Mapping and Charting: A Perspective for the Office of Charting and Geodetic Services (1985)

Pages
63

Size
5 x 9

ISBN
0309322871

Committee on Cartography; Board on Earth Sciences; Commission on Physical Sciences, Mathematics, and Resources; National Research Council

Mapping and Charting

A Perspective for the Office of Charting and Geodetic Services

Committee on Cartography
Board on Earth Sciences
Commission on Physical Sciences, Mathematics, and Resources
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1985

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

Available from
National Oceanic and Atmospheric Administration
Office of Charting and Geodetic Services
Rockville, MD 20852

COMMITTEE ON CARTOGRAPHY

Jon M. Leverenz, Rand McNally and Company, Chairman
Thomas C. Finnie, Defense Mapping Agency (retired)
Norris Krone, Jr., University Research Foundation
Harold Moellering, The Ohio State University
Mortimer Rogoff, Navigation Sciences, Inc.
Charles R. Spath, Martin-Marietta
Wayne A. Rosenkrans, Jeppesen/Sanderson

Staff

Hyman Orlin, Staff Consultant
Betty C. Guyot, Administrative Secretary

John G. Heacock, Office of Naval Research
Linn Hoover, U.S. Geological Survey
Catherine A. Kitcho, National Aeronautics and Space Administration
George A. Kolstad, Department of Energy
Ian D. MacGregor, National Science Foundation
Dallas L. Peck, U.S. Geological Survey
A.G. Unklesbay, American Geological Institute
Kenneth N. Weaver, Maryland Geological Survey
Arthur J. Zeizel, Federal Emergency Management Agency

Joseph W. Berg, Jr., Staff Director
William E. Benson, Senior Staff Officer

CONTENTS

EXECUTIVE SUMMARY

The evolving fields of cartography and other mapping sciences (hereafter referred to as cartography) are having an impact on the charting activities of the Office of Charting and Geodetic Services (C&GS), the National Ocean Service (NOS), and the National Oceanic and Atmospheric Administration (NOAA). Changing user requirements; the emergence of new cartographic products, such as electronic maps and charts and digital data files; and advancements in automated data processing are affecting the agency's traditional charting functions and are placing a strain, caused by uncertainties, on its organization and management. Technological advances are affecting the design, development, and use of charts and chart products, and the prognosis is for active continuation of this trend.

This report is the result of a review and analysis of the C&GS aeronautical and nautical charting operations by the Committee on Cartography in the National Research Council's Commission on Physical Sciences, Mathematics, and Resources for the purpose of assisting C&GS in determining its future direction. The recommendations cover a wide range of topics on which C&GS can focus its attention. Most of the recommendations call for management actions and are not specific, detailed comments on specific, potential problems.

The C&GS's broad responsibilities, its organizational structure, and its mode of operating were found to be appropriate for carrying out its mission as defined by Public Law 373. This statute clearly assigns to C&GS responsibility for producing navigational products and for selecting the method for carrying out this responsibility. In order for C&GS to plan better for the future, during a period of ever-increasing demand for

aeronautical and nautical products and data and with the growing pressure for efficiency in government:

The Committee recommends that C&GS establish at the level of the Director, Office of Charting and Geodetic Services, a capability to

1. Manage, assess, and apply the present and future user requirements for aeronautical and nautical charts and data. (Section 3.4.3)

2. Undertake a systematic, coordinated, and continuous technology evaluation to ascertain future uses and requirements for charting and geodetic data and products. (Section 3.4)

Because of rapid changes in electronics equipment and associated software, it is important that C&GS conduct these assessments on a continuous basis with adequate resources and an effective exploratory and applications research capability. It is not sufficient to perform such assessments by an occasional survey or by ad hoc committees. Also, because of rapid technological advances, C&GS periodically needs to review the automation methods used in order to assure that the most effective means and latest technology are being employed in the production and distribution of products.

The Committee recommends that C&GS review the present automation methods in the aeronautical and nautical charting operations to establish the viability of the programs. (Section 2.2)

Rapid technological advances have necessitated a reconceptualization of cartographic science that focuses attention on the critical role of cartographic data bases in either graphic or digital form. Today we are witnessing a transition from a former total dependence on analog data bases to an era of rapidly growing dependence on digital data bases. This development has led to the establishment of computerized or digital data bases for mapping, charting, and geodetic data. It is imperative that the data bases be interactive.

The Committee recommends that C&GS develop and adopt common standards, specifications, and procedures for their cartographic and geodetic digital data bases. (Section 3.2)

We further recommend that C&GS strongly support both the National Committee for Digital Cartographic Data Standards and the Federal Inter-Agency Coordinating Committee for Digital Cartography in developing digital cartographic data standards that apply to the current and future products of the agency

and also the standards that will benefit the broader cartographic user communities as well. (Section 3.2.2)

The development of products requires access to the data in a number of data bases, and the efficiency of the operation will depend on the effectiveness of the data-base-management system (DBMS). This DBMS should include as many common and necessary functions as possible. This would simplify data-base maintenance and make extraction and insertion of data as effective as possible.

The major management, production, and support functions performed by C&GS would benefit from an integrated management information system (MIS). The long-range goal of C&GS should be the integration of mapping, charting, and geodetic data with planning and management data across all organizational elements.

The Committee recommends that the C&GS institute an integrated management information system (MIS) for its charting and geodetic functions. (Section 3.3)

A description of a typical MIS, as it might apply to the functions of C&GS, is included in the Appendix to the report.

The Committee believes that current aeronautical and nautical products used for navigation will continue to be needed well into the foreseeable future. However, with improvements in electronic displays, high-density recording, and computer processing, C&GS's responsibility for setting standards and assuring the proper integration of new products will become more and more complex.

We recommend that C&GS give high priority to a program of technology evaluation to ascertain and predict future vehicle-system hardware and capabilities. (Section 3.4)

The reasoning for this is that future technology and attendant hardware systems often create needs for new navigation products. The recommended program of evaluation will offer another method by which C&GS may keep abreast of future user needs for new products. In this evaluation process C&GS must focus its efforts on the primary products needed by the major users of navigational products. A means should be developed by which secondary products (less essential) may be identified through evaluation of user needs so that they may be created and distributed through joint government-commercial cooperation or by the commercial sector.

With changes in technology, new safeguards must be found to ensure the integrity of the chart data. This is

particularly applicable to products provided by intermediate or value-added suppliers who transform C&GS data into an end-user product. For these suppliers C&GS may wish to prepare and propose standards for the proper use of its data.

We recommend that the C&GS undertake the preparation and analysis of standards to be proposed for products of intermediate or value-added suppliers. These standards should be prepared for voluntary compliance, including evidence of such compliance to the end users. (Section 3.4.2)

To manage resources effectively and efficiently, in the process of conducting its inherently governmental responsibility, the C&GS must use both government and commercial cartographic talent. The management staff is responsible for determining the proper mix of government and commercial resources to be used in meeting national objectives, as well as for periodically assessing the progress and effectiveness of the mix.

To guide the organization in determining the proper mix, the Committee recommends the following approach:

1. The C&GS should assess the capabilities and practicality of contracting with the commercial sector to perform parts of inherently governmental activities reliably under government responsibility. These data-assembly functions include data acquisition, evaluation, management, storage, and extract activities. (Section 4.1.1)

2. The data compilation, reproduction, and distribution activities--the data-application function--should be subject to more commercial involvement than the data-assembly function. (Section 4.1.1)

3. A capability should be established at the appropriate organizational level, with participation by other agencies, such as the Federal Aviation Administration, the Department of Defense, and the U.S. Geological Survey, to determine the data-assembly and data-application functions to be performed by C&GS and the resultant user products and services to be made available to the public and to governmental agencies. Requirements of the public and government sectors and reliability of products and services offered by commercial enterprises should be major factors in these determinations. (Section 4.1.1)

4. The staffs of NOAA, NOS, and C&GS should assess the capabilities of the commercial sector to

perform parts of inherently governmental activities reliably and the practicality of contracting for such component performance. Furthermore, contracts to the commercial sector, with proven capabilities for reliable performance, should be written and administered in a manner that would allow the contractor to apply proven expertise and professionalism in performance of the contract. (Section 4.1.2)

Efficient use of resources by controlling costs for creation of navigational products must be balanced against the need to produce timely and reliable products designed to minimize the government's liability.

The Committee recommends that C&GS address technical issues of product reliability with due consideration of advice from legal counsel regarding issues of product liability. (Section 4.1.3)

Cost recovery is an immediate issue as the government attempts to lower appropriations that fund C&GS activities.

The Committee recommends that all costs associated with and allocatable to data assembly be considered in the national interest, to be funded by appropriation, and that all costs accruing to data application commencing with the data-extraction stage be funded by reimbursement from other agencies and receipts from sales to the users who derive benefit from such activities. (Section 4.2)

With regard to cost recovery,

We further recommend that costs for specific data-application activities of benefit to both government and private users be allocated in accordance with the ratio between these groups. (Section 4.2)

Finally, product design for minimum cost to satisfy user requirements is an overriding guide that should always be followed.

We recommend that all specifications and corresponding methods of production be designed to ensure minimum cost/price without sacrifice to user needs or intended use. Particular concentration should be on those products where there is evidence that current prices are restricting widespread use. (Section 4.2)

The Committee believes that the C&GS, in meeting commitments for creating the present product line and developing automated systems based on new computer technology, will encounter budget and manpower

constraints. Therefore, it becomes evident that C&GS should act in concert with other federal agencies that perform similar mapping functions in order to share experiences and jointly to create data bases and standards that will enable it to meet demands of new technology.

1. INTRODUCTION

This report examines the Aeronautical and Nautical Charting perspectives in the Office of Charting and Geodetic Services (C&GS), National Ocean Service (NOS), of the National Oceanic and Atmospheric Administration (NOAA). The Committee's charge suggested a wide-ranging set of questions designed to consider the C&GS's existing charts, future data needs, real-time products, responses to emergencies, requirements for products related to ocean mining and space exploration, and relationships among government and commercial activities.

On December 12 and 13, 1983, the Committee was briefed on the C&GS mission, program, organization, and administration; budgets, procurement, and budget control; chart sales and pricing; major users; the relationship between the Federal Aviation Administration (FAA) and C&GS; and production control. The Committee toured the Nautical Charting facilities at C&GS headquarters, Rockville, Maryland, and the Aeronautical Charting facilities in the Gramax Building, Silver Spring, Maryland. At these sessions and at meetings on March 8 and 9, 1984, at the National Academy of Sciences, in Washington, D.C., the Committee was given internal documents that furnished information on the NOS mission, organization, and automation activities. These publications are listed in the Annotated Bibliography. Reports by Market Facts, Inc. (1984) on marketing and Arthur Young (1984) on efficiency had already been completed and submitted to NOS; however, only the Executive Summary of the Market Facts, Inc., report was made available to the Committee. The agency chose to have the reports remain confidential. Not having access to the complete reports, the Committee was denied an opportunity to review detailed studies done

by teams of professional analysts working on similar tasks.

This report presents our observations, conclusions, and broad recommendations based on the briefing sessions, published information listed in the bibliography, observations of C&GS facilities, and our varied experiences in fields related to the C&GS mission.

The report is organized around three broad, interrelated factors that help to define the role of C&GS: responsibility, organization, and operations; future directions; and resource management.

2. RESPONSIBILITY, ORGANIZATION, AND OPERATIONS

Public Law 373 of the Eightieth Congress defines the functions and duties of the now-named Office of Charting and Geodetic Services (C&GS). Stated generally, its charting responsibility is ". . . to provide charts and related information for the safe navigation of marine and air commerce. . . ." This statute, enacted in 1947, did not envision the major role that electronics and automation would play in the acquisition and dissemination of data. The intent of the Congress, however, is clear in that the dissemination of data acquired is authorized in order that full public benefit may be derived. That statute is specific as to the medium of dissemination--the compilation, printing, and distribution of nautical and aeronautical charts and related navigational publications. Another section of the law, which pertains to this study, authorizes contracting with qualified organizations for the performance of any part of the authorized functions.

It is the opinion of the Committee that Public Law 373, in defining the functions of C&GS, allows flexibility in determining the means of carrying out its responsibilities.

2.1 PRODUCTION-PROCESS ACTIVITIES

The activities in the production process, as they have evolved, are outlined in Figure 1. These activities and their definitions serve as essential background information on which the Committee made its recommendations concerning the future activities of C&GS.

The following activities serve to accomplish the basic C&GS mission:

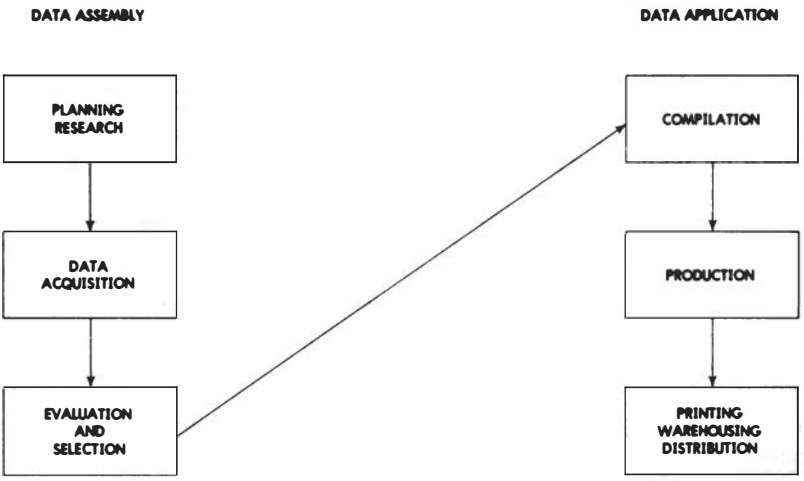

FIGURE 1 Current activities and functions in nautical and aeronautical mapping and charting.

1. Planning and Research. The overall identification and planning of user needs, programs, product designs, budgets, staffs, and implementation is the focus of this activity.

2. Data Acquisition. The data for maps or charts are acquired through photogrammetic, geodetic, topographic, hydrographic, tidal, and land surveys. Data acquisition also includes communication with field contacts and research of literature for mappable cultural features.

3. Evaluation and Selection. Individual sets of acquired data are evaluated in this activity, and decisions are made about the information to be included, based on the accuracy and currency of the data and the intended use of the chart.

4. Compilation. This activity involves the extraction, selection, and placement of features and the representation of data, such as buoys or structures, on a map or chart.

5. Map and Chart Production. This activity involves scribing (negative engraving) and film manipulation, the final steps in chart production.

6. Printing, Warehousing, and Distribution. These steps in the process are necessary to create and distribute quantities of the final product.

It is important to note that these activities are in reality a part of the overall data-management responsibility, which includes the data-assembly and data-application functions.

To accomplish their various tasks, the National Oceanic and Atmospheric Administration, the National Ocean Service, and C&GS are organized as shown in Figure 2.

The Aeronautical and Nautical Charting Divisions of C&GS employ about 700 people, with an annual budget of nearly $41 million. The activities of these two C&GS divisions are the primary focus of this report.

The Aeronautical Charting Division produces the following major navigational aids: Sectional Charts, Terminal Area Charts, World Aeronautical Charts, Airport Facility Directory, Flight Planning Charts, Instrument Approach Procedure Charts, En Route High-Altitude Charts, En Route Low-Altitude Charts, Radar Video Maps, Controller Charts, and Controller Chart Supplement.

The Nautical Charting Division produces the following major navigational aids: Conventional Nautical Charts, Small-Craft Charts, Route Charts, Bathymetric Maps, Topographic/Bathymetric Maps, Marine Boundary/Seaward Boundary Maps, Special-Purpose Maps, Tide/Tidal Current Tables, and U.S. Coast Pilot Publication.

2.2 CURRENT CHARTING ACTIVITIES

The Committee found that the C&GS has a product orientation rather than a market, or user, orientation. That is, the agency produces standard, highly accurate, useful products at affordable prices, and the user is generally satisfied (Market Facts, Inc., 1984). Consistent with this product orientation, technological changes have been viewed mainly as a means of producing the traditional paper products more efficiently and accurately, not necessarily as a means of creating different, more useful products to meet changing user needs. Though ultimately the user may be better served by new products based on a new technology, the orientation is primarily toward internal production capabilities, accuracies, and schedules. The C&GS should develop a market or user orientation where the careful assessment of the user's needs and requirements are the guiding principal in the design and development of their products.

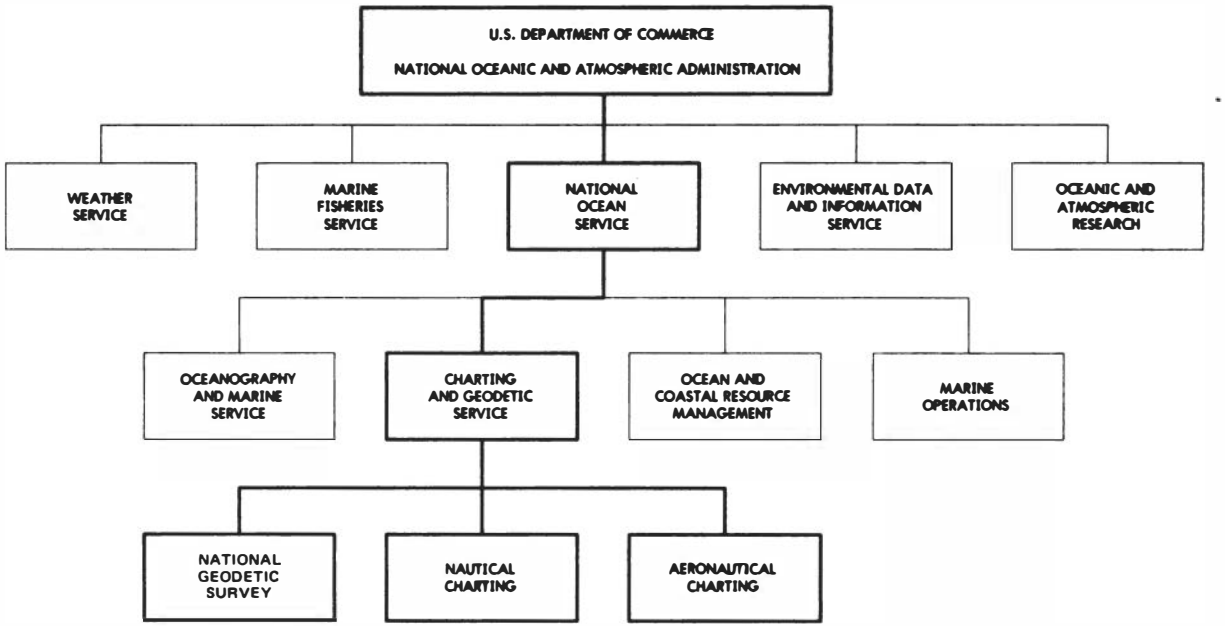

FIGURE 2 Organization of the National Oceanic and Atmospheric Administration.

The methods used to acquire, process, and produce materials needed to print the aeronautical and nautical charts and related products are still basically standard manual (labor-intensive) techniques. Similar methods are used by chart- and map-producing organizations throughout the world.

The Committee observes that C&GS has made significant progress toward digitization and automation. The Nautical Charting Division has been on a long-range program since the 1970s to digitize shoreline and hydrographic information. This data file is designed primarily to aid in more efficient production of the existing line of products. It is due for completion within the next 5 years. The Nautical Charting Division is developing a system for collection of bathymetric information. The vast majority of the data will be processed by an onboard computer.

Computer-stored, digitized hydrographic information can now be extracted and revised via a cathode-ray tube (CRT), enabling interactive editing and updating of the digital files. Again, this appears to be primarily to assist in the production process for creating the present mix of charts.

The Aeronautical Charting Division primarily uses the new technology to create data bases for the aeronautical data that change rapidly and for situations in which timely application is crucial to flight safety.

No long-range, coordinated plans for the use of the material, for the interaction between the Nautical and Aeronautical Charting Divisions, and for obsolescence were apparent. For the most part, the staff involved in developing the automated systems was also involved in day-to-day conventional manual-production activities. No permanent staff, at the level of the Director, Office of Charting and Geodetic Services, is totally dedicated to developing automated systems.

The Committee believes that the various computer-assisted automated systems now in place at C&GS warrant a review to establish the viability of the programs. The rapid development of technologies in the past 5 years has affected the efficient making of traditional chart products and also the use of charts. Therefore, many of the procedures, computer programs, and computer equipment may no longer represent state-of-the-art technology. Since the automation methods now in place will be used and improved throughout many future years, there is concern that the future not be built on an obsolescent

base or concept. The review should consider the expected lifetime of these operations, the adequacy of present computer needs, and the necessary program to function effectively throughout this period. The Committee recognizes that there are budget constraints placed on C&GS to achieve its basic mission while attempting to enter mapping's electronic age. Therefore, any review must touch on the costs and benefits of automation and how existing programs may be altered in order to fashion a long-range automated mapping and charting program.

2.3 PLANNING

With the ever-increasing demand for aeronautical and nautical products and data and the growing pressure for efficiency in government, an organization must be attuned to the creation of products based on new technologies that meet documented user requirements. Both C&GS and its customers have felt and will continue to feel the impact of major technology advances. Users will need new services, support, and products; C&GS will require new programs, organization, and facilities as a result of these changes. C&GS will find itself dealing with the following:

1. The need to supply digital data in addition to other products;
2. The need to supply rapid updates to the data files used by its customers;
3. The need to create and monitor standards against which the use of C&GS data will be measured.

The Committee finds that the Aeronautical and Nautical Charting Divisions of C&GS do not have a group specifically charged with responsibility for ascertaining user needs on a continuing basis and for applying these needs in planning future facilities and operations. Therefore, there is a need for greater organizational emphasis, at the level of the Director, Office of Charting and Geodetic Services, for assessing the latest technical developments, for determining their influences on C&GS's products and processes, for assessing the present and future user requirements for aeronautical and nautical charts and data, and for developing products that will meet those requirements (also see Section 3.4.3). For the C&GS to be successful in utilizing its resources, it

should continue to focus its efforts on the primary navigational products needed to meet its basic responsibility as described by law. Secondary, less-essential products that take a lower priority should be created and distributed totally by the commercial sector or by government-commercial cooperation.

RECOMMENDATIONS

We recommend that C&GS review the present automation methods in the aeronautical and nautical charting operations to establish the viability of the programs. (Section 2.2)

We recommend that the new possibilities arising from technological advances be explored in terms of changing user needs and a user orientation be considered in assembling and applying data to the current aeronautical and nautical products. (Section 2.3)

3. FUTURE DIRECTIONS

The future of the Office of Charting and Geodetic Services (C&GS) will depend, in part, on its ability to respond to the increasing demands and changing requirements for cartographic information, to develop a management system that incorporates all functions from product requirements to product performance, and to incorporate the latest technological developments with a minimum of lead time. The increasing demands are indicated by the following:

1. FAA Aviation Forecasts (Federal Aviation Administration, 1983), which covers aviation activity for the period of 1983 to 1994, states, "Overall, the long-term outlook for aviation is for a relatively strong growth throughout the forecast period, consistent with forecasted long-term economic growth." Aviation activity is predicted to increase 97 percent at towered airports by fiscal year 1994. Scheduled domestic and international revenue passenger miles (RPMs) are forecast to increase about 80 percent, and commuter RPMs 220 percent. The Office of Charting and Geodetic Services (1983) publication Long-Range Plans for Aeronautical Charting outlines plans to meet the needs described by the FAA report.

2. The National Advisory Committee on Oceans and Atmosphere (NACOA) 12th Annual Report, dated June 30, 1983, states "the United States depends heavily on marine transportation which carries about 99% of all world trade (by tonnage)." The January 1983 NACOA report entitled Marine Transportation in the United States--Constraints and Opportunities further reports that "our ports contribute about $35 billion to our GNP and have gross sales and services of $66 billion per year according to

1980 (Maritime Administration) MARAD figures." MARAD anticipates substantial growth in both foreign and domestic trades over the next decade. Overall, U.S. port cargo volume is expected to increase by 32 percent to a total of 2 billion tons by 1990. The NACOA reports also point out that based on a survey of 19 U.S. ports, the American Association of Port Authorities concluded that navigation-channel limitations have resulted in the loss of 25 million tons of cargo at a cost of $3.4 billion.

Cartographic evolution, data-base management, management information systems (MIS), and technology development as they relate to future direction are considered next.

3.1 CARTOGRAPHIC EVOLUTION

The developments in cartography over the last two decades clearly show that the concept and definition of maps and charts are expanding and evolving. Earlier, the concept of a map or chart was almost exclusively related to a hard-copy medium, such as a sheet map or chart, a globe, or a gazetteer. Particularly during the last decade, cartography has witnessed numerous explorations into the world of new map products, many of which are some form of electronic map.

To accommodate this electronic form, the concept of real and virtual maps has evolved. This permits a classification useful in our presentation that is based on two fundamental characteristics: whether the map is directly viewable as a graphic image and whether it has a tangible reality. Real maps and charts, such as most conventional maps and charts, have both characteristics. Virtual maps, on the other hand, may take on a different form, such as cathode-ray-tube image (graphic and viewable but not tangible), traditional field notes (viewable but not graphic), and computer-stored information (not viewable or graphic) (Moellering, 1980, 1983, 1984). Of immediate interest to C&GS in relation to this concept of maps and charts is that conventional cartography is comprised of real-to-real transformation. Therefore, in planning for future facilities and products, it is the observation of the Committee that modern interactive cartographic systems concentrate on manipulating chart information in the virtual domain, whether that work

is intended as an aid to chart production or whether it is intended for analytical operations.

Rapid technological advances have necessitated a reconceptualization of cartographic science that focuses attention on the critical role of cartographic data bases in either graphic or digital form. Today we are witnessing a transition from a former total dependence on analog data bases to an era of rapidly growing dependence on digital data bases.

The Committee believes that through this transition period the traditional hard-copy medium, as it has evolved, will continue to be a major product of the C&GS in satisfying the needs of a large proportion of users. Efforts to increase production efficiences through automation and efforts to streamline this product line based on user needs must continue to remain high in C&GS priorities.

Further, in this period the electronic form of the virtual map will continue to absorb a large proportion of available resources for research and development, even though this product may be slow in gaining acceptance and may never completely replace the traditional paper product for satisfying all the users' needs.

This transition period, therefore, will present particularly difficult problems as regards resource allocation, training, user coordination/evaluation, and distribution of products, to name only a few areas, as C&GS moves from producing hard copy to the age of the electronic map.

3.2 DATA-BASE MANAGEMENT

The divisions of C&GS have recognized the need for integrated cartographic and management-support data bases. However, it appears that there is no centralized control or unified direction in creating and maintaining these data bases. The Nautical Charting Division is approaching the development of cartographic data bases by digitizing existing hard-copy products, and the Aeronautical Charting Division is directing its efforts more toward conventional means of capturing and storing data initially in digital form. While both of these approaches can be made to result in identical internal data structures, there is no strong move to comply with a common set of specifications and procedures.

A system concept that provides both real and virtual charts using data from a common data base is indicated in Figure 3. This view is important in that it indicates that future methods and products, including electronic charts and digital data bases, can all be achieved using a common data base. Thus, the flexibility needed to expand or modify today's systems to meet evolving needs centers around the approach to data-base management.

Figure 3 shows that the data-base-management system (DBMS) interacts with the data-extraction programs. This indicates the close relationship between these software. The actual degree of interaction--the precise functions allocated to each--depends on the capabilities of the specific DBMS employed in the system. Any retrieval functions not performed by the DBMS are programmed into the extraction programs. The DBMS is not normally modified once established. The goal, of course, is to select a DBMS that contains as many common and necessary functions as possible, making the maintenance of existing extraction programs and the addition of new ones as effective as possible. One necessary function of cartographic data bases is the ability to represent spatial phenomena and their associations. Spatial data include, but are not limited to, accurate geographic coordinates, elevation data, feature descriptions (point, lineal, and area), and geopolitical associations. Thus, a major element of system flexibility is the approach taken toward data-base-management software.

3.2.1 Data-Base Management Systems

Economies may be gained through the use of a commercial, generalized DBMS, especially when all applications, programs, and data bases can utilize the same DBMS. The economies result from programmers and data-base administrators having to learn only one set of procedures and languages, thus allowing fewer personnel to maintain a larger set of applications. The acquisition cost of both software and vendor support is also less for a single DBMS than for several different ones. While the C&GS staff recognizes the advantages of an integrated data-base approach, it is hampered by the large initial cost of conversion from existing systems, software, and techniques. Nonetheless, the long-range goal of the C&GS should be the integration of mapping, charting, and geodetic (MC&G) data with planning and management data

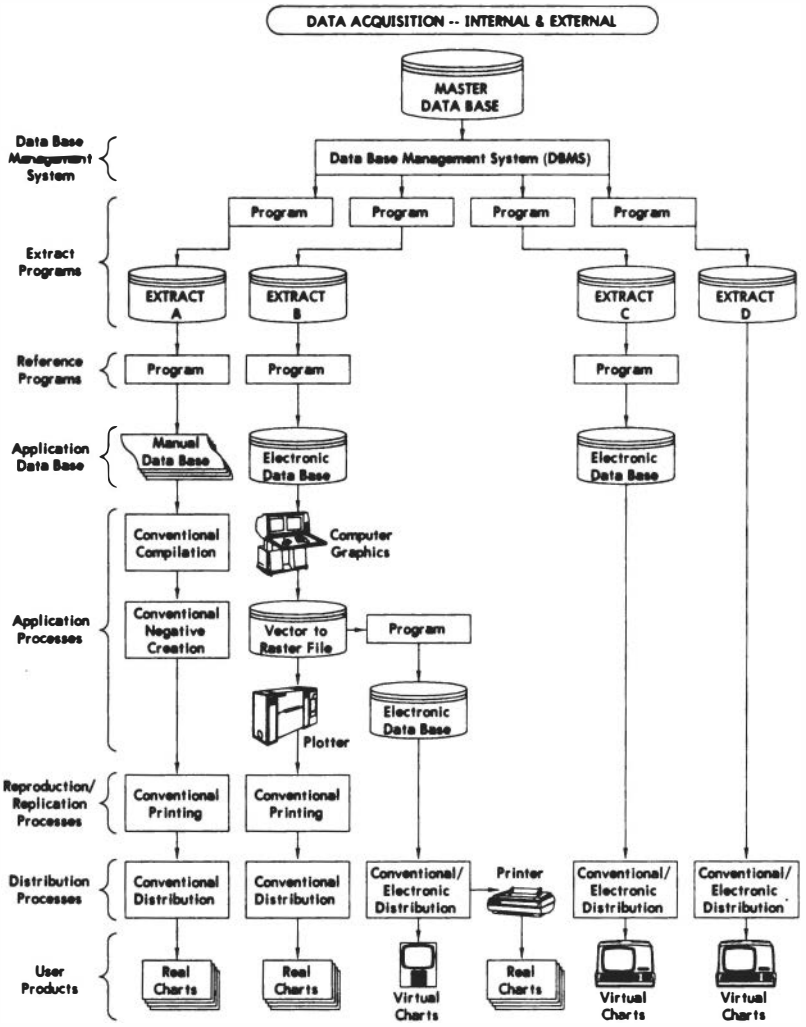

FIGURE 3 Systems view of real and virtual chart production.

across all divisions, as opposed to within each division, as is currently being planned. The Aeronautical Charting Division long-range plan identifies this need within its own domain but fails to identify the DBMS selection as a critical issue and thus also fails to address the integration approach and its magnitude.

Most currently available commercial DBMS are not specifically designed for spatial data management. However, such products may be forthcoming, and to a large degree, current offerings can support most of the C&GS management information system needs. Three aspects of spatial data management appear to be germane to C&GS needs.

1. Query by Spatial Domain. This aspect of spatial data management pertains to the on-line methods of specifying complex queries qualified by geographic references. An example might be "Display current product requirements over area A," where the coordinates defining area A are graphically selected by the user via a displayed map. The capabilities for specifying these types of queries can be developed independently of any particular DBMS and are more a subject of user-system interfaces, including workstation characteristics, than DBM. Nonetheless, future DBMS can be expected to make this interface easier to implement and maintain than those provided today.

2. Search by Spatial Domain. This aspect of spatial data management includes the internal efficiency of storing data and processing queries in interaction with the data-base resources. These characteristics of a cartographic data-base system can be provided by a commercial DBMS, by a completely new development by the using organization, or by a combination of the two. The capabilities are at the heart of the processing, performance, and maintenance costs of any cartographic information system, especially in support of future product requirements, including digital data media.

3. Computations over Spatial Domains. This aspect deals with the capabilities of querying the MC&G data base to obtain numerical measures based on geographic locations. This includes such queries as "distance between points A and B," "length of lineal feature X," or "area of areal feature Y." These capabilities appear to be desirable but not of immediate need to the C&GS information systems.

3.2.2 Digital Cartographic Data Standards

With the rapidly developing and expanding area of digital cartography, many agencies, companies, universities, and individuals are beginning to utilize cartographic data bases developed outside of their own organizations. Since, in most cases, the specifications for the data-base structure, organization, format, and captured variables coded vary widely from data base to data base, the exchange of data among organizations is usually difficult at best and sometimes nearly impossible. The fundamental reason for these complications is that at present there are no generally accepted data-exchange standards in digital cartography.

In the last few years, two cartographic data-standards committees have been founded to address these problems. The first, the National Committee for Digital Cartographic Data Standards, founded in 1982 and operated under the auspices of the American Congress on Surveying and Mapping (ACSM), has a mandate from the National Bureau of Standards to the U.S. Geological Survey to develop cartographic data standards. The committee is composed of members from federal, state, and local agencies; the private sector; and academe. Its goal is to develop digital data standards that provide broadly based solutions to the problems that apply to the entire profession of cartography and its practitioners.

In 1983 the Federal Inter-Agency Coordinating Committee for Digital Cartography was founded to address cartographic problems in the federal sector. The committee was founded as a result of a mandate from the Office of Management and Budget (OMB), based on the General Accounting Office (1982) report on duplicative federal mapping. In this case the federal committee was primarily interested in cartographic data standards, cartographic technology transfers among agencies, and coordination of cartographic activities that relate specifically to the federal agencies.

The work of both committees is critical to the future growth and development of the field of digital cartography. Currently, C&GS is involved in the work of both committees to help resolve these problems for the various mapping sciences. Continued efforts and participation in this work is important to the future of C&GS.

The need for standardization is clear. In addition to the committees on data-standards cited above, the International Hydrographic Organization has formed a Committee

on the Exchange of Digital Data (CEDD), chaired for the United States by the National Ocean Survey, an effort to standardize digital hydrographic exchange formats, and allied to the CEDD is the North American Working Group, also chaired for the U.S. by the NOS, to establish digital hydrographic exchange standards common to the United States and Canada. A still more active group is the Digital Geographic Information Working Group (DGIWG) (United States, United Kingdom, Federal Republic of Germany, France, Netherlands, and Italy), which has been in existence since June 1983 but has quickly taken giant strides in developing digital geographic information standards. (The U.S. members of the DGI Working Group seek common standards between the nations and are encouraging internal standardization as well.) Another effort at standardization is the publication and broad dissemination by the Defense Mapping Agency of the Feature File Data Collection Guide, a common menu of cartographic features, attributes, and definitions, along with a standardized coding system, to satisfy the digital MC&G needs of a wide range of users and products.

3.3 INTEGRATED MANAGEMENT INFORMATION SYSTEMS

The major management, production, and support functions performed by C&GS would benefit from the institution of an integrated management information system (MIS). Figure 4 presents a typical MIS that includes management data; mapping, charting, and geodetic data; and MC&G indices and descriptive data needed for informed decision making and to run the total operation efficiently and effectively. The details of the various functions depicted in Figure 4 are given in the Appendix.

3.4 USER REQUIREMENTS AND TECHNOLOGY DEVELOPMENT

There has been great progress in the development of technologies that affect both the making and using of cartographic products in the aeronautical and nautical mapping and charting fields. These developments have been accelerating, most noticeably during the past 5 years. The prognosis is for active continuation of these trends.

The impact of automation on mapping and charting is twofold, affecting the following:

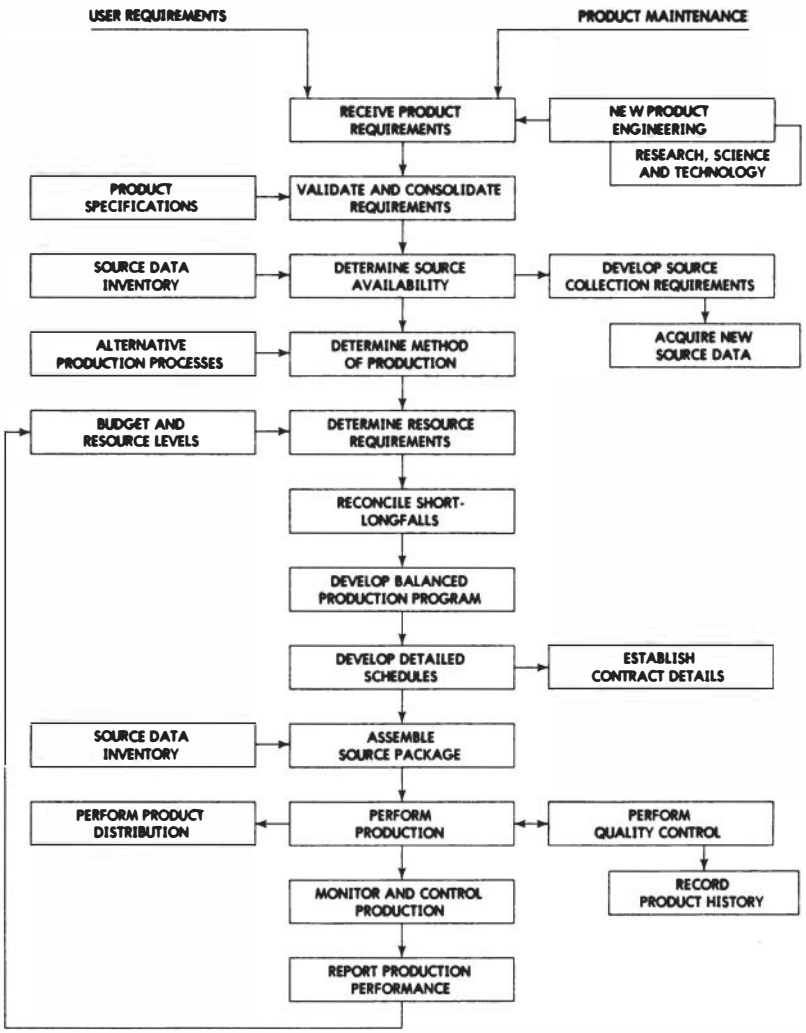

FIGURE 4 Major C&GS management, production, and support functions.

1. Methods of labor saving and efficiency improvement applicable to the C&GS traditional operations;
2. Basic changes in the nature of the products.

The factors that are driving for positive change in cartographic products and their utilization are primarily innovations in computer, recording, and display technology. These components are being integrated in the Electronic Flight Instrumentation Systems (EFIS). Similarly, nautical electronic charts are nearing the time of widespread usage. These advanced, low-cost systems now require new forms of cartographic products in order to utilize their capabilities effectively. A separate but equally significant advance that affects NOAA is the technology of mass-storage devices, for example, the digital optical-disk recorder introduced in early 1984. This technology offers a new medium to transport map and chart data that are compatible with current and projected electronic-display and navigation systems.

The application of map data to electronic cockpits is already being evaluated in a number of simulators and test beds. Associated research and development efforts by the Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and Federal Aviation Administration (FAA) in navigational displays are establishing the need for two-, three-, and four-dimensional electronic-map data bases. In each of these programs, however, the perception of users and system developers is that electronic-map displays will not be practical until a suitable data base is available. In this regard, both the Defense Mapping Agency (DMA) and NOAA have already addressed the principal elements of digital data bases. It would appear to be timely, with the commercial availability of portable mass-storage devices, such as optical disks, and the growth of EFIS in general aviation, for C&GS to monitor and assess these capabilities vigorously.

In the midst of this advancing technology environment C&GS must maintain and strengthen a close association with all segments of the community using its products. A real challenge facing the management of C&GS is to keep abreast of the industries dealing with the development of high technology systems that utilize navigational cartographic information. These industries exert a strong technology pull that must be understood as G&GS plans for future products and activities.

3.4.1 Advanced Technology Developments

The state of the art and projected trends are reviewed briefly to bring into context the technology with which C&GS products must be compatible.

Today, the fields of military, commercial, and general aviation are introducing electronic displays and instrumentation equipments in all new commercial and business jets and turboprops. In addition, some units of the general aviation community are being equipped with combined weather radar and digital navigation systems, which include electronic displays with menus for checklists and weather and navigation data.

The Air Force and Army are already demonstrating electronic terrain mapping using three-dimensional digital cartographic data. In a recent exploratory development program funded by NASA, Lockheed-Georgia developed advanced crew stations that specifically require the use of stored charts and other data found in C&GS publications. Finally, the NASA General Aviation Avionics and Control Program has been established to address innovative avionics concepts, with one of its principal goals aimed at providing pilots with en route Instrument Flight Rules (IFR) charts on electronic cathode-ray tubes.

The major problem in the transition to these development programs has been the lack of adequate mass storage or memory that is portable and an accessible data base. The recent developments of digital optical-disk technology have made a quantum leap in the amount and type of data that can now be stored and easily transported. Available for purchase in the open market are laser diode-driven optical disks that are 12 inches in diameter and that can store the equivalent of 10 to 40 magnetic reel tapes, 8,000 to 64,000 pictures, or 2 million pages of text. These disks are portable, providing the capability to carry C&GS-type charts and maps for an entire country the size of the United States on one 12-inch disk, instead of map bags full of charts. One company is also reportedly developing a 5-1/4-inch optical disk and compatible disk drive with a 600-Mbyte storage capacity. Systems such as these will be relatively inexpensive, since they will be sold in large-volume computer markets; and their size, both the current 12-inch and projected 5-1/4-inch disks, makes them suitable for aircraft and other vehicles.

3.4.2 Impact of Technology on Products

The advanced technologies and automation methods introduced over the years in both the aeronautical and nautical charting operations have been primarily responsive to the internal needs of C&GS. The primary motivation was probably the reduction of internal cost; but it is also true that automation can reduce the response time for the preparation of chart updates, thereby benefiting the user. However, the impact of technology on the user, especially the new requirements that will evolve from the availability of systems of electronic-chart displays and other advanced systems, will force modification of the C&GS operation in a much more dramatic sense--the C&GS product itself will be transformed. The C&GS will have to adapt to a new set of rules and possibly new responsibilities, in addition to continuing the more traditional roles. Assuring navigation safety through an accurate and timely cartographic product will become a much harder task for C&GS.

Because the agency functions in the public interest, it needs to respond to the change arising from technology advances. Technology can bring improvements in convenience, accuracy, availability, and reliability. But it can also result in inaccuracy and complacency. The complacency that set in when radar was finally accepted was due to the feeling that radar would prevent collisions, no matter how low the visibility or how fast the speed. Similarly, long-range navigation (loran) has fooled many a mariner into believing that the coordinate converter was giving correct latitudes and longitudes or that the automatic receiver was giving correct time differences. "Radar-guided collisions" and "loran-assisted groundings" sum up this problem in a few words. There are other instances in the field of navigation where technology has gone too far or where the proper restrictions have not been placed on its use.

Technology and charting are filled with similar difficulties. The most likely outcome of mixing these two is the use of electronically displayed charts--and these charts are most likely not going to be prepared exclusively by C&GS. What must be safeguarded is the integrity of the chart and the chart data as they are processed and displayed in the electronic system. If C&GS is going to continue as a guardian of safety at sea and in air navigation, it will have to undertake the duties of setting standards and assuring the proper

utilization of its products. Clearly this task has become more complex for C&GS. If it is to become concerned with the products of intermediate or value-added suppliers, who transform C&GS data into an end-user product, C&GS may wish to prepare and propose standards for use of its data. If these standards are respected, the accuracy, validity, and utility of products made from these data will be retained. Voluntary compliance with such standards will become an important consideration for end users to choose such products over those products that do not comply. C&GS should conduct an in-depth analysis of this issue.

3.4.3 User Requirements Process

In its role, C&GS performs a prime mission with respect to the safety of sea and air transportation. The mission is national in scope, with no measure of performance in terms of financial profit, and its attainment should never be subject to the restraints of financial benefit. On the other hand, C&GS must continue to be sensitive to the needs of its users and not provide products and services that are not needed, thereby placing necessary products and services in jeopardy.

In the nautical charts area, the user requirements have evolved over a relatively long time. To obtain insight into changes in chart use, C&GS recently contracted for a market survey (Market Facts, Inc., 1984) aimed at determining the demand for different types of charts. The survey concluded that C&GS products are the preferred charts among boat owners; information about marinas and about tides and currents would be of interest; charts are purchased when information on a new area is needed or when a chart is worn; most boat owners use charts less than half of the time; small boat owners are least likely to own a chart; and the process for determining and meeting user needs is informed and efficient as substantiated by market acceptance.

The requirements process in the Aeronautical Charting Division is quite different from that in the Nautical Charting Division. The requirements process is largely a FAA responsibility, since the FAA is charged with the safe and efficient use of the National Aerospace System. The charts provide silent communication between the pilots and the controllers--reducing the volume of radio communication. It is essential that both have the same, 100 percent accurate data at all times.

The aeronautical charts must reflect the general needs of the users but retain FAA's role in the rule-making process. The combination of rule and nonrule changes to the charts are approximately 35,000 annually. Therefore, the FAA depends heavily on the C&GS capability for both cartographic skills and knowledge of aviation. In addition to the charts published for civil and military use, the FAA establishes the requirements for internal products such as controller charts, video plates, and controller chart supplements.

There are a number of groups to question in order to obtain user requirements for the aeronautical products. First, there are the 717,000 individual licensed pilots. Second, there are organizations of users such as the Aircraft Owners and Pilot Association, Airline Transport Association, Airline Pilots Association, and National Business Aircraft Association. Third, the civil and military requirements are coordinated by the Interagency Air Cartographic Committee (IACC), which includes the Defense Mapping Agency, Department of Commerce, and FAA.

There are aspects of the C&GS operation in which the FAA determines requirements and is the sole user of the C&GS service. For example, the FAA requirements for digital positional data are growing and are required to meet numerous needs of automated air-traffic control systems, such as Minimum Safe Altitude Warning (MSAW) and Instrument Approach Procedure Automation (IAPA). Data are currently provided via C&GS ground-survey teams under the Airport Obstruction Survey Program. This program provides surveys for 733 major airports. The FAA now has Instrument Approach Procedures (IAP) for 2,500 airports and is proposing a program to establish survey monuments on each of these airports--tying them to the North America Datum and expanding the survey program by the use of local contract surveys using FAA specifications.

The product users and the major organizations, identified above, that have responsibility for establishing user requirements are normally different for nautical and aeronautical charts. However, the dual roles of production and requirements definition are the same for mapping and charting organizations, such as C&GS and DMA, that produce these products. Critical to the user requirements process is the continuing interaction and impact of rapid technology changes on the user's products, both types and formats, needed to support their operation of ships and aircraft. This interaction of technology and user's requirements creates the need for a commonality of

concepts for C&GS management of the nautical and aeronautical requirements process. This process requires:

1. Aggressive and continuing C&GS identification of and contacts with both the major user requirements groups and the technologies that drive both product/format changes and production process improvements.
2. C&GS management of internal change that responds to (a) the user's primary need and (b) internal production management factors.
3. A recognition that there always will be a continuing interaction between the changing technology drivers and the user requirements process with impacts on C&GS policies for management and organization.

RECOMMENDATIONS

We recommend that a focus, at the level of the Director, Office of Charting and Geodetic Services, be established for managing the user requirements process and that a study be undertaken to evaluate the potential benefits of concentrating the aeronautical and nautical user's requirements in a staff separate from the chart production divisions. The staff should be predominately capable in the nautical and aeronautical operating areas (pilots/navigators, supported by mapping professionals as required). (Section 3.4.3)

We recommend that the Office of Charting and Geodetic Services adopt common standards, specifications, and procedures for their cartographic and geodetic digital data bases. (Section 3.2)

We recommend that the Office of Charting and Geodetic Services institute a data-base-management system that contains as many common and necessary functions as possible. (Section 3.2)

We recommend that the Office of Charting and Geodetic Services more clearly define its requirements for spatial data base management, including the management aspects as well as the mapping, charting, and geodetic data processing needed to select or design workstations, data-base-management systems, and supporting algorithms. (Section 3.2.1)

We recommend that C&GS strongly support both the National Committee for Digital Cartographic Data Standards and the Federal Inter-Agency Coordinating Committee for Digital Cartography in developing digital cartographic data standards that apply to the current and future products of the agency and also the standards that will benefit the broader cartographic user communities as well. (Section 3.2.2)

We recommend that the Office of Charting and Geodetic Services continue its active assessment of commercial products leading to an integrated management information system and thoroughly review the collective automatic data processing requirements and plans for C&GS specifically orienting this review toward integration and consolidation. (Section 3.3 and Appendix)

We recommend that the Office of Charting and Geodetic Services undertake a systematic, coordinated, and continuous technology evaluation to ascertain future uses of and requirements for charting and geodetic data. This program should include discussions with developers of nautical and aeronautical navigational systems and the user community. (Section 3.4)

We recommend that the Office of Charting and Geodetic Services undertake the preparation and analysis of standards to be proposed for products of intermediate or value-added suppliers. These standards should be prepared for voluntary compliance, including evidence of such compliance to the end users. (Section 3.4.2)

4. RESOURCE MANAGEMENT

If the Office of Charting and Geodetic Services (C&GS) is to continue to build on its reputation for accurate, timely navigation aids, it is essential that the agency recognize and respond to user requirements and apply technological advances to product development. It is equally important that C&GS examine the resource management aspects of its operations. Applying improved management techniques to various functions has the potential for increasing the effectiveness of the organization. This potential has been recognized by the present administration's management-reform program, called Reform 88. A major component of this program is Office of Management and Budget Circular A-76, which seeks a more efficient use of all the resources, both federal and private, available to the agencies furnishing government services. The Federal Mapping Task Force on Mapping, Charting, Geodesy, and Surveying (1973) studied the resource-management aspects of the total civilian government mapping activity. This subject was reviewed again by the Committee on Geodesy (1981). Recent efficiency (Arthur Young, 1984) and marketing (Market Facts Inc., 1984) studies performed by outside consultants focused on the resource-management issue as it applies to C&GS.

We believe that the efficient use of resources can be considered in at least three contexts:

1. The government-commercial relationship in terms of responsibility for activities, contractable functions, and reliability and liability.
2. Cost recovery in terms of reimbursements from other agencies and receipts from sales to the public.

3. The C&GS in relation to the total federal mapping activity.

4.1 GOVERNMENT-COMMERCIAL RELATIONSHIP

The constant and varied interaction between the government and the commercial community plays a major part in determining effective resource management and the future direction of C&GS mapping and charting activities. Many lines of inquiry suggested to the Committee can be grouped under this heading. Contracting and liability are two topics affecting the role of C&GS in dealing with the commercial sector. First, however, inherently governmental responsibilities must be considered.

4.1.1 Inherently Governmental Responsibilities

The federal government mapping agencies have congressional authority and historic precedence for mapping and charting tasks that are inherently governmental. As stated previously, Public Law 373 of the Eightieth Congress defines the duties of the Office of Charting and Geodetic Services ". . . to provide charts and related information for the safe navigation of marine and air commerce. . . ." This general directive does not draw a line between government and commercial mapping and charting activities.

By and large, government agencies have limited their tasks to those involving the public good (security or safety) that could not be performed adequately by the commercial sector. Earlier in U.S. history, the consistent, coordinated, continuous, and accurate mapping of the nation's land, water, and airspace would not have been accomplished if left to the commercial sector. Currently, however, there are enterprises and a pool of professional surveyors, scientists, cartographers, and printers and distributors in the commercial sector that make the premise subject to reasonable question. Some believe that all activities dealing in commercial products are, by definition, commercial activities. Others believe that full public benefit would not necessarily be served by such commercial activities and question the ability of the commercial sector to perform in a reliable manner.

Recent documents issued by the Office of Management and Budget (OMB) set forth policy and procedure for making the government-commercial determinations, but they are too general in nature and, the Committee believes, are oriented toward basing the determination solely on cost. Of much greater importance is providing the public with reliable products and services. In support of this we note that the American Congress on Surveying and Mapping (1984), commenting on OMB circular A-76, suggested that the application of this circular to professional cartographic services must consider the technical quality of the service provided and not solely the cost.

The definition and interpretation of which mapping activities are to be accomplished by an in-house government staff or commercial firm in performing an inherently governmental task vary and are subject to change as national-security requirements, confidentiality of data, and products change. Therefore, to categorize activities as governmental or commercial in order to establish a set of rules that would operate under all contingencies for any reasonable length of time would be nearly impossible and would likely hamper an efficient C&GS operation. Nonetheless, it is important to review mapping tasks periodically and categorize them in order to form a guide for the organization to use in planning for the proper use of the available cartographic resources, be they government or commercial.

The Committee, therefore, believes that in determining the proper mix of government and commercial resources to perform the duties of C&GS, the management staffs of C&GS, National Ocean Service (NOS), and National Oceanic and Atmospheric Administration (NOAA) have a public responsibility to meet regularly and cooperatively in order to evaluate "efficiency" recommendations in view of the following:

1. The basic responsibility in relation to the long-range public benefit;
2. The efficiency and possible reorientation of the operation.

Certainly, efficiency studies, as well as other studies on accuracy and quality, are needed and should be encouraged in order to guide the staff in its management decisions. But ultimately, the technical managerial staff should establish the level of staffing that it believes is reasonable based on all the factors involved.

Quality of product, long-range continuity of the basic mapping program, research and planning, schedules and emergencies, as well as cost alternatives, are all major items that the technical staff must consider in determining the proper mix of commercial and government resources.

The Committee believes that the people most qualified and informed about the day-to-day problems and the potential for possible reorientation of the operation are those most familiar with the history and long-term mission of the agency. It is important to establish that the overall management, coordination, program development, and fulfillment of the functions from data acquisition to dissemination are the responsibility of C&GS. The agency must exercise the planning and control necessary to assure the availability of reliable data on which to base its decisions concerning the mix of government and commercial resources in carrying out its responsibility.

The Committee views the data-assembly function as part of the inherently governmental responsibility needing close governmental shepherding. There is good reason to believe that in some cases there will be an almost instantaneous link between data evaluation and data display for the user. The implementation of computer technology will make this more of a reality. It will be necessary to maintain closer control than previously in order to prevent inaccurate information from reaching the user. As computer-driven technology plays a greater part in the management, storage, and extraction stage of the function, it will probably become the program's most important control point. For security and long-term continuity, the Committee believes that this stage of the operation should be retained as a closely controlled government function, with appropriate parts contracted to the commercial sector.

The data-application from virtual to real maps and charts and related products, as illustrated in Figure 3, is now being performed by the government and the commercial sector. The electronic data application following extracts B, C, and D of Figure 3 is the future cost-effective means of supplying information for use in conjuction with electronic equipment developed by the commercial sector. This clearly demonstrates that future data-application activities will be shared by the government and commercial sectors, as contrasted with data-assembly activities, which will continue to be primarily an in-house government-staff responsibility, with appropriate contracting as necessary.

4.1.2 Contracting

Together with the government responsibility for managing and coordinating data-assembly and data-application activities is the responsibility for setting up procedures to evaluate which parts of an activity can be better served by outside resources. Contracting is the key to tapping these resources. However, as previously mentioned, the procurement of outside services should not be determined by costs alone. The future must be considered and attention paid to aspects that assure the continuity necessary for a long-term program.

The Committee is aware of concerns voiced by the public, carried by the media, and investigated by the Congress regarding the studies and contracting efforts of NOAA. We acknowledge the concerns for the continued availability of timely, accurate, and reliable products and services for the safe navigation of marine and air commerce and also endorse the intent of OMB Circular A-76. The Committee believes that the government need not become engaged in any activity to serve the public when the performance of commercial enterprise is satisfying such public need. Further, the government should avail itself of commercial resources in the performance of governmental activities.

Commercial resources offer time-proven expertise and professionalism in a wide variety of cartographic activities. The competitive atmosphere in which they exist demands efficient and reliable performances abreast of the latest technology available to them. The application of commercial resources becomes a matter of evaluating available resources and their compatibility with the governmental activity.

Safeguards that will ensure quality and schedule control are part of the challenge to management in this area if improved productivity and response to user requirements are to be maintained. The Committee believes, however, that contracting large blocks of research, creative, and production processes would harm long-term effectiveness and continuity of an in-house capability. We also do not believe that the C&GS should retain only a skeletal staff to administer, research, and create prototypes for the program. On the other hand, we do not believe that there is a need to maintain complete in-house backup capabilities for those operations that are contracted on a continuing basis.

4.1.3 Reliability and Liability

Product or service reliability, in terms of data content, timeliness, validity, accuracy, and understandability, is a technical issue associated with the design and production processes. It is vital to the safety of the transportation operations to which the product is applied and relates to potential liability litigation in the event of damages as a result of alleged deficiencies.

The Committee is aware of concerns expressed by the public, carried by the media, and investigated by the Congress regarding liability associated with performance by the commercial sector under contract from the government. We share these concerns regarding performance by the commercial sector in a manner that would, at least, uphold the reliability of the government product or service and minimize the government's exposure to potential liability litigation.

Product or service reliability is an important consideration in determining production processes eligible for contracting, providing specifications for the guidance of the contractor, selecting the contractor, and administering the contract in a manner to assure expressed performance.

C&GS is responsible for the reliability of all of its products and services, whether produced in-house or under contract. Since reliability is basic to the legal issue of liability litigation, these considerations must also be responsive to legal counsel.

4.2 COST RECOVERY

Receipts from sales to the public and reimbursements for production costs and expenses incurred on behalf of other agencies provide recovery of defined costs and expenses of C&GS. Appropriations from Congress provide the balance of C&GS funding.

Greater cost recovery through increased prices of government products and services is a current objective of OMB, suggesting that all costs and expenses of providing a product or service be funded by those who benefit from the product or service.

The pricing of NOS products and services available to the public is governed by Public Law 88-441 of the Eighty-eighth Congress, providing for recovery only of costs and expenses of printing and distribution. This

statute precludes greater cost recovery, such as for cartographic processes of data-application activities. Suggested price increases have also created concerns regarding reduced distribution and use of charts and related publications in the navigation of marine and air commerce.

The Committee believes that the future role of C&GS in data assembly and application activities, addressed earlier in this report, creates an acceptable and realistic model that may be referred to when defining which costs and expenses may be recovered.

Our suggestions are as follows:

1. Data-assembly activities prior to extraction of data needed to produce a product, real or virtual, are of benefit to the national interest, are an inherently governmental responsibility, are of benefit to the public at large, and should realistically be funded by appropriations.
2. The data extraction for a specific product (the last process in the data-assembly function) is the first process subject to cost recovery to private and public users and to other government agencies using these extracts.
3. The data-application activities ultimately benefit marine and air commerce as well as other government agencies using the navigational products and should realistically be funded through cost recovery from those users.
4. Costs for specific data-application activities of benefit to both government and private users should be allocated in accordance with the ratio between these groups.
5. If prices restrict either sales or distribution, the product design should be altered to reduce costs without sacrificing user requirements.

These cost-recovery principles are also applicable to today's real charts and publications. If applied to determination of reimbursements and prices, it is believed that drastic price increases would not be realized, and the future electronic data products and services would be priced to what the market could bear.

4.3 FEDERAL MAPPING ACTIVITIES

The determination of an efficient organization of C&GS's cartographic programs cannot be considered in isolation. The agency's basic functions and mission must be viewed in relation to the responsibilities of other civilian mapping agencies if the most efficient use is to be made of available limited human and material resources. With the rapid development of technology and greater demands placed on C&GS, it is obvious to the Committee that neither C&GS's budget nor its manpower is adequate to maintain the expected leadership in the areas of cartographic research, development, and service. We believe that the trend toward budget stringency will continue; therefore, C&GS may find it more difficult to operate efficiently when acting separately from other agencies performing similar mapping tasks.

4.4 GENERAL OBSERVATIONS

The current activities resulting in the supply of nautical and aeronautical materials to the Defense Mapping Agency, precluding their duplication of C&GS effort in satisfying total Department of Defense requirements, are commendable as economical solutions to dual requirements. Similarly, the current activities of supplying such items as video maps and controller charts to the Federal Aviation Administration (FAA) precludes a mapping activity within that agency.

Interagency activities will also involve data-assembly functions, such as the airspace and facilities data emanating from the FAA, which could ultimately become a matter of a singular data base residing in the FAA with extract programs for C&GS data-application activities at the direction of the FAA. Similarly, the topographic data required for visual aeronautical charts are assembled by other agencies as required to fulfill their mission and could be made available for C&GS application activities with extract programs.

A number of observations about C&GS charting operations point to a growing difficulty for the agency to proceed on its traditional path, using the same or similar management and production techniques that were successful in the past. These observations fall under two main topics: the difference between nautical and aeronautical programs and the cross use and management of data.

First, the nautical and aeronautical programs of C&GS serve two widely different user groups with different requirements. The nautical program serves the marine community, which in itself is diverse. This diversity makes it relatively difficult to assess user needs. Nautical products, and the design of them, are largely determined by C&GS's internal management staff, with additional input from user groups. The aeronautical program, on the other hand, is established largely by the FAA. The major user of C&GS aeronautical products, the FAA determines product needs, schedules, and design. These differences obviously set varying and complex requirements for internal data acquisition, production, schedules, and procedures as well as for research and development approaches. Future products and design also suffer because of the greatly different user requirements.

Second, in regard to data, the citizenry, politicians, and public policymakers are increasingly emphasizing effective planning for the rational use and management of the Earth's limited resources. Therefore, data that form the basis for the nautical and aeronautical charts take on new significance. With the increased emphasis on effective planning and interagency cross use of information, the Committee wonders if, under NOAA's present organizational structure, it is possible for C&GS to answer questions such as the following:

1. Is there a larger user community than C&GS currently recognizes for the use of the data that it captures?
2. Are the present data being captured adequate for the U.S. resource-planning effort?
3. Can nautical and aeronautical data be merged with resource and environmental data in other data files for broader use?
4. Can C&GS efficiently incorporate the latest technology into its cartographic programs merely by cooperative relationships with other civilian mapping agencies?

Under proper direction and with a broader outlook concerning its mission, the present organization can mold itself to meet the expanded requirements for products, services, and cross use of information expected in the future. In fact, the Committee believes that because of its specialization C&GS has developed an organization that can respond quickly to the user needs as currently

defined. This strength would have to be maintained in any reorganization attempt. However, an alternate means for the agency's achieving its goals may be to follow the recommendation of the Federal Mapping Task Force (1973) and the Committee on Geodesy (1981), which states that there should be formed a single agency, a Federal Surveying and Mapping Administration, for civilian mapping, charting, geodesy, surveying, and the multipurpose cadastre.

In regard to the more general government-commercial relationship, cartographic products for the public have been supplied by interaction of the various elements in the government and commercial sectors of the total U.S. cartographic community.

The government-commercial interaction is most evident, and the public well served, when the government is able to use competent commercial services in meeting its inherently governmental assignment to supply products for the public good. The public is also well served when the commercial sector identifies needs and develops products for special public interests. Those needs cannot be met by the government agencies if the agencies are to carry out their inherent basic responsibility efficiently.

In these two areas, use of commercial services and development of products, the proper balance has been obtained by the way the technical staff of the government interprets its responsibility. Input from the commercial sector on key issues of contracting, liability, product design, and need have not been on a continuous or formal basis.

We believe that there is a need to consider a means to a formalized, continuous dialog between the government and commercial sectors involved in mapping and charting. This formalization and continuity could help to develop general policies that are compatible for all concerned groups.

We hope that the activities of the Committee on Cartography, which is made up of members from the government and commercial sectors, is a start in what could develop into an ongoing, joint, government-commercial group to examine key issues and policies involving mapping and charting that relate to the public benefit.

RECOMMENDATIONS

We recommend that the data-acquisition, evaluation, management, storage, and extract activities--the data-assembly function--of C&GS total inherently governmental responsibility should be controlled closely by the government staff with appropriate commercial involvement. (Section 4.1.1)

We recommend that data compilation, reproduction, and distribution activities--the data application function--of the C&GS total inherently governmental responsibility should be subject to more commercial involvement than the data-assembly function. (Section 4.1.1)

We recommend that a capability be established at the appropriate C&GS organizational level with participation by other appropriate agencies, such as the U.S. Geological Survey, FAA, and DOD, to determine (1) the degree of appropriate involvement by the commercial sector in the application functions performed by the C&GS and (2) resultant user products and services to be made available to the public and other agencies. Requirements of the public and other agencies and the reliability of products and services offered by commercial enterprise are to be the basis of these determinations. (Section 4.1.1)

We recommend that staffs of NOAA, NOS, and C&GS assess the capabilities of the commerical sector to perform parts of inherently governmental activities reliably and, further, assess the practicality of contracting for such component performances. (Section 4.1.2)

We recommend that C&GS primarily address technical issues of product reliability with due consideration of recommendations from legal counsel regarding issues of product liability. (Section 4.1.3)

We recommend that all costs and expenses associated with and allocatable to the data-assembly functions, excluding the data-extract processes, be expenditures in the national interest funded by appropriations. (Section 4.2)

We recommend that all costs and expenses associated with and allocatable to data-application functions, commencing with data extracts, be funded by reimbursement

from other agencies and receipts from sales to segments of the public who derive benefit from such activities. (Section 4.2)

We recommend that fixed costs and expenses of specific data-application activities of benefit to other agencies and to the public be allocated based on the ratio of users. (Section 4.2)

We recommend that all specifications and corresponding methods of production be designed to ensure minimum cost/price without sacrifice to user needs or intended use. Particular concentration should be on those products for which there is evidence that current prices are restricting widespread use. (Section 4.2)

APPENDIX

We present here a typical integrated management-information system (MIS) for mapping, charting, and geodesy (MC&G) (see Section 3.3).

Receive Product Requirements. This function receives specific product requirements from external customers (e.g., Federal Aviation Administration, Defense Mapping Agency) and derives maintenance requirements for existing products. Periodically, new product requirements are received as a result of internal research, science, and technology in response to changing needs. An MIS could collect, record, and track both near- and long-term product requirements for production analysis. Searches could be provided to view area correlation, peak, and changing demands and allow for analysis of requirements satisfaction when compared with quantities produced and revenues.

Engineer New Products. Evolving product requirements must be analyzed and designed to assure that production capabilities exist and to establish product specifications, including accuracy, scale, currency, features, and symbology to meet customer needs. Prototypes are produced to aid in the analysis.

Analyze Research, Science, and Technology. Emerging technologies must be constantly analyzed to evaluate and develop new production techniques, maintaining current, cost-effective production capabilities for both in-house production and for contracting potential.

Validate and Consolidate Requirements. The Office of Charting and Geodetic Services (C&GS) must constantly assure that product requests are valid from its mission viewpoint. In addition, the potential for serving several customers with a common product is also possible

if a net product criteria can be established. The C&GS must also determine if requirements can be satisfied with an in-stock product to preclude unnecessary production. An MIS would enable C&GS to record product descriptions and the results of any consolidation of requirements based on specifications, intended use, and need dates.

Determine Source Availability. Before any product requirement can be scheduled for production, C&GS must determine if adequate source data, including geodetic, is available or will be available in time to meet the required need date. This analysis could be greatly enhanced if all available source-data records were available via an information system. The available source will determine the potential for contracting.

Maintain Source Data Inventory. This function is needed to determine production schedules. It should include indices to all types of source data, such as control, elevation, bathymetry, and features. Among the items that should be included are digital MC&G data, photo imagery, existing products, library gazetteers, and place-name sources. Interfaces to U.S. Geological Survey products and sources and to Landsat should be considered.

Develop Source-Collection Requirements. As a result of determining if adequate source data exist, C&GS will identify source needs to satisfy requirements. Thus the automated tracking of source-collection requirements and schedules will allow determination of production options.

Acquire New Source. The acquisition of new source data from external agencies as well as from NOAA efforts should result in updating the source inventory and in notifying production of its receipt.

Select Method of Production. The selection of a method of production can include cooperative agreements among government agencies, only in-house production, only contracting, or cooperation between in-house and contracting production. The determination must be made on a combination of cost, liability, safety, and availability of source data. This function could be supported by detailed schedule requirements and economic and production-process models.

Establish and Maintain Production-Process Alternatives. The C&GS must establish production alternatives, including resource availability, cost, risk, and schedules to be used both in determining production methods and in managing, scheduling, and controlling the production process. This function is

aided by science and technology in establishing the most effective use of technological resources.

Determine Resource Requirements. The C&GS must develop plans for meeting requirements to establish both budget needs and production capabilities. Resource requirements are a direct result of product requirements and methods of production. This function could be greatly supported with computational and schedule models of production alternatives and their effect on resource requirements.

Reconcile Resource Shortfalls and Longfalls. When product requirements cannot be met with available resources, or when excess resources are available, C&GS must reconcile the differences either by adjusting the production requirements or by adjusting the resources. This function could be aided by an MIS analyzing the impact of combinations of adjustments on final resource requirements.

Develop Balanced Production Program. This function includes the final resolution of production plans to meet budgets and product requirements. It establishes the contracting plans for the planning horizon as well as the C&GS production allocations.

Develop Detailed Schedules. This function converts the balanced-program plan into detailed schedules and assignments. It includes the detailed contractor requirements. An MIS could aid in developing detailed milestones and assignments.

Establish Contracting Details. Based on the plans and detailed schedules, specific contracts must be established, including selection of contractor technical representatives and contractor. The size of this effort is directly dependent on the size and number of individual contracts and must have been considered in the selection of production methods. An MIS could aid in developing work statements, including identification of source materials to be used and detailed schedule requirements.

Assemble Source Package. Before any product is developed, the necessary source material must be either gathered (in the case of hard-copy source) or identified as to its content and location (in the case of digital MC&G data). This process must occur regardless of whether the product is to be developed in-house or through contractor participation. An MIS could help by allowing access to an automated source-data inventory to identify, select, and order the necessary data and to record the contents of the data package for current and

future reference. This is a government responsibility regardless of the method of production.

Perform Production. The detailed production steps differ depending on the product and the available source data. The specific steps to be contracted are largely determined by economic and capability analysis, as stated previously. It is the government's responsibility to ensure that production is accomplished. Thus, the availability of "second sources" of production must be established where contractors perform production functions either through in-house capabilities or alternative contractors.

Perform Quality Control. The intended use of each product determines the level of quality control. For navigational products, the highest level of quality control must be implemented, including quality inspections at various stages of production. For other products, the level of quality control should be proportional to the government's liability in the event of errors within the product's intended use. For digital MC&G products, an automated system for ensuring accuracy could be provided. Because quality control begins with product specifications and source-data selection, the use of source-data inventory supports the quality-control function.

Record Product History. The history of production, including source data used, methods of production, and quality-assurance analyses, must be recorded. It is used in determining alternative uses of the product beyond that originally intended and the potential for using the product as source data for other products and in the event of litigation.

Perform Product Distribution. To meet product requirements, the final product must either be delivered to users or made available in a reasonable manner. While this function can be contracted, it is nonetheless a responsibility of the government. This function could be supported by MIS capabilities tightly coupled with the requirement, production scheduling, production planning, and inventory control.

Monitor and Control Production. This function consists of evaluating production progress and taking corrective action when needed. The detailed level of monitoring and controlling depends on whether the production is performed in-house or by contracting. Nonetheless, C&GS must collect sufficient production-performance data to determine the accuracy of estimating models, compliance with prescribed production methods,

compliance with resource allocations, and schedule compliance. An MIS that collects such data at a detailed level equivalent to plans and schedules would greatly enhance C&GS production-control processes.

Report Production Performance. Based on analyses of production monitoring and control, it is a government responsibility to report on production performance for evaluation of cost and schedule compliance. An MIS could support this function by analyses of variances and production of suitable reports.

REFERENCES

American Congress on Surveying and Mapping, Letter dated May 9, 1984, addressed to the House Committee on Merchant Marine and Fisheries (1984).

Committee on Geodesy, National Research Council, Federal Surveying and Mapping: An Organizational Review, National Academy Press, Washington, D.C. (1981).

Federal Aviation Administration, FAA Aviation Forecasts, U.S. Govt. Printing Office, Washington, D.C. (1983).

Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying, Report to Office of Management and Budget, U.S. Govt. Printing Office, Washington, D.C. (1973).

General Account Office, Duplicative Federal Computer--Mapping Programs: A Growing Problem, The General Accounting Office, Washington, D.C. (1982).

Market Facts, Inc., Report dated March 5, 1984, 1611 N. Kent Street, Arlington, Va. (1984).

Moellering, H., Strategies of Real-Time Cartography, Cartographic Journal 17(1), 12-15 (1980).

Moellering, H., Designing Interactive Cartographic Systems Using the Concepts of Real and Virtual Maps, in Proceedings of the Sixth International Symposium on Automated Cartography (Auto-Carto Six), Volume II, B.S. Wellar, ed., Steering Committee, Sixth International Symposium on Automated Cartography, Ottawa, pp. 53-64 (1983).

Moellering, H., Real Maps, Virtual Maps and Interactive Cartography, in Spatial Statistics and Models, G.L. Gaile and C.J. Willmott, eds., Riedel, Amsterdam, Holland, pp. 109-132 (1984).

Office of Charting and Geodetic Services, Long Range Plans for Aeronautical Charting, NOAA, Rockville, Md. (1983).

Young, Arthur, Draft report dated January 27, 1984, 1025 Connecticut Avenue, N.W., Washington, D.C. (1984).

ANNOTATED BIBLIOGRAPHY

Aeronautical Chart Branch, National Ocean Service, NOAA. Aeronautical Chart Branch. NOS. NOAA. 1983.

The responsibilities, organization, functioning sections, and units of the branch are described. Included are lists of the series of charts, schedules of production and revision, and future programs. Legislation authorizing and defining the mission of the NOS as it concerns aeronautical charts, major users of the products, and the 1983 to 1984 budget is discussed. (44 pages, 8 1/2" x 11")

Coordination of Digital Cartographic Activities in the Federal Government, First Report to the Director, Office of Management and Budget. Federal Interagency Coordinating Committee on Digital Cartography. USGS. October 1983.

Committee responsibilities, organization, and personnel are outlined, and current and proposed digital cartographic programs for some 30 participating federal government agencies are summarized. (60 pages, 8 1/2" x 11")

Duplicative Federal Computer-Mapping Programs: A Growing Problem. The Comptroller General of the United States. General Accounting Office. November 22, 1982.

A problem in many federal agencies is the undertaking of expensive computer-mapping programs in an uncoordinated fashion that results in unnecessary duplica-

tion and expense. The report recognizes the need for a multipurpose data base with standards used throughout government agencies. Two recommendations are made to OMB: a circular should be drafted requiring interagency coordination of computer mapping, and the Secretary of the Interior should accelerate production of computerized maps most in demand by other federal agencies. Such activities can be funded through user charges, reallocation of funds, and new appropriations. Though not part of the formal recommendation, GAO's report indicated that the U.S. Geological Survey should be the focal point for coordinating computer-mapping activities in the federal government and that adequate provisions can be taken to protect the missions of other agencies.

FAA Aviation Forecasts, Fiscal Years 1983-1994, FAA. U.S. Department of Transportation. FAA-APO-83-1. February 1983.

The aviation activity at FAA facilities is forecast, including airports with FAA towers, traffic-control centers, flight service, and flight stations. (72 pages, 8 1/2" x 11")

Federal Surveying and Mapping: An Organizational Review. Panel to Review the Report of the Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying, July 1973. National Academy Press. 1981.

This summarizes the 1973 report of the Federal Mapping Task Force and points to areas needing updating because of changing national priorities, such as geodynamics, population shifts, cadastral surveys, and urban renewal. The panel concludes that to achieve important recommendations of the 1973 report, consolidated planning and unified program direction from a single agency is necessary. The panel urges that prompt consideration be given to the primary recommendation for formation of a Federal Surveying and Mapping Administration by the Executive Office of the President.

Long Range ADP Plan, Overview. Aeronautical Charting Division, NOS. NOAA. November 3, 1983.

The plan to increase efficiency through the use of automated data processing techniques is described. Major areas discussed are management and production control, cartographic data base and computer-assisted chart compilation, cost and job-status information, phototypesetting, order processing, inventory control, etc. (187 pages, 8 1/2" x 11")

Long Range Plans for Aeronautical Charting. NOS. NOAA. November 1983.

A significant document that describes the authority for NOS's aeronautical charting responsibility; relates the expected national needs of pilots, planners, and managers of the national airspace (FAA); and gives details of the expected growth of air transportation. Future plans for chart production, reproduction, and distribution are presented, and automated capabilities and plans are outlined, including on-line access to data by users. Also discussed is the necessity for sensitivity to the needs of the principal user. The FAA is mentioned in conjunction with a more efficient national airspace system plan and a national airspace review. New methods of efficiently updating charts and eliminating duplication are discussed. Recovery of cost through user fees and a proposal to authorize the Secretary of Commerce to secure copyrights for charts are mentioned. Marketing surveys, contacts with users, and other ideas are outlined in an attempt to plan and better meet future needs for aeronautical navigation products. (37 pages, 8 1/2" x 11")

Nautical Charting Division Briefing Material. Nautical Charting Division. NOS. NOAA. December 12, 1983.

The draft of the nautical charting plan, 1984, is contained and offers a 53-page comprehensive, organized presentation about objectives, user requiements, field support, publications, reissue schedules, all the way to various planned programs from 1983 to 1992.

Otherwise much of the document is an uncoordinated assemblage of pre-existing documents that present the nautical charting division organization, personnel, mission, etc. Generally the data are in outline form, with many pages containing a few statements. Information is often repeated in different sections and is extremely detailed. (About 300 pages, 8 1/2" x 11")

Program and Production Management Staff. NOS. NOAA. 1983.

The aeronautical charting program is described, together with the produc- tion staff in control of the program, from development to distribution. Specific expenditures for the 1984 budget as well as internal controls, employment, and major contracts are included. (15 pages, 8 1/2" x 11")

Requirements and Technology Staff. NOS. NOAA. 1983.

The mission of NOS is stated, and methods are described by which the staff provides technical guidance, long-range planning, developmental support, and special-product direction for NOS cartographic requirements and product specifications, computer systems, new products, and marketing initiatives. The management information system (MIS) is also discussed. Included is the report microMIS, a Microcomputer Local Network Management Information System. NOAA. (24 pages, 8 1/2" x 11")

Statement of Work: A Study of the Usage of and Market Potential for National Ocean Service (NOS). Aeronautical Navigation Products. NOS. NOAA. 1983.

The parameters are established for bids on a market study to determine the market, demand, preferences, distribution channels, and competition for NOS's aeronautical products. The study is to furnish market information to aid NOS in determining how it may recover a larger proportion of expenses through higher user fees.