, notices, and accomplishments of the organization in the fields of geodesy, mapping, charting,

hydrography, photogrammetry, surveying, positioning, data handling, and information dissemination.

Approximately 10,800 copies of this free publication were distributed quarterly during 1993 outside NOAA to individuals and organizations in the private sector, academia, industry, and Government. Approximately 1,700 of the total number distributed externally were mailed to individuals and organization outside the United States. Several thousand copies were distributed throughout NOAA. During 1994, additional subscribers will be sought through contact with professional organizations and by participation in technical conferences involving C&GS employees.

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

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

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

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

- ACD participates in many programs to enhance the safety and usability of aeronautical charts and publications and to assess future requirements of the aviation community. These programs include:

  - The FAA Industry Charting Forum,

- The Society of Automotive Engineers G-10 Subcommittee for Aeronautical Charting,
- The Interagency Air Cartographic Committee,
- The Aeronautical Charting Division External Review, and
- Coordination and liaison with user groups such as the Aircraft Owners and Pilots Association and the Airline Pilots Association.

- As part of C&GS' marketing efforts during FY 93, ACD completed construction of three new exhibits for use at all the technical shows attended by C&GS. In addition, a new exhibit structure was acquired and new graphics were designed and constructed for an aeronautical exhibit which will be utilized at the air shows.

- Several times throughout the year, ACD publishes an Agent NewsMemo which is distributed to the more than 4,200 of its chart agents throughout the world. This publication includes information on new products and services and other informational items to keep the chart agents abreast of the activities within NOAA.

- In FY 93, ACD took part in a market research project which was sponsored by IMTA, several Government agencies, and commercial establishments. The project involved a survey of map and chart users and buyers across the country to profile the market and to determine buying habits and trends among the general population. Specific questions dealing directly with requirements, background, and interests of the users of C&GS charting products were included in the survey. A second phase of the survey, which would target only the segment of the population which uses NOAA charting products, is proposed for FY 94.

TOTAL QUALITY MANAGEMENT

Customer satisfaction is a major concern in ACD. The nature of aviation-related products to safe air flight and timely delivery associated with them demand a great commitment by management, as well as by the Division's employees, to provide products and services of the highest quality. Responses from questionnaires and inquiries indicate that customer recognition of improvements in products, order processing time, billing accuracy, order fulfillment accuracy, and delivery time are major factors contributing to increased satisfaction. Many of these improvements resulted from increased participation of management and employees in the TQM process, as a means for accomplishing the Division's mission.

SCIENTIFIC PAPERS AND TECHNICAL REPORTS

Bolton, Ronald M., "The Cartographic Challenges of Air Traffic Control Graphics for the Advanced Automation System," North American Cartographic Information Society XIIII, October 20-23, 1993, Silver Spring, Maryland.

McCann, Robert X. Jr., "Evaluation of the Effectiveness of Aeronautical Charting Division (Coast and Geodetic Survey) User/Outreach Program in Convincing Civilian Aircraft Pilots to use Up-To-Date Aeronautical Charts," Master's Degree Capstone Project, Central Michigan University, October 25, 1993, Silver Spring, Maryland.

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, hydrographic surveys were conducted in Alaska, California, Massachusetts, Delaware Bay, Gulf of Mexico, and Lake Michigan. Work continued on digital archiving systems for hydrographic surveys, and historical hydrographic data were recovered from deteriorating storage media. All surveys were conducted using the Hydrographic Data Acquisition and Processing System (HDAPS) with differential GPS as the primary positioning mode. A new shallow water multibeam surveying system was successfully tested. Photogrammetric missions were carried out throughout the United States to support nautical charting and airport obstruction programs. Modernization of cartographic and field data acquisitions operations continued. New nautical charts were issued and support for the national Electronic Chart Display and Information Systems (ECDIS) Project was continued.

HYDROGRAPHIC SURVEYS

The Hydrographic Surveys Branch (HSB) planned and conducted hydrographic surveys during the year using five NOAA ships and two mobile field parties in the following areas: Southern Stephens Passage, Alaska; Southern Alaska Peninsula; Northwest Prince William Sound, Alaska; Alcan Harbor (Shemya Island), Alaska; San Francisco Bay, California; Buzzards Bay, Nantucket and Vineyard Sounds, Massachusetts; Approaches to Delaware Bay, Delaware; Solomons Island Naval Annex Pier, Maryland; Biscayne Bay, Florida; Offshore Biscayne Bay, Florida; Choctawhatchee Bay, Florida; Pensacola and Perdido Bays, Florida; Louisiana Coast Item Investigations, Louisiana; Approaches to Port Isabel, Texas; Approaches to Corpus Christi, Texas; Western Shore of Lake Michigan, Wisconsin; and Grand Island Harbor, Michigan.

HYDROGRAPHIC DIGITAL ARCHIVE

As a result of a cooperative project with NCD's Nautical Charting Research and Development Laboratory (NCRDL), the task of transferring 3,202 digitized hydrographic survey data files from magnetic tape to optical disk media has been completed. These surveys, covering the period from 1929 through 1965, were acquired by traditional (nonautomated) methods and were digitized during the early 1970's. In addition, approximately 1,000 automated survey files, acquired since the late 1960's, have also been transferred from magnetic tape to optical disk. To complete this task and to make NCD's digital archive current, approximately 450 digital survey files of the Atlantic and Pacific Hydrographic Sections, located at NOAA facilities in Norfolk, Virginia, and Seattle,

Washington, respectively, remain to be transferred. This task should be completed during early FY 94.

HYDROGRAPHIC DATA RECOVERY

HSB received additional funding from NOAA's Earth System Data and Information Management Program (ESDIM) for FY 93. ESDIM's goal is to improve the management of all NOAA environmental data, including the recovery of historical data that are now on deteriorating storage media, and make it available to all users. The funding received this year was utilized to digitize surveys for the Sandy Hook to Cape Hatteras areas on the east coast and the Mexican border to Point Reyes areas on the west coast. When completed, these areas, and those for Chesapeake Bay that were completed in FY 92, will comprise the most recent digital survey coverage presently available.

HYDROGRAPHIC SURVEYING WITH DIFFERENTIAL GPS

During the 1993 field season, all NOAA hydrographic surveys were conducted using the Differential Global Positioning System (DGPS) as the primary mode of positioning. Positional accuracies of 5 meters have been obtained with the 12-channel GPS receivers deployed in the field. This action has resulted in substantial productivity gains, virtually eliminating the need for shore-based support of electronic short and medium range navigation stations.

There are two DGPS configurations utilized for positioning control of hydrographic vessels. One configuration uses portable DGPS systems consisting of a GPS receiver set up over a geodetic control station. The GPS receiver transmits correctors to the survey platform via a VHF or HF radio. The other configuration uses a system developed by the U.S. Coast Guard (USCG), removing the need for NOAA-installed reference stations.

The USCG system of DGPS radio beacons will provide correctors to mariners along the entire continental U.S. coastline and in Hawaii, Puerto Rico, and parts of Alaska. Currently, eight prototype stations are in operation, four along the northeast coast, three in the western Gulf of Mexico, and one in the Great Lakes. The newest beacon at English Turn, Louisiana, was established as a joint venture between the USCG, U.S. Army Corps of Engineers (COE), and NOAA.

Currently, C&GS is using three DGPS radio beacons as the primary positioning system, and three others are being used as backups and for data quality checks. No shore control of any kind was required for these projects, thereby increasing the productivity and efficiency of the field units.

SHALLOW WATER MULTIBEAM SYSTEM FOR HYDROGRAPHIC SURVEYING

Personnel from HSB and the Hydrographic Technology Programs of NCRDL have completed shipboard integration and testing of a Reson SEABAT 9001 shallow water multibeam swath echo sounding system on the NOAA Ship HECK. SEABAT has been configured to operate with an IBM-compatible personal computer using HYPACK, a commercially available hydrographic data acquisition software package produced by Coastal Oceanographics. SEABAT enables the vessel to acquire detailed least depths on wrecks and obstructions. Software has been written by the Hydrographic Technology Program to select the least depth from the large digital data set acquired by the SEABAT sensor. Additional development is underway in anticipation of operational deployment of SEABAT on the NOAA Ship RUDE during the 1994 field season.

HYDROGRAPHIC DATA ACQUISITION AND PROCESSING SYSTEM

All NOAA field units conducting hydrographic surveys in support of nautical charting had Hydrographic Data Acquisition and Processing System (HDAPS) capability during FY 93. Systems are deployed aboard the NOAA Ships RAINIER, MT. MITCHELL, WHITING, RUDE, and HECK, as well as the Atlantic and Pacific Field Parties. The total number installed includes 18 Data Acquisition Systems (DAS) and 15 Data Processing Systems (DPS).

DAS units are deployed on three types of vessels: 30 to 70-meter ships, 9-meter Jensen launches, and 7-meter MonArks. The ship and Jensen DAS units and all of the DPS units are based on the Hewlett-Packard Series 9000 Model 340 and 382 computer systems. The MonArk DAS is based on Intel 80286, MS-DOS compatible computers.

HYDROGRAPHIC PROCESSING SYSTEM

In FY 93, the Atlantic and Pacific Hydrographic Sections, located at the NOAA Marine Centers in Norfolk, Virginia, and Seattle, Washington, respectively, began converting their processing system from HDAPS DPS and a 1970's vintage HARRIS minicomputer to a personal computer (PC)-based system. The new PC system, which has been named the Hydrographic Processing System (HPS), will be fully implemented in FY 94. It is expected that the new system will greatly improve data quality and increase data throughput.

PHOTOGRAMMETRIC SURVEYS

The photogrammetric mapping mission of NOAA is carried out by the Photogrammetry Branch (PB) to provide contemporary data and information utilized by a variety of Federal, state, and local government agencies, as well as the general public. PB's digital cartographic data are required for the production of contemporary nautical and aeronautical products, NOAA's benthic studies, and hydrographic surveying. Program

activities include aerial photographic surveys, coastal mapping which encompasses the shoreline and the coastal zone, location of fixed aids to navigation, nautical chart revisions, airport obstruction surveys and mapping, aeronautical navigational aid surveys, LORAN C navigation system surveys, airport datum tie upgrade surveys, submerged aquatic vegetation mapping, and marine sanctuary boundary demarcation.

During the year, two aerial photographic missions flew for a total of 483 hours providing 5,100 natural color photographs, 900 of which were for a special project for the Tennessee Valley Authority. Over 300 photographs were acquired of flooded regions along the Mississippi River as part of a special mission in support of the National Weather Service's monitoring of flooding predictions. In support of delineating the mean high and mean lower low water line for selected portions of coastal mapping projects, 1,300 infrared panchromatic photographs were acquired. For the Obstruction Charting Program, 3,800 panchromatic photographs of airports were acquired. Photographic missions for obstruction charting secured photographs of 142 airports throughout the conterminous United States and Hawaii. Aerial photographs required for coastal mapping projects were secured for portions of the Florida, North Carolina, Maryland, Texas, Washington, Michigan, Louisiana, Mississippi, and Hawaii coastlines.

Total aeronautical surveying and mapping accomplishments included the completion of 124 airport surveys, 96 LORAN-C surveys, and 138 airport datum tie upgrades; publishing 145 Airport Obstruction Charts, 107 LORAN-C surveys, 44 airport datum tie upgrade surveys , and 140 Airport Obstruction Data Sheets. Within the coastal mapping program, 9 projects were completed, which covered 3,170 miles of shoreline and consisted of 39 map files in graphic and digital form. The coastal mapping project provided 10 map files in Alaska, 2 in California, 2 in Florida, 4 in Illinois, 7 in Texas, and 14 in Washington.

INTEGRATION OF NEW PHOTOGRAMMETRIC TECHNOLOGY

During FY 93, the Daedaleus Multispectral Scanner (MSS) was forwarded to the manufacturer for refurbishment. While refurbishment of the MSS was in progress, procurement was submitted to NOAA administration for the acquisition of a gyro stabilized mount, with delivery planned for November 1993. After the condition of the data recording system was analyzed, a recommendation was made to upgrade the recording system, resulting in a digital-to-digital data transfer system which would improve efficiency. The data recording system will be upgraded and will be ready for test flights in 1994. The data processing system required to handle the volume of MSS data must also be acquired. Expertise of NGS in data processing will be needed to provide workable solutions for this requirement.

The NOAA Citation jet will ultimately serve as the platform from which the MSS will be operated. Alterations to the jet are planned for mid-1994 and include the placement of the

gyro stabilized mount, as well as alterations to the interior of the jet to complement the additional equipment related to MSS operation. In the interim, the MSS will be temporarily mounted in another NOAA aircraft to gain experience in data acquisistion and processing, and to detrmine how well the resultant information meets coastal mapping needs. Once the MSS system has been tested, a strategy will be developed for meeting potential demands for the MSS data for C&GS' coastal mapping program and other NOAA programs.

GPS technology has provided enhanced positional capabilities for all program areas within the Branch. During the past 5 years, the application of GPS technology has been expanded beyond positioning horizontal control for coastal and hydrographic surveys to include airport datum tie upgrades, the flight management system for both aircraft, and the positioning of the camera exposure stations for the NOAA Citation Jet aircraft.

In February 1993, PB personnel conducted GPS observations throughout the U.S. Virgin Islands as part of a regionally coordinated effort that also included the Departments of Transportation of Mexico and Texas, Florida Department of Natural Resources, Louisiana State University, and NASA's Jet Propulsion Laboratory.

Based on the success of the U.S. Virgin islands project, plans were developed for a Pacific Rim regional GPS survey. A major contributing factor in developing this project was the numerous inquiries from the Department of State regarding positional information on various islands in the Pacific Rim region (Hawaiian Islands, American Samoa, Micronesia, Northern Marianas, Marshall Islands, Palau, and Guam). C&GS' nautical charting program needs new charting information for the update of nautical charts of the region. A third and major factor for conducting the project is a requirement by FAA for new airport obstruction and navigational facilities surveys and photogrammetric surveys of the airports of the region.

The Pacific Rim project was perhaps the most logistically challenging project C&GS has conducted in years when considering geodetic station research, GPS observation coordination, movement of personnel and equipment throughout the region, and the delivery and operation of the NOAA Citation Jet aircraft. Many Federal agencies had been contacted for their requirements and possible assistance in completing this endeavor. The response was very favorable with many agencies realizing that this project could resolve their long-standing requirements for geodetic data and aerial photography of Pacific Rim islands.

Field survey reconnaissance and field surveying phases for Pacific Rim islands were completed during September and October 1993. The photographic mission completed the photography phase for the Hawaiian Islands portion of the project in October. The photographic mission will attempt coastal and airport obstruction photography of the Pacific Rim islands beginning in February 1994. The last phase of the project will involve

airport obstruction field surveys of the Pacific Rim island airports which is scheduled for later in 1994.

CUSTOMER OUTREACH BY PHOTOGRAMMETRY

During the year, numerous briefings, tours, and project meetings were held with Federal, state, and local government personnel. Perhaps one of the more significant meetings involved one on project coordination held through the efforts of the California Coastal Commission (CCC). Recent photogrammetric surveys of the Channel Islands National Marine Sanctuary, Tomales Bay, and Trinidad Harbor cover only a small portion of the California coastline. The majority of the California coastline has never been surveyed by C&GS through photogrammetric techniques.

To address this situation, C&GS participated in a meeting with various California agencies in cooperation with the CCC. C&GS developed a plan to perform mapping of the entire California coast and targeted 1994 for the field surveying and photographic mission phases. An overview of PB's Coastal Mapping Program was presented, including plans to construct a high-accuracy digital data set of cartographic information. The digital data could be used to populate state agency data bases as the first step toward creating a high-quality Geographic Information System (GIS). In addition, aerial photographs have become a popular tool in coastal zone management. C&GS aerial photographs may also be used for the creation of orthophoto maps, which are not produced in C&GS but are available through the private sector. The state agencies have forwarded a response via the CCC which defines tangential coastal zone areas of interest, project assistance, and requested products. Meetings of this nature are an important step in developing Federal/state partnerships for coastal zone management. The success of this meeting is already bearing fruit. C&GS representatives are scheduled to hold a similar meeting with representatives of Massachusetts to discuss a planned coastal zone survey of that state.

During the year, PB received an increasing volume of requests for briefings on its projects. The Branch Chief traveled to Israel to present three formal lectures on GPS and Photogrammetry, as well as informal information exchange events at the Technion (Israel Institute of Technology). The lectures were well received and attended by academia, private business engineers, and other interested individuals. Israel is in the initial phases of implementing GPS. Using this technology transferred by C&GS and information from other sources, Israel will be able to develop GPS implementation plans.

Customer outreach activities for FAA included the development of prototype "Engine-Out" specifications for straight and curved flight paths and expansion of data delivery in digital form.

NEW CHARTING PRODUCTS

Five new charts were issued during FY 93. These charts include:
- 12221TR - Chesapeake Bay Entrance. This is a training chart covering Chesapeake Bay Entrance,
- 13394 - Grand Manan Channel - Northern Part, 1:50,000-scale. This is a cooperative chart with the Canadian Hydrographic Service of the Maine/New Brunswick border area,
- 11366 - Approaches to Mississippi River, 1:250,000-scale,
- 16304 - Alaska - Kuskokwim River-Kuskokwim Bay to Bethel, 1:100,000 scale, and
- 18543 - Columbia River - Pasco to Richland, 1:20,000-scale.

In addition, the following four charts were reconstructed:
- 11463 - Florida - IWW - Tarpon Basin to Matecumbe, 1:40,000-scale,
- 12208 - Virginia - Approaches to Chesapeake Bay, 1:50,000-scale,
- 18655 - California - Mare Island Strait, 1:10,000-scale, and
- 18657 - California - Carquinez Strait, 1:10,000-scale.

Two other charts were cancelled:
- 13327 - West Quoddy Head to Cross Island, Maine, and
- 13328 - Calais to West Quoddy Head, Maine.

At this time, nine new charts are in various stages of completion. They include:
- 16423 - Alaska - Shemya Island to Attu Island,
- 16450 - Alaska - Amchitka Island and Approaches,
- 16465 - Alaska - Tanaga Island to Unalaga Island,
- 16467 - Alaska - Adak Island to Tanaga Island,
- 16703 - Alaska - Northwest Prince William Sound - (Preliminary Chart),
- 17377 - Alaska - LeConte Bay,
- 18658 - Suisun Bay, California - Roe Island and Vicinity,
- 18668 - Suisun Bay, California - Pittsburg to West Island, and
- 18667 - Suisun Bay, California - Freeman Island to Pittsburg.

NCD now maintains a suite of 1,002 nautical charts; 301 were published as new editions during FY 93.

Implementation of NAD 83 in the nautical charting program continued. 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 910 charts have been converted to NAD 83.

Another conversion activity, metrication of the nautical chart scheme, also continued. During the past fiscal year, five existing charts (11363, 11364, 11368, 11369 and 18661) and two reconstructed charts (18655, 18657) were converted to metric format. Additionally, two new charts (11366, 13394) were constructed in metric units. A total of 37 charts have been converted to charts in metric units. Although C&GS has a very ambitious plan to convert all NOAA nautical charts to metric format, implementation has been slow due to limited resources. At this time, the annual conversion rate is approximately 5-10 charts.

PRODUCT AUTOMATION AND DIGITAL DATA

NCD continued to automate more of its chart production processes. Computer-assisted techniques support the production and maintenance of new and reconstructed charts. With the use of personal computers, C&GS has enhanced its ability to process data collected on the Intergraph Digitizing System and the SCITEX Raster Plotter System. Color separate reproducibles for chart production are created in-house. The Computer-Assisted Revision System (CARS) allows the use of automated compilation techniques to replace portions of the labor-intensive manual cartographic process. These procedures have assisted the metrication program, mentioned above, in which new editions of charts are converted to metric units through semiautomated methods.

CRITICAL CORRECTION SOFTWARE

Notice to Mariner corrections are entered into the Critical Aids Data Base (CRIT). As a drawing is advanced in the production process, a mylar plot of all changes to these features is generated. Corrections to the chart drawing are applied from this plot. The data accrued in this process is available for the Automated Nautical Charting System II (ANCS II) data base load.

DIGITAL NAUTICAL CHART

NCD has begun to collect vector data from a substantial number of NOAA charts for the Digital Nautical Chart (DNC) Project for DMA. The resulting fully attributed data sets are provided to ANCS II and the DMA in their required formats.

PRODUCTION MANAGEMENT

The chart production unit maintains PRODTRAK, an automated system of tracking the various processes of chart production. In addition, the application of hydrographic surveys is maintained in a dBASE format. These files, which reside on the Local Area Network (LAN), enable management to evaluate the chart production process and allocate resources in a more efficient manner.

AUTOMATED NAUTICAL CHARTING SYSTEM II

ANCS II is the next generation automated nautical charting system being developed by NCRDL. Progress is described below in the section on research and development. The C&GS chart compilation effort will remain in its present mode for the next year. ANCS II will be phased in across the entire production area over the next 5 years. The system will consist of two major data bases, the Nautical Information Data Base (NIDB) and the Chart Graphics Data Base (CGDB). NIDB is a chart-independent geographic information system (GIS) and the CGDB is a chart-specific data base.

NCD will continue to enhance its personal computer-based chart production capabilities and digital data bases. The LAN will be expanded, serving more people with more files. Software will be developed to provide additional supplemental graphics for chart production.

RASTER NAUTICAL CHART

A separate activity involves the conversion of charts to raster format. The goal of the Raster Nautical Chart (RNC) Project is to create nautical charts in a digital raster format to complement the corresponding paper chart. Data for each chart are obtained by scanning the original color separate chart films which are then combined into a single raster color chart. The original scanning density would be sufficient to support normal NOAA paper chart production processes. Plans are to make the entire suite of NOAA charts available within 3 years. New editions of the raster charts would be issued concurrently with new editions of paper charts. These raster charts are intended for use by both NOAA and the "value added community."

DIGITAL PRODUCTS SALES

NCD continues to provide a variety of digital products for sale to government agencies, commercial interests, and the general public. They consist of digital shoreline data, digital navigational data, and LORAN-C overlays.

Digital Data

These products respond to the needs of electronic chart users, manufacturers, academia, and individuals who require digital charting data. Due to limited resources, NCD has been unable to maintain the shoreline and aids to navigation digital data files to reflect the most current published nautical charts. As these data age, NCD will have to determine whether it is worth the cost to update these data files or to discontinue sales until new, up-to-date data are available from ANCS II.

LORAN-C Overlays

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

ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM (ECDIS) DEVELOPMENTS

NCD continues to participate with USCG and other Federal agencies in the U.S. ECDIS Test and Evaluation Program (TEP), primarily to evaluate the International Maritime Organization (IMO) Provisional Performance Standards for ECDIS. The TEP has completed the first series of field trials in Buzzard's Bay, Massachusetts, aboard the USCG Cutter BITTERSWEET. Additional testing is continuing in New York Harbor and Western Long Island Sound aboard the training vessel KINGS POINTER. A formal report on the results of the TEP was submitted to the IMO/International Hydrographic Organization (IHO) Harmonization Group on ECDIS at the end of April 1993. The trials focused on human factors relative to bridge workload and safety, radar superimposition, display features and functions, user confidence, and data adequacy. Tests in 1994 will focus on updating of the Electronic Nautical Chart.

Another significant project to be completed is the Canadian Pilot Project. This project is a joint effort with the Canadian Hydrographic Service, Canadian Coast Guard, Canadian Transport Development Centre, USCG, and C&GS that will involve 20-30 installations of commercial ECDIS units over the next 3 years. Some installations will be on government vessels, some on commercial vessels, and some will be on simulators. A third continuing project is the U.S. ECDIS Testbed Project, a joint activity with Woods Hole Oceanographic Institution and various commercial firms. This project will also utilize ECDIS installations on a variety of vessels over the next 2 years. The practical experience gained with these projects is expected to enhance knowledge of how to develop C&GS digital data products and how to construct the regulatory infrastructure necessary for ECDIS use.

It is expected that the TEP will continue at least until the ECDIS Performance Standards are adopted by the IMO Assembly (earliest date possible is 1995). At the recent meeting of the IMO Sub-committee for the Safety of Navigation, the Performance Standards for ECDIS were successfully forwarded to the Maritime Safety Committee (MSC) for action. Another subcommittee reporting to MSC on radio communication commented that many questions concerning updating of ECDIS and the suitability of ECDIS data formats remain unanswered. They have suggested the performance standards not go forward until these issues have been resolved through sea trials. (NCD's planned updating project may be critical to the actions taken at MSC.)

NCD has three separate data collection objectives:

- to populate a paper chart production data base,
- to produce digital nautical chart products (for DMA in vector product format), and
- to produce an ECDIS data base in the DX-90 format.

In order to accomplish these objectives in the most efficient manner, NCD has created a "super schema" which allows the one-time collection with sufficient attribution to satisfy all three objectives. NCD now has prototype products in Buzzard's Bay (6 charts), New York (13 charts), San Francisco (9 charts), and Prince William Sound (4 charts). By February 1994, NCD expects to have data sets available for Norfolk (23 charts), Puerto Rico (10 charts), San Diego (9 charts), and Puget Sound (16 charts). The plan is not to release the production data sets until a mechanism is in place to update NCD's digital products.

EXCHANGE FORMAT STANDARDIZATION

NCD is implementing DX-90, the IHO exchange format for the transfer of digital hydrographic data. Data base prototypes are available for test areas in Buzzards Bay, New York, and San Francisco. Additional test areas will be available later this year. C&GS has also initiated action to create a DX-90 profile for the Spatial Data Transfer Standard (SDTS), the U.S. government standard for spatial data. This will make DX-90 fully compatible with SDTS. The use of SDTS has been mandated for Federal agencies in the United States beginning in February, 1994.

USER INTERACTION

NCD continued to participate in boat shows, trade shows, and other similar functions to maintain close contact with the users of NOAA nautical products. This allows C&GS to be aware of user needs and interests and to be more responsive to new requirements. Most recently, NCD participated in a joint NOS/Canadian Hydrographic Service (CHS) exhibit at the Seattle Fish Expo. The exhibit demonstrated the cooperative efforts of NOS and CHS.

NCD has also recently initiated a formal proactive customer outreach program in order to:

- learn the needs and concerns of users of NOS marine products, and
- correct or modify products or services according to valid user input.

Although outreach-related activities regularly occur at functions such as boat shows, symposiums, and other events, NCD now regularly conducts meetings in major port cities

with the sole purpose of receiving and acting upon user comments. Meetings have taken place in port cities such as San Francisco, New Orleans, and Newport, Rhode Island. In the past, C&GS invited the traditional users of marine information (for example, USCG, pilots' associations, Navy, commercial shipping lines, fishing associations, and others) to these meetings. Now, invitations are being extended to nontraditional users of marine information such as marine sanctuary managers, state geodetic advisors, chart agents, and coastal zone managers.

U.S. HYDROGRAPHIC CONFERENCE '94

NCD is actively involved in the preparation of the 1994 U.S. Hydrographic Conference. NOS is one of the primary sponsors of this conference, and NCD is providing support in the areas of registration, publicity, and planning the technical program. The conference is scheduled for April 18-23, 1994, at the Omni International Hotel in Norfolk, Virginia.

RESEARCH AND DEVELOPMENT

These activities are conducted by NCD's Nautical Charting Research and Development Laboratory (NCRDL) to modernize all facets of map and chart production including automated cartography and hydrographic and photogrammetric technology.

AUTOMATED NAUTICAL CHARTING SYSTEM II

With ANCS II, C&GS has embarked on a major modernization program of its nautical charting program. This modernization effort will lead to the automated production and maintenance of NOAA's entire suite of 1,000 nautical chart products. When completed, it will provide NOAA with a new technology infrastructure capable of supporting such goals as:

- near real-time generation and submission of Notice to Mariners,
- a data base environment for facilitating and maintaining nautical charting data and information,
- the ability to generate new digital nautical charting products,
- a capacity and throughput capability for processing digital hydrographic and topographic surveys and other nondigital graphic and text sources,
- the ability to exchange digital nautical charting data using standard exchange formats such as DX-90 and SDTS,
- a production control environment for management and planning, and
- a full audit trail capability, which is required for product liability reasons.

When fully developed, ANCS II will be the primary platform that will link NOAA to an "intelligent" digital world.

ANCS II will employ a variety of Intergraph 6000 RISC-based color workstations and personal computers that are physically distributed over an NOS Ethernet network. ANCS II is designed to operate and run in a distributed multiuser and multiserver environment. The UNIX/CLIX operating system is the primary software platform. ANCS II workstations are connected to Intergraph data servers via a TCP/IP network and NFS software. ANCS II employs Oracle Version 6.1 OLTP relational data base management system software (RDBMS) which is configured to operate in a client/server architecture.

Central to all ANCS II functions are the following three primary data bases:

- Navigational Information Data Base (NIDB),
- Chart Graphics Data Base (CGDB), and
- Production Control Data Base (PCDB).

The NIDB and the CGDB reflect a dual data base design strategy that separates real world geographic data extracted from source documents from the highly symbolized cartographic product data. A fused data base architecture and a shared data base schema are two key aspects of ANCS II data bases. Data base fusion is important because it allows for multiple graphic representations of a nautical charting feature to share one common set of data base attributes. Features and attributes are stored in relational data base feature tables. Graphics are linked to features, attributes, and enumerated values via a proprietary MicroStation Link ("mslink") pointer. The PCDB exists to schedule, track, record, and report on various production and control tasks.

Over 90 Oracle RDB tables are used to store information about nautical charting sources, features, products, and production control information. For example, feature tables (containing features, shoreline, sounding values, etc.) are used to store both current state and historical information for a variety of spatial-temporal nautical charting features. An active source catalog table stores current information about each source document logged and evaluated. A product catalog table stores relevant cartographic information and charting specifications for each nautical chart panel. All RDB tables and graphic files reside on one of three Intergraph data servers. The initial capacity for online disk storage exceeds 100 gigabytes. The projected size of the data base, when fully populated, is 50 gigabytes.

ANCS II uses a distributed storage strategy that allocates portions of Oracle RDB tables to different servers. Each server contains features, sources, and graphics for a contiguous geographic area. Application software, which consists of both custom and Intergraph COTS software, resides at each of the 40 ANCS II workstations. To date, over 500,000 lines of code have been written for ANCS II. The software has been developed and integrated onsite by a team of 35 Intergraph programmers and system engineers (see Figure 4 for ANCS II software architecture). A custom forms interface provides end-users with a user-

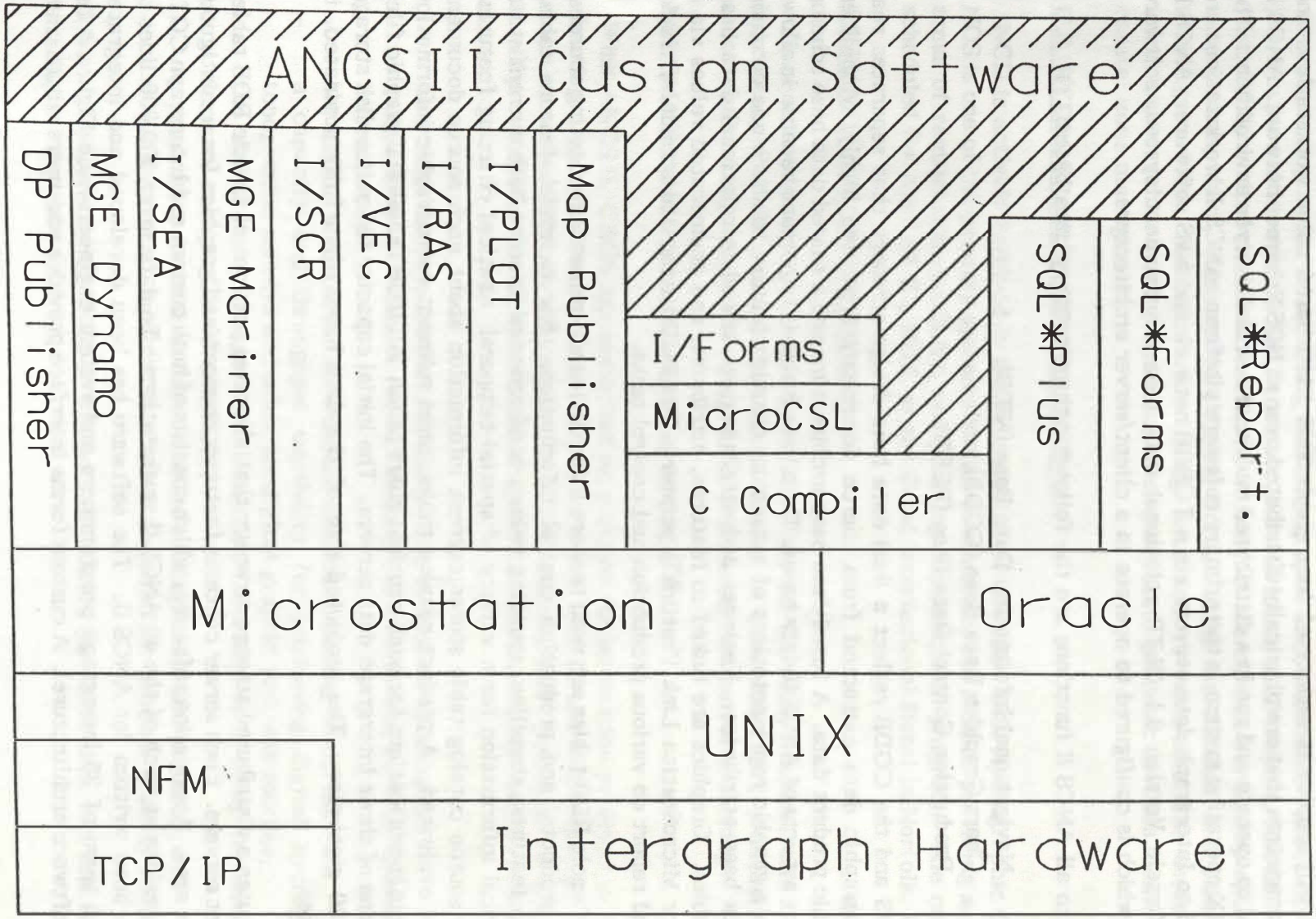

Figure 4. Diagram of Automated Nautical Charting System II (ANCS II) software architecture.

friendly access to each functional area via a pull-down menu. Custom task management software was designed specifically for production control and is used by management for scheduling, planning, tracking, reporting, and allocating resources. Updating the "master" NIDB and the product specific CGDB is done interactively by an NCD nautical cartographer at an ANCS II workstation.

ANCS II Functional Areas

Software has been developed in five incremental phases. The bulk of the written code supports the five major functional areas that comprise the ANCS II system. The five functional areas are:

- Manage Source,
- Produce Charts,
- Produce Manuscripts,
- Manage Archives, and
- Manage System.

The following descriptions provide an overview on each functional area.

The Manage Source functional area supports the logging and evaluation of all source documents, the identification of critical data required for Notice to Mariners generation, the application of source data to NIDB, linkage of NIDB changes to products, temporal tracking of spatial features, composite features, cartographic generalization, feature locks, treatment of derived graphics and features with special needs, hydrographic and topographic digital data processing, MGE Mariner (microstation GIS environment software), and a complete audit trail function.

The Produce Charts functional area supports all compilation activities required for updating, generating, and reconstruction for all NOAA nautical charts. It also provides functionality for enforcing the Cartographic Law of application of source through the scales; provides initial mockup chart functionality, history of cartographic work, and tools for Notice to Mariners and chartlet generation; and prepares the chart for final finishing, symbology, and the development and maintenance for new digital nautical charting products.

The Produce Manuscripts functional area supports the creation and processing of Notice to Mariners submissions and provides a desktop publishing platform and environment for future development and implementation of the U.S. Coast Pilot series.

The Manage Archives functional area provides separate archives for storing historical information offline for all spatial-temporal features, critical Notice to Mariners features,

fully applied source documents, and graphic snapshots for each new edition of a nautical chart.

The Manage System functional area encompasses the entire ANCS II environment. It consists of such functions as scheduling cartographic compilation jobs, performing backup and recovery, monitoring the system software and network traffic, and performing hardware and software maintenance. These five subsystems are interconnected and tightly coupled by system software and hardware to provide C&GS with a state-of-the-art, end-to-end digital nautical charting production system.

Milestones

A functional test of the developed software for ANCS II is scheduled to begin in December and continue through January 1994. Test scripts and scenario flows have been developed to test the system. For functional test, the contractor will follow an approved test script and is responsible for performing all tests. NCD personnel will monitor and record the results for each test. The test area covers NOAA nautical charts 12222, 12245, 12241, 12235 and 12254. Test data have been collected, processed, and translated by the contractor into the NIDB and the CGDB. After the functional test is completed, the contractor will perform training onsite for NCD cartographers. Training will begin during the second quarter of FY 94 and will last 2 months.

A 6-month trial production test of the developed system is scheduled to begin in March 1994. Trial production will be staged in a simulated production environment. A 50-chart test area of the Chesapeake Bay area will be used to perform all cartographic production and maintenance tasks required to fully exercise the system. Performance tuning and final debugging of the system is also expected to be made at this time period.

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

AUTOMATED CHART COMPILATION PROGRAM

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

The original objective was to develop an embedded expert system capability to be installed into conventional digital cartographic production systems such as ANCS II. This was expanded to include certain GIS algorithms necessary to enable the expert system to accomplish its processing. The embedded system will reduce the burden on cartographers from having to perform tedious and detailed chart compilation decisions by issuing higher level commands. These chart compilation processes include:

- symbol selection,
- spatial conflict detection and resolution,
- feature generalization when changing scales, and
- placement of text.

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

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

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

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

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

GPS ATTITUDE SENSOR

An Ashtech 3-DF navigation system for roll, pitch, and heading was tested on two different small platforms. Real-time output at 2 hertz was attained to a resolution better than 0.1 degree.

SEABAT 9001 BATHYMETRIC SURVEY SYSTEM

C&GS has acquired a SEABAT 9001 system to determine least depth on wrecks and obstructions which are now being detected using side scan sonar. Analysis of test results to determine suitability of the sensors for field operations is not yet completed. The SEABAT 9001 sonar system was mounted to the NOAA Ship HECK for a survey in the Miami, Florida, area. The surveyed depths ranged from 100 meters to 10 meters. The volume of data overwhelmed C&GS' existing processing capacity. This prompted a concerted effort to increase the processing abilities to handle large shallow water multibeam data sets. The SEABAT 9001 was tested by C&GS at HYGRO-93 (Hydrographic Ground Truth Experiment) in October 1993 at St. John, New Brunswick, Canada.

LEAST DEPTH DIVER GAUGE

A hand-held diver least depth gauge has been developed and tested both in-house and in the field. The diver-deployed gauge will be used operationally in the 1994 field season. It will replace the leadline and the pneumatic depth gauge which have been used to obtain the least depth readings.

AIRBORNE LASER BATHYMETRIC MEASUREMENTS

NCRDL has been at the forefront of laser hydrography for the past decade and continues to maintain international recognition for its analyses of system performance prediction based on environmental conditions and waveforms detection techniques. But faced with present-day funding limits, it is unlikely that the $10 million capital investment needed to acquire and field a system can be obtained. However, work by NCRDL continues to contribute to several Federally-funded laser hydrography development projects such as the

U.S. Army Corps of Engineers Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system which is presently undergoing field tests. NOAA will benefit when these systems become readily available for lease operations, thereby avoiding the large one-time capital expenditure.

MARINE DATA COMPUTER BULLETIN BOARD

The computer bulletin board, developed to provide public access to existing nautical charting digital data, was operated throughout the year. There were four receiving nodes where the users were able to log on using a personal computer, modem, and ordinary telephone lines. Callers searched the available data bases and downloaded results. The bulletin board usage was reviewed for assessing the demand for and uses of nautical charting digital data. The bulletin board will be reduced to two nodes for the next year.

INTEGRATED DIGITAL PHOTOGRAMMETRIC FACILITY

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

The IDPF configuration consists of five stereoviewers and their peripherals, forming photogrammetric workstations linked as networked nodes sharing a common data base. The relationships are diagrammed in Figures 5 and 6. The three data bases are as follows:

- project data base,
- camera calibration data base, and
- OC data base.

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

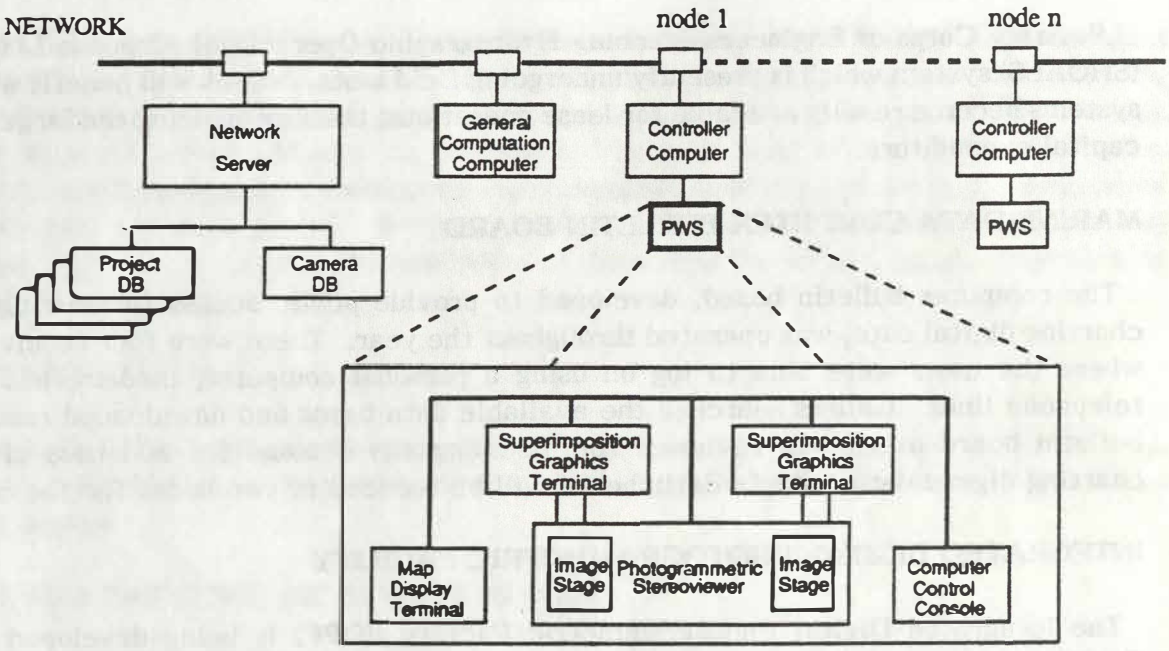

Figure 5. Diagram of a photogrammetric workstation in one node of the Integrated Digital Photogrammetric Facility (IDPF) network.

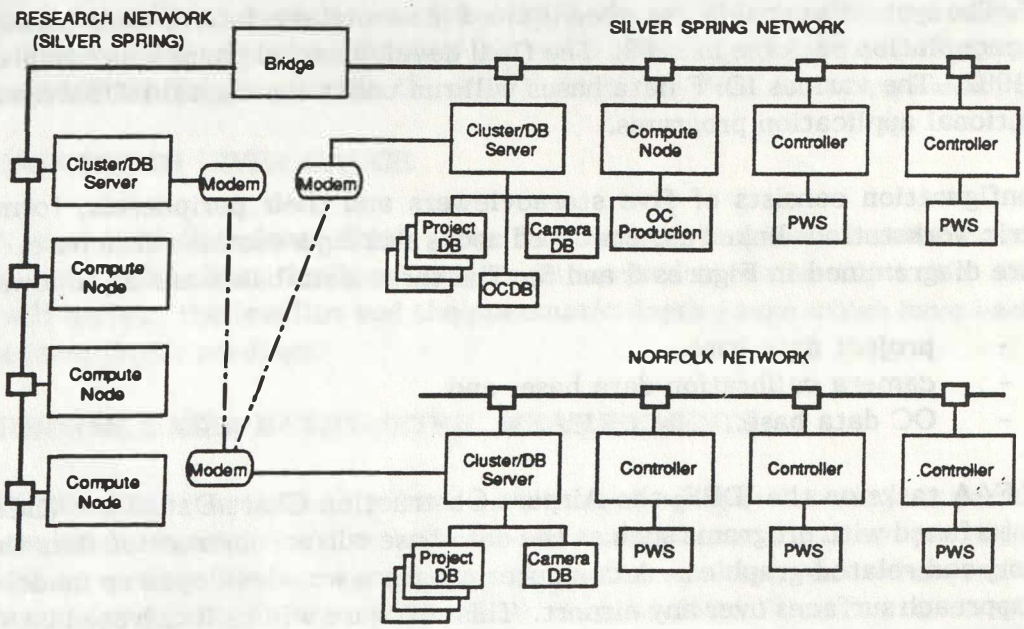

Figure 6. Diagram of the Complete IDPF showing the relationships between the Norfolk, Virginia, and Rockville, Maryland, production units and the Rockville Research Network.

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

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

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

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

- An entirely new data base format for projects and cameras has been incorporated.
- The screen data editor has been vastly improved and modified.
- New editors for the project and camera data bases have been incorporated.
- Improvements in labelling and plotting digital maps have been made.
- The GIANT program has been modified to include adjustments for GPS data, self-camera calibration, and elimination of unknown systematic errors during photography.

ADVANCED CORRELATION TECHNOLOGY

The implementation of Advanced Correlation Technology (ACT) was started in 1988 using an existing C&GS instrument and correlation algorithms developed by Dr. Uki Helava. The Laser Mann Automatic Stellar Comparator (LMASC) is an existing comparator at C&GS. It was selected because of its extremely precise measuring capability of less than 1 micron

and its large-stage size of 9 by 18 inches. The combination of ACT on the LMASC has created the ACT workstation (ACTWS) capable of performing many photogrammetric applications utilizing correlation techniques. The implementation of ACT has required considerable software development in addition to the correlation software. The integration of the correlation software into a photogrammetric applications package was directed by NCRDL personnel.

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

Currently, the correlation system has several measuring functions that have been integrated into easy-to-use applications. These functions include hierarchical relaxation correlation for robust measuring of conjugate image pairs, least squares correlation for accurate measuring of multiple conjugate images, density centroid for pointing on circular images, and cross-centering for pointing on the intersection of two lines. Combinations of these functions have been integrated using application software for aerotriangulation and various types of calibration plate measuring. A triangulation package has been developed that is compatible with IDPF. Other enhancements to the correlation engine are ongoing. These enhancements improve the speed and operators ease of use.

SHORELINE DELINEATION FROM MULTISPECTRAL IMAGERY

A primary function of C&GS is the accurate delineation of shoreline for the United States and its territories. Several types of boundaries are determined from this delineation. Currently, this delineation is a manual tracing process from photographs in sophisticated photogrammetric instrumentation. An alternative process of shoreline delineation is being developed through the SBIR program. The SBIR vehicle has made possible the development of a semiautomated process for delineating shoreline. The process has two important features. First, it can be applied to virtually any digital data set, for example, satellite or airborne remote sensing data and even digital data sets from scanned aerial photography. Second, it provides for human assistance when needed. Currently, aerial photography is of interest because of its availability and superior accuracy. The process can be readily applied to various multispectral sensor, both satellite and airborne, as their availability and accuracy match the demands of shoreline delineation.

Phase II of the SBIR program is scheduled for completion by the end of the first quarter of FY 1994. The software development is targeted for existing microcomputer platforms. The completed system will support input from various multispectral data sets and produce

vectorized shoreline in formats compatible with NCD operations. The system combines classification, vectorization, geocoding, and editing processes to produce a polygonal extraction of an edge shared by two continuous surfaces, land and water. The classification portion provides for constructive human intervention which significantly enhances the efficiency of the process.

C&GS PARTICIPATION IN HYDICE

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

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

The Naval Research Laboratory (NRL), acting as agent for the CIA, has contracted with Hughes Danbury Optical System for development and integration of the airborne HYDICE sensor system and will handle the acceptance testing which is scheduled to begin in July 1994. NCRDL is participating in the activities of the HYDICE Collection Working Group (CWG) and the HYDICE Exploitation Working Group (EWG). The CWG is developing a data acquisition plan so that a limited number of collection missions will provide ample data for evaluating the benefit of this hyperspectral sensor for the various remote sensing requirements of all participants. The EWG will investigate, test, and implement hardware, software, and methods for evaluating and exploiting the collected data after completion of each mission. This cooperative effort will provide each participating civilian agency with access to data from a sensor system they could not, individually, afford to develop. Likewise, NRL will have assistance in evaluating their system from experts in all specialties of remote sensing.

KINEMATIC GPS PHOTOGRAMMETRY

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

A system calibration method has been developed and tested with data acquired in October 1988 at the Transportation Research Center of Ohio where an elaborate array of targets for aerial photography has been accurately positioned by ground survey using GPS. The calibration consists of precise determination of:

- the components of the vector from the camera to the aircraft antenna,
- the accuracy with which the exposure time is recorded,
- the conventional elements of a lens calibration, which are not usually determinable from photos taken with the camera in its operating orientation, and
- the effect of the camera port window.

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

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

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