Charting a Course into the Digital Era: Guidance for NOAA's Nautical Charting Mission

Committee on Nautical Charts and Information, National Research Council

ISBN: 0-309-58731-X, 152 pages, 8.5 x 11, (1994)

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Committee on Nautical Charts and Information
Marine Board
Commission on Engineering and Technical Systems
Mapping Science Committee
Commission on Geosciences, Environment, and Resources
National Research Council

National Academy Press
Washington, D.C. 1994

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The program described in this report is supported by Cooperative Agreement No. 14-35-0001-30475 between the Minerals Management Service of the U.S. Department of Interior and the National Academy of Sciences and Cooperative Agreement No. DTMA91-94-G-00003 between the Maritime Administration of the U.S. Department of Transportation and the National Academy of Sciences.
Limited copies are available from:
Marine Board
Commission on Engineering and Technical Systems
National Research Council
2101 Constitution Avenue, N.W.
Washington, DC 20418

Additional copies are available for sale from:
National Academy Press
Box 285
2101 Constitution Avenue, N.W.
Washington, DC 20055
800-624-6242 or 202-334-3313 (in the Washington Metropolitan Area)

Library of Congress Catalog Card Number 94-66559

International Standard Book Number 0-309-05139-8

B-459

Front cover: Photo of an electronic chart of Buzzards Bay, MA, courtesy of Woods Hole Oceanographic Institution
Back cover: Reproduction of NOAA chart 13223, Narragansett Bay, RI.
Printed in the United States of America

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PREFACE

BACKGROUND

Accurate and reliable nautical charts are essential to the safety of those who go to sea for either commerce, defense, or recreation. Increasingly, the information in nautical charts is important for other uses as well, such as environmental assessment and marine and coastal resources management.

At the request of the National Oceanic and Atmospheric Administration (NOAA), a National Research Council (NRC) committee was convened to assess national needs, trends, and opportunities in nautical charting information.[1] The committee assessed the present and future needs of users of nautical information; reviewed the state of existing and emerging technology; examined a number of major issues associated with information acquisition, chart preparation, and dissemination; and stimulated dialogue among interested parties. Based on these activities, the committee prepared the present report, which addresses user requirements for improved nautical chart products as well as technical and programmatic issues related to the need for and provision of nautical information.

NOAA produces and maintains nearly 1,000 nautical chart editions, nine coast pilots, and numerous miscellaneous supporting publications. About 1.4 million charts are printed and sold each year.

The transition from paper charts to electronic charts is well under way. This transition raises a number of technical, legal, and economic questions that must be resolved so that mechanisms and processes are in place to deal appropriately with the technology that is on the immediate horizon. Furthermore, digitization of existing nautical information is a costly undertaking, which, given present resources, would require many years to complete.

Other issues facing NOAA's nautical charting mission relate to setting priorities for selecting geographic areas to survey prior to issuing new charts or to resurvey for

[1] The committee operated under the oversight of the Marine Board of the NRC's Commission on Engineering and Technical Systems and the Mapping Science Committee of the Commission on Geosciences, Environment, and Resources. The committee's activities were administered under the Marine Board.

revision of existing charts. NOAA's budget for chart updating is not sufficient to update each of its many products on a schedule that meets all user needs. Consequently, NOAA requested guidance from the NRC regarding allocation of its limited resources for fulfilling its nautical charting mission.

COMMITTEE COMPOSITION AND SCOPE OF THE STUDY

A committee of 12 members was convened by the NRC to review national needs, trends, and opportunities in nautical charting and information. Biographies of committee members appear in Appendix A. Expertise on the committee included experience in nautical chart production and dissemination; geographic information system development and applications; and familiarity with the concerns of key user groups, including cargo shipping, the fishing industry, offshore oil and gas development, recreational boating, and the ocean science research community. Care was taken to include a range of expertise and representation of various user groups. Additional views of specific user communities were solicited through questionnaires and from workshop participants. The committee was assisted by liaison representatives from federal agencies involved in conducting oceanographic research, boating safety, marine transportation, and/or programs relating to ships, including the sponsoring agency for the study (NOAA), the U.S. Coast Guard, the Defense Mapping Agency, the Office of the Oceanographer of the Navy, the U.S. Geological Survey, and the Maritime Administration. The principle guiding the committee, consistent with NRC policy, was not to exclude any information, however biased, that might accompany input vital to the study but to seek a balanced and fair treatment of all viewpoints.

The committee was tasked with the following objectives:

- to develop clear statements of user requirements for improved nautical information products, including products using advanced technologies;
- to identify key issues and supporting facts relating to the need for and provision of improved nautical information products;
- to stimulate dialogue among all involved in the process of developing, providing, and using nautical information; and
- to provide guidance concerning the optimal level and methodology for updating charts and issuing new ones.

The scope of this study was specifically limited to an examination of information found in nautical charts and associated digital data bases. Synoptic information about sea conditions and ocean forecasting (tides, currents, water level, weather, climate) was excluded. Another Marine Board report, *Opportunities to Improve Marine Forecasting* (NRC, 1989), deals with this area of marine information needs.

Although the central information-gathering activities of the investigation involved a comprehensive survey of users and a workshop, the committee sought to

combine the interests expressed by participants in the study with broader perspectives that take into account the ongoing transition to new technologies and the international nautical information community in which the United States participates through NOAA's Coast and Geodetic Survey. These perspectives were obtained through participation in relevant national and international meetings of the world hydrographic community and the electronic chart producers, and through review of the literature available in appropriate professional journals.

HOW THE STUDY WAS CONDUCTED

The committee initiated its investigations with briefings from NOAA personnel, who provided an overview of the current status and capabilities of nautical charting activities. Over the course of its work, the committee obtained information about user communities' needs for chart products through a widely distributed questionnaire and a workshop.

A concerted effort was made to identify and include in the survey and workshop the full range of users of NOAA nautical charts, including other federal agencies and nonfederal users such as cargo and cruise ships, fishing vessels, recreational craft, and other specialized craft; marine resource development industries; and those interested in incorporating this data into geographic information systems for land-use planning and/or environmental research and management purposes. The workshop also involved other interested parties, such as developers of geographic information system technology and private-sector value-added chart products. The questionnaire was available to any requestor through the Notice to Mariners and was also printed in a popular nautical magazine in an abridged form. The questionnaire mailing and responses were not controlled to produce a statistically valid sampling of the user community, and the structure of the questionnaires allowed incomplete, subjective, and impressionistic responses; consequently, the responses are not suitable for rigorous statistical analyses. Despite the limitations of the investigation, results of the survey and discussions held during the workshop indicate clear trends and provide useful insight into the preferences of various user groups for nautical information products. The questionnaires are being used by NOAA to analyze user needs for specific products under consideration for development.

The committee analyzed the means for best meeting user needs through a review of public- and private-sector activities in producing, updating, distributing, and obtaining feedback about chart products; an evaluation of technological opportunities; and an assessment of legal and economic issues associated with current practices and future options.

The primary focus of the investigation was on chart products and the information in them. Associated activities, such as chart production and data acquisition technologies, were considered insofar as they related to the central issue of providing an accurate and reliable information base from which to create products that meet user requirements. For example, the process of acquiring data in a timely and

efficient way was deemed to be vital to providing an accurate and reliable nautical information product and, therefore, was included in the investigation in this context. Legal issues involving international standards for nautical charts and matters relating to copyright and liability also were considered by the committee because they relate to the development of alternative scenarios for making the transition to the new electronic era in nautical information.

ORGANIZATION OF THE REPORT

This report represents a synthesis of information gathered by the committee through briefings, analysis of the user survey, findings from the workshop on user needs, and additional information gathered from interviews, articles, participation in professional meetings, and visits to NOAA's charting facilities. The report is an examination of the current status of NOAA's nautical charting mission with the objective of formulating a plan to improve the agency's capability to meet the nation's needs for more accurate, reliable, up-to-date, and technologically advanced products in the future.

Chapter 1 provides a review of NOAA's nautical charting mission and related activities of other agencies, and introduces the forces of change that are creating a mismatch between user needs and current products—for example, the inability of the current system to keep up with demand and the emergence of new technology, new users (environmental, coastal planning), and demands for new products by traditional users.

Chapter 2 presents a description and analysis of the findings from the survey of users' needs and the discussions at the workshop, as well as from a review of other sources on users' needs.

Chapter 3 provides a discussion of the current activities and technologies for collecting nautical charting data to produce new charts and update existing ones. It also describes the current system of setting priorities for allocating resources to accomplish these tasks. Chapter 4 describes the technological transition from paper charts to electronic charts and the implications for NOAA now and in the future. Chapter 5 describes the emerging groups of new nonnavigation users, such as those who use nautical information for environmental assessment and coastal zone planning, and the relationship of nautical charting data to a broader marine geographic information system.

Chapter 6 lays out alternative approaches for NOAA to meet new needs and provide better and new products through a new concept of partnerships with other agencies, states, and the private-sector producers of value-added products, along with a strategy for implementing these new approaches. Chapter 7 discusses problems related to accomplishing the proposed changes in a time of decreasing budget allocations and constraints on public and private resources.

The major conclusions and recommendations that follow from the findings of the investigation are presented in Chapter 8. An Executive Summary provides a

synopsis of the report. Appendixes are included to provide the reader with additional materials relevant to the study.

The report is intended to serve as a guide to NOAA in making decisions about the appropriate allocation of resources available for its nautical charting mission and to the private sector and other agencies in stimulating thought and action to forge formal and informal sharing of resources and ideas for meeting the need for nautical information products in the future.

ACKNOWLEDGMENTS

The committee wishes to thanks all the federal liaisons. They actively participated in the study and provided invaluable information on their agencies' activities and perspectives. In particular, we thank the Director of the Coast and Geodetic Survey, J. Austin Yeager, and his staff for their generosity in facilitating access to their facilities and operations by committee members and NRC staff.

Special appreciation is due Gail E. Langran of Intergraph, Inc., for invaluable technical assistance throughout the study.

REFERENCE

National Research Council (NRC). 1989. Opportunities to Improve Marine Forecasting. National Academy Press: Washington, D.C.

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EXECUTIVE SUMMARY

The nautical chart represents the culmination of a process that begins with hydrographic surveys at sea and ends with dissemination of a paper chart to users. The chart captures one snapshot of water depth, shorelines, aids and hazards to navigation, and similar information needed for safe navigation. Some of the data elements change slowly enough that infrequent resurveys and periodic reissue of the charts meet mariners' needs. Other elements require frequent corrections to maintain currency; and some vital navigational information, such as the state of tides and currents, is so dynamic that, like weather, frequent reports and forecasts are the only reasonable representation of reality.

The primary purpose of nautical charts is to help ensure safe navigation. Since navigation safety is as important to other maritime nations as it is to the United States, the practice of charting is internationally coordinated and regulated. Nautical charts are an underpinning of a wide range of enterprises: commercial transport, naval operations, the commercial fishing industry, recreational boating and fishing, and nonnavigation uses such as coastal land development, research, conservation, and coastal zone planning.

The Coast and Geodetic Survey of the National Oceanic and Atmospheric Administration's (NOAA's) National Ocean Service is exclusively mandated to produce the nautical charts for U.S. waters. The nation's needs for these products and services have been well met by NOAA and its predecessors since the early 1800s. However, at the present time, the nation's charting system is severely stressed.

NOAA produces and maintains nearly 1,000 nautical chart editions, over 400 bathymetric charts, nine coast pilots, and numerous miscellaneous supporting publications. About 1.4 million charts are printed and sold each year. Nearly 40 percent of these are provided to the U.S. military; the rest are used mainly by the commercial shipping and fisheries industries and by recreational boaters. There is a growing backlog of requests for surveys, both for new areas that have never been charted and to update existing charts.

Electronic chart products, which use a digital data base to display a chart directly on a computer screen, are becoming increasingly useful and affordable. Their primary limitation is that they are not legally admissible to satisfy internationally mandated chart carriage regulations. About 30 percent of NOAA's hydrographic data are now in digital form; the percentage of digital data will grow, as new data are entered and retained digitally. Such data bases serve as the source of electronic charts, which are integral to advanced ship navigation and piloting systems.

In the near future it is likely that professional mariners will rely on electronic navigational information systems, providing that legal requirements to carry paper charts are modified to allow the use of a certified electronic chart system in place of paper charts. At

the same time, many small-craft operators—particularly recreational boaters—will continue to depend on traditional paper products. A nontraditional category of users of nautical information is emerging in the community that seeks information about coastal areas for purposes of environmental assessment, management, regulation, and planning for development. These users seek access to the nautical information data base as part of a larger marine geographic information system. The needs of these different user communities do not necessarily represent divergent requirements, because the digital data required to support electronic navigation will provide the basis for more frequent updates of paper charts.

As the requirement for navigational information expands and evolves, the process of creating nautical charts, like so many other traditional and essential government functions, is undergoing a technological revolution. The availability of the Global Positioning System provides both the surveyor and the navigator with accurate real-time position. Multibeam fathometers, side-scan sonars, and airborne lasers enhance both the accuracy and the rate of survey capability. Digital storage and display systems enable the development of a wide range of new electronic chart-based products.

As a result of expanding needs for information for use in the management of coastal and marine areas, as well as for use in navigation, NOAA's nautical charting mission is evolving from that of producing a one-product finished paper chart series to that of creating and maintaining a digital data base from which many products, analyses, and services will flow to customers. Map and chart information has traditionally been provided in the form of paper products. The expanded use of computers and electronic display systems is changing the concept of data management and product information, thus creating a demand for digital data. The data base will allow automated production of maps, introduction of new graphic products, and design of map products at scales with features specifically suited to the user's needs.

NOAA is thus faced with the need to satisfy an increasingly diverse user community and to adapt to rapid changes in technologies associated with its nautical charting mission. Both of these challenges come during a period of severe budget constraints on federal agencies, a situation that is likely to Continue in the foreseeable future. In adjusting to these changes, NOAA must necessarily establish priorities and make choices regarding the allocation of its limited resources among the three basic tasks that go into producing nautical charts and information products: collection and certification of survey data; processing and maintenance of a nationally certified nautical information data base; and production and distribution of certified data, charts, and other products.

In the course of its investigation the committee concluded that the key to successfully responding to these challenges is for NOAA to focus its nautical charting program activities on the tasks associated with building and managing the nautical information data base and to seek partnerships with the private sector and other federal and state agencies in fulfilling the other components of the nautical charting mission: collection of survey data and product dissemination.

Specific conclusions and recommendations following from the examination of these issues are presented in Chapter 8. They are intended to assist NOAA in making wise choices in the transition to the digital era in nautical information. Some of the recommendations can

be undertaken immediately. In some cases, legislation will be required to modify existing regulations to enable NOAA to obtain benefits from new arrangements. Such legislation has precedents in other agencies.

Implementation of the strategies recommended in this report will require innovation and openness to change on the part of NOAA's management. Existing institutional arrangements, regulations, and processes may not be adequate in the future when the task to be completed has evolved into a new form and new technological capabilities make old approaches obsolete.

1

OVERVIEW OF THE NAUTICAL INFORMATION SYSTEM

A nautical chart represents the culmination of a process that begins with data collection at sea and culminates in dissemination of the paper chart to users, directly or via chart agents. The chart captures one moment in the state of the seabed and adjacent shoreline, which are actually in a state of constant change. This change is usually slow, so that deviation from the chart and the reality it represents is small enough to be accommodated by periodic updates and incremental hydrographic resurveys. In other cases, seabed processes or works and actions by humans result in rapid or even sudden changes that may lead to serious discrepancies between the chart and the reality of the ocean bottom or surface (in the case of hazards or navigation aids), with concomitant safety implications for mariners.

Safety of navigation is crucial to the U.S. economy: 99 percent of all U.S. trade by weight (48 percent by value) is carried by marine transportation (U.S. Bureau of the Census, 1991). Other sectors that depend on nautical charts as an underpinning of their activities include the commercial fishing industry and marine recreation—particularly recreational fishing and boating. Safe navigation is similarly important to other nations, and the practice of charting is internationally coordinated through the International Hydrographic Organization and the International Maritime Organization.

THE INTERNATIONAL CONTEXT

The International Hydrographic Organization and the International Maritime Organization play significant roles in regulating the use and production of nautical charts. The International Maritime Organization was created as a specialized agency of the United Nations in 1959 and has been the leading forum for international cooperation on issues of maritime trade, including safety. standards, such as the international carriage requirement for nautical charts in the Safety of Life at Sea (SOLAS) Convention, a requirement that is implemented and enforced by International Maritime Organization member states. The International Maritime Organization is in the process of developing standards for electronic charts that will allow them to be used in place of the paper charts traditionally required under SOLAS.

The International Hydrographic Organization was formed in 1921 by the world's maritime nations to coordinate member states' hydrographic survey and nautical charting practices, including standards for survey density and accuracy and the symbology used on

nautical charts. More recently, it has developed formats for the exchange of digital nautical information among hydrographic offices and has played a major role in developing standards for data and display characteristics for electronic chart systems.

While practices and law regarding chart production and copyright vary considerably, in virtually all nations the development and management of a quality hydrographic data base and preparation of associated charts are accepted as a basic responsibility of the national government.

From a regulatory viewpoint, international chart carriage requirements and government backing of charts are the primary forces driving the present nautical charting system. Like other maritime nations, the United States has implemented the international chart carriage requirements of the SOLAS Convention. All vessels over 1,600 gross registered tons operating in U.S. waters must carry up-to-date charts published by the National Oceanic and Atmospheric Administration (NOAA) or an equivalent recognized government authority. Documented commercial fishing vessels operating beyond U.S. boundary lines also are required to carry approved charts under the Commercial Fishing Vessel Safety Act of 1988.

The United States backs its nautical charts by consenting to be sued for negligence in their preparation and dissemination. This consent is an exception to the sovereign immunity traditionally maintained by government against suits for civil wrongs and is central to the usefulness of nautical charts in the legal regime that governs marine navigation. A more complete discussion of the regulatory and legal issues surrounding nautical charts can be found in Chapter 6.

NOAA'S NAUTICAL CHARTING MISSION

A nautical chart is published primarily to serve the informational needs of the mariner in allowing for safe and efficient marine navigation. Charts are also used in managing ocean and coastal resources and supporting national security and defense requirements. The chart details the nature and form of the coast, depths of the water, character of the bottom, aids to navigation, marine limits, electronic positioning lines, magnetic variation, danger areas, cultural details, certain port and harbor facilities, and other man-made or natural features (see Figure 1-1). A nautical chart is only as good as the currency and accuracy of its information to ensure continuing value in the support of safe and efficient marine navigation.

The nation's needs for these products and services have been the responsibility of NOAA and its predecessor agencies since the 1800s. Basic authority for activities of the "Survey of the Coast" are contained in the Organic Act of February 10, 1807 (2 Stat. 413), in which it is ". . .authorized and requested to cause a survey to be taken of the coast of the United States in which shall be designated the island and shoals . . . for completing an accurate chart of every part of the coast. . . ." In the ensuing years additional legislation was passed that further clarified the U.S. Coast and Geodetic Survey's activities. Under Presidential Reorganization Plan No. 4 of 1970 (84 Stat. 2900), NOAA was formed and previous functions of the U.S. Coast and Geodetic Survey and the charting mission of the U.S. Lake Survey Center were transferred to NOAA.

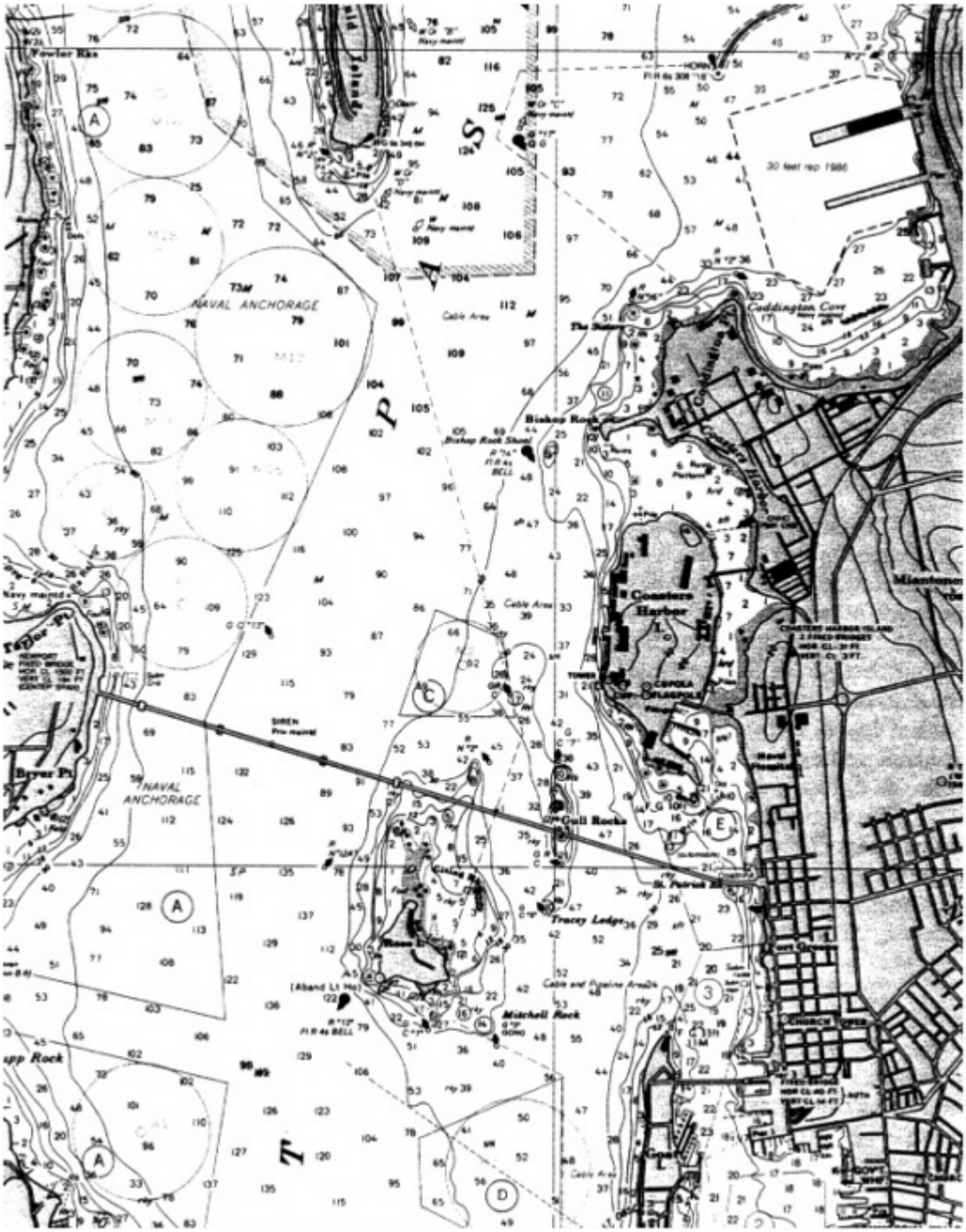

Figure 1-1 Section from NOAA Chart 13323, Narragansett Bay, RI.
Source: NOAA, National Ocean Service.

The Coast and Geodetic Survey of the National Ocean Service is responsible for NOAA's mapping, charting, and geodesy programs and provides nautical charts, maps, and related products for the coastal and adjacent ocean areas of the United States (including possessions and territories), the Great Lakes, and other inland navigable waters. In addition, the Coast and Geodetic Survey provides aeronautical charts and performs geodetic, hydrographic, and photogrammetric surveys and field investigations. It processes air and marine mapping and charting data obtained from various sources to produce approximately 1,000 nautical charts, nine volumes of Coast Pilot publications, approximately 600 bathymetric maps, and approximately 10,000 aeronautical charts. In fiscal year 1992 the Coast and Geodetic Survey issued 1.8 million marine maps and charts and more than 11.1 million copies of aeronautical charts and publications (NOAA, 1992).

Although NOAA has the primary responsibility for charting the nation's waters, other federal agencies conduct activities that intersect with NOAA in this area. A description of these other agencies' activities and roles is found in Appendix B.

Federal Data Activities

The Office of Management and Budget (OMB) created the Federal Geographic Data Committee through Circular A-16 and has charged the Committee with the responsibility to coordinate various surveying, mapping, and spatial data activities of federal agencies to meet the needs of the nation. NOAA's Nautical Charting Division participates in the Committee through the Subcommittee on Bathymetric Data, which held its first meeting in April 1993. The purpose of this Subcommittee is to coordinate federal bathymetric mapping activities. These include bathymetric, hydrographic, and photogrammetric surveys for producing nautical charts, bathymetric maps, and related data sets. The Subcommittee also coordinates standards and exchange formats that are used in the analysis, display, archiving, and exchange of bathymetric data.

The National Research Council (1993) recently published a report recommending enhancement of the national spatial data infrastructure, which is defined as "the means to assemble geographic information that describes the arrangement and attributes of features and phenomena on the Earth. The infrastructure includes the materials, technology, and people necessary to acquire, process, store, and distribute such information to meet a wide variety of needs."

Vice-President Gore's national performance review report identified the national spatial data infrastructure as one of the initiatives necessary to "reinvent government" (Gore, 1994). Partnerships with nonfederal sectors were recognized as key to minimizing redundancy in the creation of geospatial data and in facilitating means of access to these data for solving critical problems. The Federal Geographic Data Committee has also been charged with coordinating a variety of activities with state and local governments and the private sector to evolve the national spatial data infrastructure.

FORCES OF CHANGE

Satisfying the user communities' needs for nautical charts and related publications has been relatively straightforward for many decades. The primary consideration was safe navigation of merchant ships and naval fleets, which dictated the type of charts and, in turn, the type of hydrographic operation required. Identification of major shipping ports and coast-wide routes was a comparatively simple task, as was determination of the need for high-density modem surveys or areas that could be adequately charted utilizing less derailed or older data.

Changes in User Needs for Information

A number of trends and forces are converging to require changes in NOAA's nautical charting mission. The most salient among these are changes in customer requirements, with a growing demand for customized and digital nautical information products (see Chapter 2); a changing customer base that encompasses use of nautical charts in conjunction with coastal management, regulation, and development activities (see Chapter 5); and advances in technologies both for acquiring survey data (see Chapter 3) and for structuring, displaying, analyzing, and disseminating nautical information (see Chapter 4).

Utilization of marine and coastal areas for commercial and recreational activities has dramatically expanded during the past two decades, and indications are that this will continue into the next two as well (NRC, 1989). Consequently, the need for more accurate, high-density information of the marine topography must be considered not only for navigation but also for the safe and efficient development of our coastal and ocean areas and the protection of living and nonliving resources.

As a result of the expanding needs for information for use in management as well as navigation, NOAA's nautical charting mission is evolving from that of producing a one-product finished paper chart series to that of creating and maintaining a digital data base from which many products, analyses, and services will flow to customers.

The Impact of Technology

The rapid growth of computer technology over the past two decades has enabled a radical departure from the traditional paper chart—the electronic chart, which is an electronic digital display of information (a navigation data base and input from a variety of sensors). Once completed, the internationally approved electronic chart system known as ECDIS (electronic chart display and information system) will fuse state-of-the-art radionavigation sensors, digital nautical chart information, real-time environmental data (tides, currents, wind force), and other information about vessel systems into a display that is expected to improve the safety and reliability of coastal and harbor navigation (Prahl and Danley, 1993).

Development of the Global Positioning System (GPS) provides the mariner with real-time position accuracy to within 5 to 10 meters in harbors and harbor approaches with

differential augmentation (Alsip et al., 1992-1993; Conley, 1993). Advanced technologies for hydrographic and photogrammetric data acquisition are increasingly used to ensure the accuracy and reliability of survey data (GPS, shallow-water multibeam sonar, airborne laser, multibeam side-scan sonar, digital recording side-scan sonar, swath bathymetry, GPS-controlled photogrammetry, and multispectral remote sensing).

In response to these forces, NOAA's Coast and Geodetic Survey has attempted to expand its services to traditional and new customers by offering new charting products, improving the currency and quality of nautical information products, and increasing the efficiency of its operations in producing these products by adopting new technologies for many of the processes in chart compilation and production. But change has usually been incremental (e.g., the introduction of color to portray water depths) rather than through an overhaul of the entire system in response to these sweeping technological advances.

PROBLEMS AND CONSTRAINTS LIMITING CHANGE

Limited Resources

The resources available to NOAA's nautical charting programs over the past 5 years have decreased in constant dollars in relation to NOAA's overall budget (see Figures 1-2 and 1-3) and are insufficient to meet the changing user demand for new products, to digitize existing nautical data, and at the same time, to adopt new technologies. All of these activities incur additional costs above the ongoing program mission. It is, therefore, unavoidable that NOAA will have to make choices and establish priorities for emphasizing certain aspects of its ongoing nautical charting mission while deemphasizing others. For example, the backlog of requests for new and updated surveys (see Chapter 3) is accumulating with little hope of diminishing at the present rate of survey activity. Similarly, digitizing existing charts is a costly process and is limited by availability of resources (see Chapter 4).

Yet the conversion of commercial ships to the use of advanced technologies for navigation and piloting will be constrained, in part, by the availability of accurate and reliable charts in a digital format. Use of nautical information for other purposes—such as management of coastal and marine areas—will also be limited by the availability of data in a form useful for these purposes (see Chapter 5). For these and other reasons, NOAA needs to make a timely transition to the digital era in its nautical charting mission.

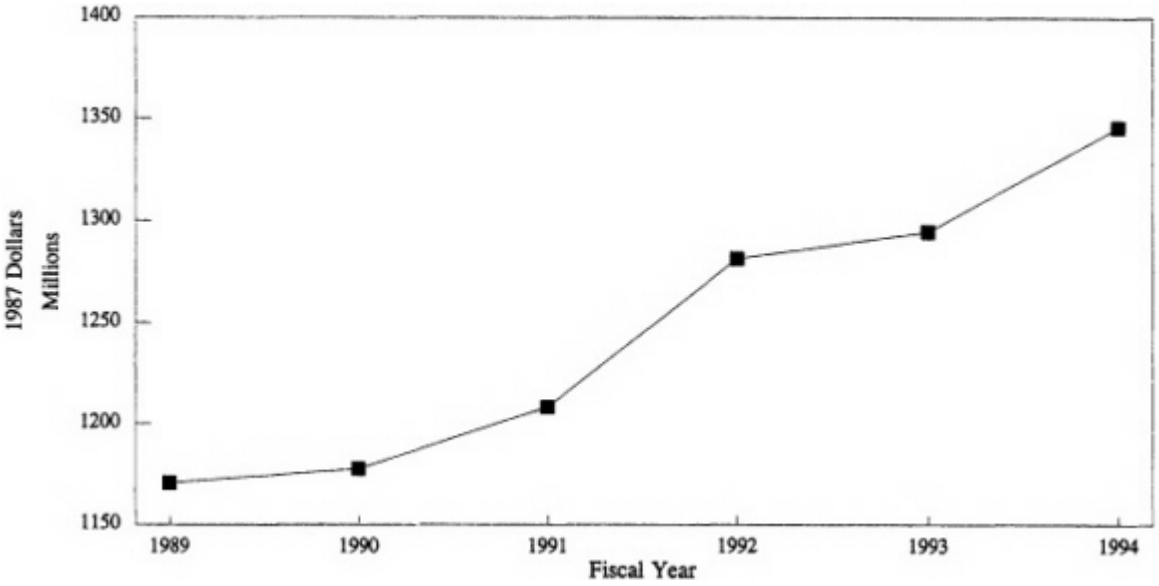

Figure 1-2 NOAA expenditures for 1990-1994, in 1987 dollars.
Source: NOAA, National Ocean Service, personal communication.
Note: Figures for 1994 are estimates.

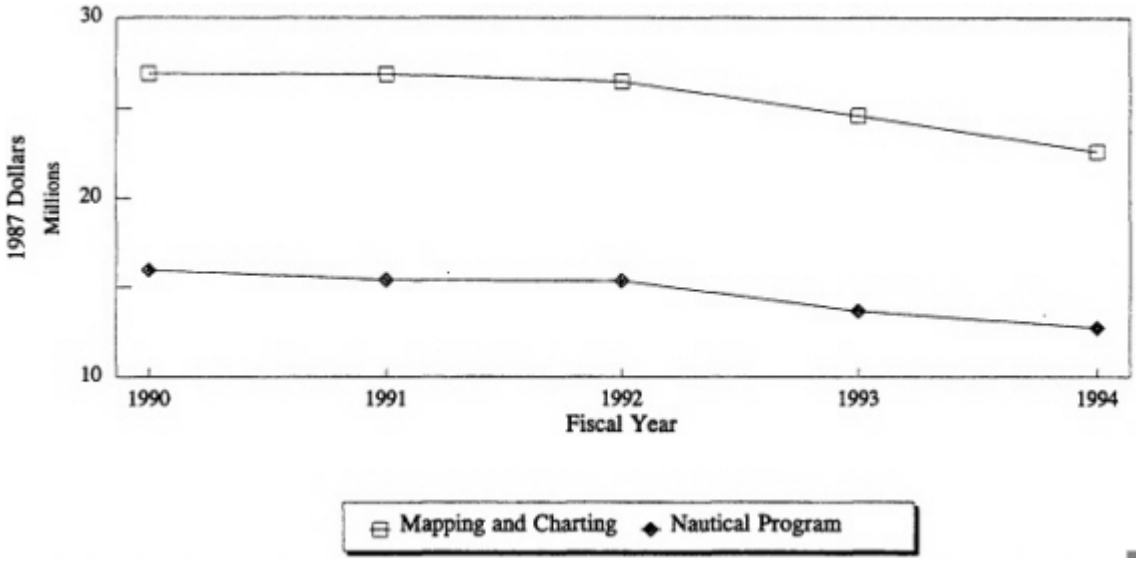

Figure 1-3 Mapping and Charting Division and Nautical Program expenditures for 1990-1994, in 1987 dollars.
Source: NOAA, National Ocean Service, personal communication.
Note: Figures for 1994 are estimates.

Concerns About Liability and Copyright

Other issues that arise from the transition from a paper chart to an electronic data base are related to the creation and use of this data base by people outside NOAA to produce value-added nautical information products, including hardware systems for handling data, software programs for analyzing the data, and data products organized into custom products or data bases for particular uses. Should NOAA attempt to retain control over such a data base, both for the purpose of liability considerations involving safety (e.g., accuracy and reliability of the information) and for the purpose of obtaining reimbursement of the costs of creating and maintaining the data base? In connection with these issues, the relationship between the public and private sectors in this product area will inevitably be transformed as a result of the forces of technological change. These matters are discussed in detail in Chapters 6 and 7.

SUMMARY

The need for nautical data is expanding, and the methods of acquiring, producing, and disseminating these data are changing dramatically. The following chapters describe the problems confronting NOAA and suggest a new vision of how to accomplish NOAA's nautical charting mission in a time of rapid change.

REFERENCES

Alsip, D. H., J. M. Buffer, and L T. Radice. 1992-1993. The Coast Guard's differential GPS program. Journal of the Institute of Navigation 39:4, Winter.

Conley, Rob. 1993. Navigation. Journal of the Institute of Navigation 40:3, Fall.

Gore, Albert. 1994. Reinventing Government. U.S. Government Printing Office, Washington, D.C.

National Oceanic and Atmospheric Administration (NOAA). 1992. Coast and Geodetic Survey, Annual Report, 1992. Department of Commerce, Washington, D.C.

National Research Council (NRC). 1989. Our Seabed Frontier: Challenges and Choices. National Academy Press, Washington, D.C.

National Research Council (NRC). 1993. Toward a Coordinated Spatial Data Infrastructure for the Nation. Mapping Science Committee. National Academy Press, Washington, D.C.

Prahl, N. A, and H. P. Danley. 1993. The nautical chart—time for a new paradigm. Sea Technology June, 29-35.
U.S. Bureau of the Census. 1991. U.S. Merchandise Trade: Selected Highlights. December. Bureau of the Census, Washington, D.C.

2

USER NEEDS FOR NAUTICAL INFORMATION

The starting point of this study was to identify the present and potential users of nautical information products and theft specific information needs. The process for obtaining this information was, first, to elicit responses to a questionnaire from a broad range of users, and, second, to invite a representation of those communities to participate in a workshop on the future needs of users of nautical information.

Traditional users of nautical information need charts for navigation safety (professional mariners, recreational boaters, commercial and recreational fishers). An emerging new group of users needs nautical information for nonnavigational purposes such as coastal zone planning; regulatory activities of federal, state, and local governments; and modeling for environmental and other scientific assessments and evaluations. Navigation users can be further separated into two categories: commercial shippers that operate under international regulations requiting carriage of approved charts, and other mariners, including recreational boaters, whose need for nautical information is governed by individual preference.

Another community of interest for this study is the private-sector producers of value-added marine information products. These include companies producing equipment or hardware to process nautical information and those in the business of repackaging data (paper or electronic) into value-added products for use by mariners.

A SURVEY OF USER NEEDS

The first task of the committee was to determine the product needs of mariners and other users of nautical information products. From the outset these needs were recognized to differ among various user groups. It was proposed, therefore, that a broad cross section of users and potential users be queried to obtain a representative response.

A representative sample of each of the user communities was surveyed by means of a questionnaire mailed to a targeted list of over 1,000 individuals, supplemented by questionnaires published in sources that provided exposure to the largest marine audiences (e.g., nautical magazines and the U.S. Coast Guard's Notice to Mariners). Analysis of the results was used to identify critical questions and issues that were addressed at a subsequent workshop.

The questionnaire, reproduced in its entirety in Appendix C-l, attempted to identify which present needs are being satisfied by existing products, and what new products or

services might be required to meet other present needs. The same questions were posed for future needs.

The questionnaire also examined the effects of the emergence of new of technology on marine navigation and obtained the response of the commercial maritime community to this technology revolution. It was clear from responses that future needs and, to a lesser extent, present needs are being driven by the evolution of navigation technology. The introduction of low-cost, highly accurate positioning technology makes it possible for mariners to determine their position at any time and in any weather with an accuracy that frequently exceeds that of the chart upon which they plot their position. Parallel efforts in the public and private sectors have resulted in digital representations of navigational charts, which can be interfaced to a Global Positioning System (GPS) via either general- or special-purpose computers to enable tracking of vessels in real time on a computer screen. The mariner can, at a glance, see a ship's present location relative to its intended track, navigational aids, channels, obstructions to navigation, bathymetry, and coastlines.

In 1986 the International Maritime Organization's Maritime Safety Committee agreed on the need to produce a standard that would ensure recognition of an electronic chart display and information system (ECDIS) as the "legal equivalent of a paper chart" within the meaning of the internationally mandated Safety of Life at Sea carriage requirement for nautical publications (Kite-Powell, 1992). International interest in the development of a legal ECDIS has led to the development of prototype systems. Some evaluations of these systems have indicated that the "availability of ECDIS on the bridge consistently and substantially reduced the mariner's workload for navigation. In addition, mariners were able to achieve a sometimes substantially greater accuracy of navigation as measured by a smaller cross-track distance from the planned track line" (Akerstrom-Hoffman et al., 1993).

The discussion that follows summarizes the findings of the questionnaire and describes how, through the subsequent workshop discussions, these findings were sharpened and then synthesized into a coherent set. It should be pointed out that neither the questionnaire responses nor the workshop was controlled to constitute a statistically valid sampling of any user populations. The purpose of both exercises was to elicit responses from a varied community of users and to stimulate dialogue within these communities and among users, the producers of nautical information products, and the National Oceanic and Atmospheric Administration (NOAA).

SUMMARY OF THE SURVEY

In an attempt to reach a representative cross section of users of navigational information, mailing lists were assembled from 12 user communities, including commercial shipping, recreational boating, and managers of state coastal areas. Notification of the availability of the questionnaire was provided through advertisements in appropriate magazines and the Notice to Mariners. All who requested the questionnaire received it. An abridged version was printed in a popular nautical magazine (*Soundings*). Due to the lack of controls on distribution, statistical analyses of the responses would not have been suitable. Over 1,000 questionnaires were mailed; 670 were returned in time to be analyzed as part of

this study. A graphic display of the responses can be found in Appendix C-2. Respondents to the questionnaire were representative of all geographic areas of interest to the study. Most of the respondents now use NOAA or Defense Mapping Agency charts, but a significant fraction use Chart Books. Loran, radar, and GPS were the most frequently used navigational aids. Very few of the respondents used digital products. Those who updated their charts did so primarily by use of either U.S. Coast Guard or Defense Mapping Agency Notices to Mariners.

Questionnaire Findings

Over half of the respondents indicated that presently available products did not meet their needs. Concerns included information content, accuracy, currency, and scale. Those who chose commercial products over government products generally did so for some combination of cost, convenience, size and format, and value-added information. Better-quality paper for the present products was a frequent request, as was a plea for better-quality, higher-resolution bathymetric data. Professional mariners generally wanted less cluttered charts, while recreational boaters wanted more supporting information. The respondents who were using electronic navigation systems seemed universally well satisfied with them and expressed the conviction that electronic navigation is the "wave of the future."

WORKSHOP ON USER NEEDS

The workshop included representatives of all of the user communities identified for the questionnaire mailing. The first priority of the workshop was to stimulate dialogue among the representatives and to examine the extent to which the survey results were confirmed by the workshop participants' discussions. A list of participants is found in Appendix D.

An early conclusion of the group was that the needs of the various users were sufficiently diverse that no single product would satisfy all needs. For example, U.S. Navy requirements fall into both the "professional mariner" and the "nontraditional" categories. A subsequent conclusion was that the universe of users could rather conveniently be divided into three groups:

- ***Professional mariners*** are defined as those who go to sea to make a living. This group included commercial fishing and cargo carriers, the U.S. military, marine pilots, and the offshore petroleum industry. Professional mariners are trained to use nautical charts and are required to use them by law or regulation. They generally desire accurate and current chart features, particularly soundings, navigation aids, and hazards. The professional mariner uses the chart as a navigation tool and, therefore, generally wants uncluttered charts, believing that information which is available elsewhere (such as marina facilities) should not be included on navigation charts.

- ***Recreational boaters'*** knowledge, skill, and training vary widely with individual need and preference. The recreational boater generally has less storage and working space on board as well as fewer crew members and frequently prefers that as much planning information as possible be printed on the chart. While having the most current chart is generally important to the recreational boater, chart update information is generally not a critical requirement.
- ***Nonnavigational users*** use nautical charts as a geographic basis for analyzing and displaying other oceanographic, geophysical, or topographic information. The nonnavigational warfighting requirements of the Navy fall into this category. Chart data might be used solely as a background or might actually be used in the definition of the product. While accuracy and currency needs for this group are not as stringent as for navigational users, coverage and data content requirements are extensive. This user group includes real estate developers, coastal zone planners, wetlands managers, state coastal regulatory agencies, research scientists, and others. The nonnavigation needs of the nontraditional users other than the U.S. military are examined in further detail in Chapter 5 and, therefore, are not included in the discussions that follow in this chapter.

WORKSHOP FINDINGS

Repeated Themes

Throughout the workshop discussions, four ideas or themes recurred so frequently that it is appropriate to identify them at the beginning of the discussion of user needs:

- ***Need for safety through boater education.*** It was obvious to all workshop participants that more could be done to improve boater safety through education than by any possible improvement to charts or other information products. Educating boaters about the need to have current charts on board, and about using them correctly and effectively, would pay immense safety dividends.
- ***Need for improved bathymetric information.*** Charts and other information products are no better than the information they display.
- ***Need for a nautical information data base.*** The diverse needs of the various users would seem to best be served by the establishment of a digital nautical information data base that would support "layers" of information appropriate to the different uses.
- ***"Not for use in navigation."*** Although this disclaimer appears on nearly all chart-like products created by anyone other than NOAA, both paper and digital, it is unrealistic to believe that the products are not being used for navigation. Recognition should be given to the fact that such products are, in reality, being sold and used as navigational products; a means of certifying their navigational suitability should be established.

Common Needs

The workshop discussions of user needs by user community identified several areas that are common to all users and some that are unique to a specific group. Needs that cut across all users included the following:

- ***Better paper products.*** Users were nearly unanimous in their requests for better-quality paper charts. Better-quality paper that could be folded and refolded without disintegrating, waterproof charts, standardization in size, and increased legibility were high on everybody's list.
- ***Better update capability.*** *The* update process via Notices to Mariners is so cumbersome that only professional mariners update their charts with any regularity.
- ***Quicker product delivery.*** The time delay between the date edition (i.e., last update is entered on the chart) of a chart and the date at which it is available to the public is perceived as unduly long.
- ***Electronic and non-NOAA paper products certified for navigation.*** Non-NOAA paper products are nearly universally in use; there is a need to provide the quality assurance necessary to make them acceptable for navigation or at least identify which products are acceptable.
- ***Real-time information.*** The technology to measure water levels, currents, and microscale weather in real time, and to integrate and display these data on an ECDIS-like system, has been available for many years. The availability of these data could significantly reduce risks to life and property. There was universal interest among user groups in having real-time information available.

Needs of Specific Users

- ***Professional mariners,*** including the military, prefer to have their charts "uncluttered" by extraneous information, which they define as "anything that can be found someplace else." Safety of navigation is their priority, for which they would like to have improved bathymetry on commercial routes and more frequent chart editions. The commercial fishing community would like detailed bathymetry, including better definition of obstructions, to depths of 800 fathoms. All would like to have chart boundaries redefined for those cases in which an approach is split between two charts and to have chart projections optimized for the best display of significant features.
- ***Recreational boaters,*** by contrast, want "user-friendly, one-stop shopping" for their charts. They would like to have anything and everything they might ever want to know for navigation, as well as shoreside features, services, and facilities, on the same chart. Loran grids extending into harbors, waypoint definitions, bridge names and opening schedules, tidal ranges, bottom types, and chart symbol definitions would all be welcomed.
- ***Military users'*** needs encompass both the needs of professional mariners and those of the emerging nonnavigation users:

***Navigation*:** Charting requirements to support safe navigation are paramount. In addition to accurate and current soundings, navigational aids, and hazards, the Navy requires real-time tidal and water-level information. Like the professional mariner, Navy chart users want "uncluttered" charts. Finally, submarine navigation in U.S. coastal waters extends the need for accurate bathymetry and hazards into waters deeper than currently surveyed for surface navigation.

***Nonnavigation uses*:** While paper charts and information are still necessary, the military is moving rapidly into a digital environment. In the future the Navy will require that all of its nautical information products be in digital form. Products specific to Navy warfighting needs will establish requirements for digital data fields beyond those required for navigation.

FUTURE NEEDS

It is likely that, in the near future, the greatest need for new products that are presently not available from NOAA will come from users of electronic chart systems. Electronic charts are computer display systems that combine digital chart data with real-time electronic position inputs (like GPS or loran) to provide the mariner with an automatic, real-time plot of a vessel's position. The automation of position plotting represents a significant improvement in timeliness and accuracy over traditional manual plotting methods. Electronic charts also allow greater efficiency and accuracy in other functions, such as route planning; and they can warn of potential groundings by analyzing a vessel's course and the nautical chart data describing the waters ahead. The advantages offered by electronic chart systems in safety and efficiency are likely to make them standard equipment for many commercial vessels in the near future. Already, simple versions are widely used on recreational boats and fishing vessels.

The main obstacle to the full commercial use of electronic chart systems, and especially of the ECDIS—expected to be designated by the International Hydrographic Organization and the International Maritime Organization as a potential equivalent (replacement) of the paper chart as a basis for commercial navigation in the near future—is the lack of availability of digital data sets issued on the authority of national hydrographic agencies. Although private firms have digitized selected features from many of the world's charts for use in simple electronic charts on fishing vessels and recreational boats, these data sets cannot be used as the legal equivalent of paper charts by commercial vessels because they do not carry the legal certification of government hydrographers. Nevertheless, a growing proportion of the world's commercial shipping fleet already carries some form of electronic chart system. The demand for official digital data sets is strong and is likely to increase dramatically as electronic chart technology gains acceptance and as local, national, and international carriage requirements for electronic chart systems are enacted.

SUMMARY

From the committee's review of technology-driven international trends, the questionnaire summaries, and the workshop deliberations, it is apparent that user needs are changing rapidly in response to two forces. First, traditional users are seeking new navigational products in response to rapidly evolving navigation and computation technology. Second, an expanding community of nontraditional users is creating a different set of needs for nautical data that can serve as the basis for analysis of various coastal and ocean processes and environmental parameters.

The workshop discussions indicated that nautical information products must be tailored to meet the needs of individual users and that no single product line could meet the needs of all users. The charts and products issued by NOAA presently satisfy most of the needs of the knowledgeable mariner and the navigation needs of the military. The value-added producers are meeting many of the additional needs of the boating public. Although many of the changes requested by present users could easily be satisfied with some rather minor changes, others would require significant effort on the part of NOAA, particularly the following items, which were requested by all user communities:

- more detailed and accurate bathymetry;
- more frequent chart updates; and
- faster distribution of products.

Although the questionnaires themselves did not reflect a large demand for digital products at the present time, it was clear that this was the result of a lack of familiarity on the part of most of the respondents with the status and capability of electronic navigation systems, which have only recently become commercially available. The background briefings received by the committee on both the "pull" of international charting requirements and the "push" of rapidly advancing technology emphasized the need for NOAA to move into the electronic chart era. Discussions at the workshop indicated that the greatest need for new products in the immediate future will come from direct and indirect users of electronic chart systems.

REFERENCES

Akerstrom-Hoffman, R., C. Pizzariello, M. W. Smith, S. Seigel, T. E. Schreiber, and I. Gonin. 1993. A closer look at mariners' use of electronic chart display and information systems. The Second Annual Conference and Exposition for Electronic Chart Display and Information Systems. Proceedings, ECDIS '93 98-105. Baltimore, Maryland.

Kite-Powell, H. 1992. Rationale, Processes, and Effects of Technical Standards in Marine Electronics. Ph.D. dissertation, Massachusetts Institute of Technology, Cambridge.

3

FILLING THE DATA BASE: DATA COLLECTION

The accuracy, reliability, and currency of the data that form the basis of the charts are central to providing accurate and reliable nautical charting products. This chapter begins with a discussion of the need for data collection to support nautical charts and information and then describes what is currently produced as well as the present backlog of requests for new charts. Also discussed is the National Oceanic and Atmospheric Administration's (NOAA's) current process for prioritizing the backlog of survey requests and also new chart requests. Two alternatives for managing these backlogs are assessed. An underlying theme supported by the material in this chapter is that NOAA should focus a large portion of its data collection efforts on quality assurance and the efficient management of data collection resources.

CURRENT DATA COLLECTION ACTIVITIES

NOAA is responsible for the charting and updating of approximately 95,000 miles of coastline and 3.5 million square nautical miles of oceans, inland rivers, and lakes. International agreements in which the United States participates imply that the U.S. government will provide charts adequate to ensure safe navigation in U.S. waters. U.S. coastal waters have never been completely surveyed, however, and when most existing surveys were performed, procedures for collecting closely spaced data in an economical manner had not been developed. As a result, some minimum-depth hazards were missed. Obviously, the quality and reliability of a chart are directly linked to the quality of the hydrographic data from which the chart is produced.

Of NOAA's 1,000 nautical charts, approximately 300 are revised (new editions issued) each year. Each chart is assigned a revision cycle based on its scale and geographic location. In practice, new edition cycles are influenced by the number and type of critical corrections affecting a chart, remaining shelf stock, receipt of new basic data, format or regulation changes, and most of all by the availability of financial resources. Critical corrections include, but are not limited to, those to aids to navigation, obstructions, shoaling, facility changes, and dredging. Generally, 30 to 100 critical corrections trigger a new edition. During fiscal years 1990 and 1991, new chart editions were published when an average of about 75 critical corrections had accumulated. Ideally, for safe navigation a chart should contain all known critical corrections at the time of purchase.

Requests for New Charts

The Mapping and Charting Branch of NOAA's Coast and Geodetic Survey routinely receives requests for new charts. The Chart Request File presently contains over 1,000 such requests. Each request is scored to determine its priority rank.

The main factors considered in scoring include the importance of the requestor, the chart adequacy of the area, marine use of the area, and area dynamics. Other factors that can influence the score are national defense needs, data availability, and annual cost. About 140 requests are rated 6 (out of a maximum score of 10) or higher.

It is anticipated that production changes associated with the use of ANCS II[1] will permit the construction of about 50 new charts per year by 1998, which will greatly improve NOAA's ability to address the new chart request backlog. However, the need to update old survey data and improve the data density remains a critical requirement to be addressed by NOAA.

Requests for New Surveys

Requests for new charts and requests for surveys are related but separate challenges for the Coast and Geodetic Survey. A request for a new chart may or may not require a new survey as preparation; a request for a new survey may or may not require publication of a new chart. Often, a request for one results in an implicit requirement for the other. This requires coordination of two branches within the Nautical Charting Division of the Coast and Geodetic Survey: the Charting Branch, which handles chart requests, and the Hydrographic Surveys Branch, which handles survey requests.

Sixty percent of the survey data used in the compilation of NOAA's present nautical chart suite comes from surveys that were completed prior to 1940, with technology that was much less accurate for determining position than that now in use. Each year the Nautical Charting Division registers hundreds of requests for surveys of perceived hazards from a wide spectrum of users. At present, three NOAA vessels are engaged in survey work, but the workload clearly exceeds their capability to complete it in the foreseeable future.

As of August 1993, the Survey Request File contained more than 2,000 individual survey requests dating back to 1984, when it was established. Requests range in scale from large-area hydrographic surveys to local investigations of reported obstructions. About half of the requests tracked had been completed as of 1993, leaving a backlog of approximately 1,000 requests. Requests are received from individuals or groups within NOAA (NOAA initiates nearly half of the outstanding requests now on file), commercial shipping interests, the Defense Mapping Agency, the U.S. Coast Guard, state and local authorities, the fishing industry, the recreational boating community, and others.

[1] Automated Nautical Charting System; see discussion in Chapter 4.

DATA COLLECTION NEEDS AND VALUES

Findings from the user questionnaire (Appendix C) are consistent with the outstanding requests for hydrographic surveys. Questionnaire results suggest that significant need for new surveys comes from many sectors of the user community, including military, commercial shipping, commercial fishing, and recreational users. As described in Chapter 2, the need for better bathymetry around commercial shipping routes is a prime concern of commercial shipping users. Similarly, military user requirements have led to recommendations for the development of a high-resolution, near-shore bathymetric data base (see Shaw et al., 1993). Commercial fishing users voiced a need for better bathymetric detail to 800 fathoms. All of these varied requirements cannot be met by the existing surveys for most areas, since most existing surveys consist of relatively widely spaced soundings. Many areas will require new surveys, using multibeam and/or side-scan systems, for complete bottom coverage.

Several federal agencies other than NOAA have requirements for hydrographic or bathymetric data. The U.S. Geological Survey (USGS) and the Minerals Management Service use bathymetric data to support federally funded programs, such as geological studies of the Exclusive Economic Zone and offshore mineral and energy resource assessment and development. The U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers require other bathymetric and hydrographic data for use in monitoring construction and other activities for environmental impacts. Also, NOAA's environmental and fishery programs require similar data.

Setting Priorities

The need for establishing priorities for hydrographic surveys is clear: limited resources do not allow NOAA to conduct all requested surveys over short time periods, and NOAA must decide in which order to conduct them. The efficient solution to the prioritization problem is to first conduct those surveys that produce the greatest benefit to the country for each dollar spent on the survey. In theory, this means estimating the benefit-cost ratio for each possible survey, and then conducting the surveys in order of decreasing benefit-cost ratio as quickly as available resources allow, so long as the benefit-cost ratio remains above a specified (national) cutoff value. Efficient use of resources available to conduct surveys requires not only that they be performed in the order suggested above, but also that the cost be kept to a minimum (with quality requirements taken into account).

NOAA's present approach attempts to implement this type of priority scheme. Areas are selected for survey projects based on their area score; a review of the age and adequacy of existing surveys in view of modern standards; and consideration of vessel traffic, bottom topography, scheduling of survey vessels, and other concerns. Thus, the Survey Request File rating of requests and areas is only one input to the final survey prioritization decision.

The Survey Request File decision process is a formalized, empirically tested process for integrating survey requests with NOAA's knowledge of national needs and incorporates many of the elements logically important in prioritizing surveys. However, two elements of

the process are subjective. First, estimation of the importance of the requestor is arbitrary and subject to political influence, and is not likely to produce the best objective estimate of value to the nation of a particular survey project. Second, the relative costs of competing (alternative) survey projects are not explicitly included in the algorithm for ranking surveys. Although cost considerations probably enter subjectively into the final deliberations, nonexplicit treatment of these costs suggests that resources may not be allocated to projects in the most cost-efficient manner. A more explicit application of benefit-cost analysis may be necessary to ensure efficiency in a time of constrained resources (see Appendix E).

SOLUTIONS TO THE SURVEY REQUEST BACKLOG

As described in Chapter 4, ANCS II will do much to relieve the backlog of new chart requests, if the necessary survey data can be supplied. Given the backlog of survey requests and NOAA's limited in-house resources to conduct surveys, it is apparent that alternative data-gathering means are necessary. The following discussion explores additional resources available to NOAA—the use of private contractors and cooperative survey ventures with other government agencies—to better leverage NOAA's surveying resources. Although these approaches obviously require funds, other agencies have found that efficiencies are gained through the use of private contract services, so that costs may, in fact, diminish in relation to the mount of data obtained. Some of the reasons for these savings can be found in the flexibility obtained through contracting.

Private Contract Surveys to Supplement NOAA Capabilities

One proven means for NOAA to increase the collection of data is to use private contractors for data acquisition. Under similar requirements for data accuracy, the U.S. Army Corps of Engineers has successfully evolved from exclusive use of in-house crews and equipment for data acquisition to use of contract crews and equipment for roughly 40 percent of the hydrographic survey data presently acquired.

The Corps of Engineers uses a formal selection process to select technically qualified contractors based on merit from a list of respondents prior to any price considerations. Cost effectiveness is measured through formal audit to determine that negotiated prices are based on actual operational cost plus a reasonable profit margin. At the contracting officer's discretion, negotiations can be terminated with the selected respondent if equitable rates cannot be agreed upon. Negotiations can then immediately commence with the second qualifier. The Corps of Engineers' contracting experience is described in detail in Appendix F.

There are a number of experienced hydrographic survey firms in the United States that are capable of meeting NOAA's hydrographic survey standards and those prescribed by the International Hydrographic Organization. Typically, contractors would be expected to comply with NOAA quality control requirements, and NOAA's field oversight role would become that of quality assurance inspection. The amount of quality assurance oversight

would depend on the contractor's experience and NOAA's confidence in the contractor's ability.

The use of private contractors by NOAA does not reduce the agency's liability for the integrity of the data as displayed on the final product. However, NOAA would be indemnified against professional negligence through the contractors' professional liability insurance. NOAA would additionally have recourse through the Federal Board of Contract Appeals to withhold payment and/or obtain settlements for inadequate surveys.

Responsibility for the data base requires substantial control over the quality of data collection efforts. However, it may be possible for NOAA to maintain quality control over data without collecting all data itself. For example, it might set quality standards and certify private operators to collect data. Efficiency gains would be achieved by NOAA by paying only for actual data collection activities and associated administrative charges. NOAA would essentially eliminate charges associated with equipment (vessel) downtime, maintenance, and lost time due to transit tune to the survey site location. In addition, large capital outlays for new vessels and equipment, replacement equipment, and maintenance and upkeep can be delayed or avoided. Further, the private sector is in a position to more rapidly adopt new technologies, thereby improving efficiency.

Interagency Collaborative Efforts

NOAA has had a longstanding program of cooperative agreements with state governments as a means for accelerating its national geodetic control program. The USGS has cooperated with as many as 35 states per year for several years in succession to expedite topographic mapping and hydrologic investigations. In some instances these cooperative ventures have nearly doubled the annual output of the total base program. Other federal organizations, such as the U.S. Department of Transportation, the U.S. Environmental Protection Agency, and the U.S. Department of Agriculture, have cooperative programs as well.

Opportunities exist for obtaining data for NOAA's hydrographic and bathymetric digital data bases through joint efforts with federal agencies and the private sector. The success of cooperative endeavors with other organizations depends on several factors: the resolution of liability requirements, adoption of agreed-upon standards, technology development, training of cooperative groups, and availability of some additional resources for use by the Coast and Geodetic Survey in monitoring these joint ventures. Cooperative ventures are now becoming more innovative, especially as federal resources shrink, technology changes, and the demand for graphic and digital data becomes more pervasive. Mechanisms and policies for the arrangement of future partnerships and cooperative agreements are addressed in Chapters 5, 6, and 7. The following discussion focuses on specific prospects for collaboration in hydrographic surveying between NOAA and other federal agencies.

NOAA Use of Corps of Engineers Survey Resources

Approximately 100 Corps of Engineers engineering survey parties are strategically located to cover the nation's major river and harbor projects. All major coastal inland waterway navigation projects and ports employ permanent Corps of Engineers hydrographic survey crews. Since many of NOAA's critical ("emergency") requests to investigate reported navigation hazards occur in or near these major commercial navigation projects, these resources could be readily deployed to perform surveys.

Utilization of Corps of Engineers engineering survey resources could have significant advantages to NOAA. Survey support could be made available within 24 hours in emergency situations throughout most of the country. Most significantly, NOAA would eliminate major costs that accrue when mobilizing and demobilizing survey vessels and personnel from their two main marine centers. In addition, NOAA would not have to divert crews from other field operations for short-duration requirements.

NOAA Use of Corps of Engineers Contract Forces

An alternative option is to use commercial firms already on active Corps of Engineers contracts. The Corps of Engineers maintains approximately 30 active contracts with firms that have hydrographic capabilities, covering all major coastal areas and inland waterways. NOAA could requisition any of these firms through the district holding the base contract through issuance of a standard delivery order. Usually, one to two weeks is required to effect a routine notice to proceed; 24 hours in emergency cases. These firms follow the same standards required of Corps of Engineers in-house crews and could perform surveys in places and times when it is impractical to mobilize either a NOAA crew, a NOAA contract crew, or a Corps of Engineers crew. The main advantage to NOAA is enhanced flexibility of coverage. Cost-savings benefits to NOAA could be realized in that, if only intermittent use on a particular contract is assumed, NOAA would not incur contract administration costs. These administrative costs can be a substantial percentage of the cost of a survey with small and widely dispersed requirements.

NOAA Use of Department of Defense Survey Forces

The U.S. Navy operates several hydrographic survey vessels, presently used primarily for surveys in foreign waters. As the Navy turns its focus from deep-water to littoral areas of operation and becomes more interested in near-shore training exercises and maneuvers in U.S. coastal waters, its needs for hydrographic information from waters covered by NOAA's charting mission will increase. It is possible that Navy survey vessels may be used, in some cases, to assist with survey missions in U.S. waters.

U.S. Geological Survey

Current agreements are in effect between USGS and NOAA to exchange geodetic and bathymetric data. The results are a more robust geodetic data base for the nation and a map series ("topobathymetric" maps) for coastal areas that is extremely valuable to a broad user community. Progress in completing this map series and creating a digital data base has been slow because of a lack of bathymetric data. Work on this data set holds the potential for a cooperative venture, and additional NOAA resources would expedite this program.

Retaining a Federal Hydrographic Survey Capability

Although the private sector should be encouraged to perform the majority of actual hydrographic surveys in U.S. waters, the federal government (NOAA, in cooperation with the U.S. Navy and the Army Corps of Engineers) will need to maintain an in-house, state-of-the-art capability for hydrographic data collection to enable it to set standards, train personnel, develop and test advanced technology, and meet national requirements.

SUMMARY

NOAA's Survey Request File and Chart Request File data bases document a backlog of over 1,100 survey requests and over 1,000 requests for new charts. Both backlogs are growing. While the backlogs suggest that demand for surveying and charting services exceeds what NOAA presently provides, by themselves they do not make a solid case for additional public investment in surveying and charting. First, it costs users nothing to make requests, and some fraction of the documented requests may not be of sufficient importance to warrant NOAA's attention. Second, for those requests that are of significant importance, NOAA, to date, has not conducted economic analyses of the costs associated with the delay imposed by present surveying and charting resource constraints.

A high-quality survey data base is a prerequisite for meeting user needs. NOAA can only produce this data base by increasing data-gathering efforts through (1) maintaining, in partnership with the military, a leading capability in gathering survey data that will enable it to lead in new technological changes and oversee quality assurance by private collectors; (2) increasing use of private contractors for gathering survey data; and (3) improving collaboration with other federal agencies conducting surveys. In addition, the prioritization process could be improved by inclusion of benefit-cost considerations in the prioritization scheme.

REFERENCES

International Hydrographic Organization (IHO). 1987. IHO Standards for Hydrographic Surveys. Special Publication No. 44, 3rd ed. Copenhagen.

Shaw, K. B., D. A. Byman, S. V. Carter, M. T. Kalcic, M. G. Clawson, and M. M. Harris. 1993. An Analysis of Navy Digital Mapping, Charting, and Geodesy Requirements. Naval Research Laboratory NRL/USGSFR/7441-92-9402, April. Stennis Space Center, Mississippi.

4

THE DIGITAL NAUTICAL DATA BASE: FROM PAPER CHARTS TO ELECTRONIC CHARTS AND BEYOND

Changes in information technology often require organizations to adapt to new modes of operation. This is true for geographic data—data referenced to the surface of the earth. The value of geographic data has been accentuated through its widespread use in geographic information systems for many purposes, such as infrastructure planning, demographic analysis, and environmental research. A geographic information system is a system of spatially referenced information, including computer programs that acquire, store, manipulate, analyze, and display spatial data.

Traditionally, government organizations have used paper maps to convey spatial information. Increasingly, they are required to integrate disparate data types for coherent analyses of complex problems. To fulfill this responsibility, many public agencies, such as the U.S. Geological Survey and the Bureau of Census, have invested in state-of-the-art computerized technologies, especially automated data collection techniques for generating source data and geographic information systems for spatial data analysis. The Federal Geographic Data Committee, of which the National Oceanic and Atmospheric Administration (NOAA) is a member, is developing standards for facilitating exchange of spatial data among federal agencies.

The availability of these new technologies has had a profound impact on producers as well as users of traditional map products and will inevitably affect the way future data bases will be constructed and disseminated. The emergence of associated technology has been a major catalyst to the growth of the spatial data industry, which now conducts several billion dollars worth of business annually.

The availability of new and evolving information technology provides new options for how nautical data are managed, disseminated, and used. Digital technology gives data producers and users powerful tools to store, transmit, update, view, and manipulate information about the marine environment. The nautical charting world reflects these changes in a growing demand for digital data sets to support electronic charts and other uses of marine geographic information and in new automated nautical chart production systems.

This chapter begins with a review of the rationale for making the maintenance of a national nautical information data base a central focus of NOAA's nautical charting activities. It provides an overview of NOAA's efforts to develop an automated nautical chart system and reviews the agency's plans to develop a data base of digital nautical

information. The chapter concludes with a discussion of issues associated with implementation of the nautical data base and suggestions for focusing NOAA's effort.

STEWARDSHIP OF THE NATIONAL NAUTICAL INFORMATION DATA BASE

The U.S. government, through NOAA, assumes liability for the navigational data it certifies for use. To fulfill this responsibility, NOAA must establish and enforce standards by which survey data are collected, entered into the data base, and disseminated. Data acquisition (Chapter 3) and product distribution (Chapter 6) are aspects of its mission that NOAA can delegate, at least in part, to the private sector. Maintenance and control of the master nautical data base for the nation's ocean and coastal waters—the ultimate source of the information disseminated in nautical chart products—will be the central aspect of NOAA's future nautical charting mission. This activity is a "natural monopoly," intimately tied to quality assurance and, therefore, a function appropriately managed by a federal agency as a unique and specialized mission. In the future, maintenance of the master nautical data base and associated functions is likely to be the most important component of NOAA's in-house nautical chart and information activities.

In the past, NOAA's data base was a collection of survey records and analyses of surveys recorded on paper. Recently, it has also included digital records of surveys; in the near future the data base will consist primarily of digital data. Reaching this objective requires the conversion of much existing data to digital form in a centralized digital nautical data base. The Automated Nautical Charting System (ANCS II) currently is being developed by NOAA as a means of automating the production of paper chart products from such a data base.

ANCS II is a computer system designed to support the production of a consistent and up-to-date suite of NOAA nautical chart products from a digital nautical data base known as the nautical information data base (NIDB). The NIDB is the ANCS II-specific master nautical data base and is one possible implementation of the digital nautical data base described above. Using digital data to produce paper chart products can lead to a much more efficient means of implementing the entire production and maintenance process than the current updating methods. Unless the process is transformed by these new technologies, it is inconceivable that NOAA could ever slow the growth of the backlog of new chart requests described in Chapter 3.

Ultimately, development of a digital nautical data base for U.S. waters is the crucial element for improving all nautical information products. Official chart data in digital form are in demand not only from present and potential users of electronic charts but also from many nontraditional users of chart information (see Chapter 5). All of these demands can be met only if NOAA builds and maintains a robust digital nautical data base.

OVERVIEW OF ANCS II

ANCS II, which is expected to be operational in fiscal year 1994, was designed primarily to facilitate the production of paper charts. The ANCS II NIDB (which may form a basis for a digital nautical data base) will contain a superset of all features (e.g., buoys, water depths, tidal variations) shown on all chart products. All updates from surveys and other sources are to be applied to this data base, and NOAA's product updates will be derived from the NIDB using operators' cartographic decisions stored in a separate chart graphics data base.

There are numerous advantages to the automated approach embodied by ANCS II. For example, since chart currency is known, and the NIDB is constantly updated, the system can report on how outdated each product edition is relative to the data base. The best information is used; updating is expedited, and resources are used more efficiently; and, as a product moves toward release, managers can monitor new changes in that area and perform last-minute updates as needed.

A major benefit resulting from full development of a digital nautical data base would be the basis for support of official digital data sets for electronic chart users. Future goals include making ANCS II the source of a suite of digital products, including digital nautical charts for the Defense Mapping Agency and data for International Hydrographic Organization member countries and users of electronic chart systems. Another future goal should be to extend ANCS II to accept and produce data in the appropriate format for use by nonnavigational users of marine information for various applications in a geographic information system (see Chapter 5). ANCS II has the potential to significantly improve the rate at which new chart information is disseminated to users, and to help meet the demand for digital products, if all extensions are implemented.

Detailed analyses of the NIDB and ANCS II design, implementation, acquisition, and extensions were beyond the scope of this study. It is not clear that present plans and processes surrounding ANCS II address the requirements described above in the most efficient way. For example, it is not certain whether a system designed for paper chart suite production can readily be extended to support the content and compilation requirements of digital products. The committee's endorsement of the ANCS II NIDB loading effort is based only on the recognition that the NIDB conceptually resembles the master digital nautical data base, which is essential to improving the efficiency of NOAA's nautical information activities in the future.

PLANS FOR LOADING THE ANCS II DATA BASE

Converting paper chart data to the digital format required for the ANCS II data base involves two steps: digitization and attribution. Digitization is the process of constructing a numerical description of the lines, points, and other features shown in the paper chart. It is commonly accomplished by first scanning the paper chart to produce a "raster image" or digital picture of the chart and then building a vector data set from the image. Vector data describe individual features by geographic coordinates. Geographic data stored in vector

format can be manipulated and interrogated by logic built into the software; it enables "intelligent" queries and analyses of the features embodied by the data. Pure raster data, by contrast, are simply a digital picture and do not readily lend themselves to intelligent manipulation; such data have the advantage of being easier to display. While vector/raster hybrid data may be used to capture the advantages of both data types, some vector data are necessary for the operation of marine geographic information systems and electronic chart technologies. The committee's vision of a digital nautical data base does not preclude raster data but has at its foundation a vector data set.

Attribution is the addition to the vectorized data of feature codes and text describing each of the objects (shoreline, depth contours, buoys, soundings) that make up the chart image. The two operations—digitization and attribution—are labor intensive and therefore time consuming. Digitization and attribution are estimated to account for 80 percent of the total data collection and loading effort in terms of both time and costs (McCarty, 1991).

Loading the ANCS II data base with all information presently contained in NOAA's suite of paper charts is expected to require 8 to 10 calendar years given present levels of effort and resources, at a cost of $20 million (about $20,000 per chart in the present suite). Under present plans, the Defense Mapping Agency will bear about 25 percent of the cost of data capture, which will support part of the digitization and attribution of 475 charts covering Navy home ports over a period of approximately 5 years. NOAA's attempts to raise funds to capture the remaining data have been unsuccessful to date.

Faced with an extensive and largely unfunded effort to load the ANCS II data base with vector data, NOAA has recently pursued a second approach to automating its paper chart production system for the 75 percent of the chart suites for which vector data collection is unfunded. This approach entails preparation of a separate data base of raster chart images, which are much less expensive to generate since they do not require vectorization or attribution. These raster images can be edited and used to produce printing plates, thereby reducing the delays now associated with printing new editions.

While the raster images contain the same source information from which vectorized data ultimately will be produced, the plan to maintain and support a separate raster data base represents a significant departure from the goal of rapidly populating the ANCS II vector NIDB. This activity threatens to divert resources from the development of the NIDB and to delay further the time when the full advantages of a vector-based master digital nautical data base will be attained.

The production of color separations and printing plates from a raster data base is a relatively simple task, but maintaining the raster data requires manual editing of raster images, which is skill intensive and time consuming, even when software tools such as CAR (computer-assisted revisions) and SCAR (super CAR) are used. When the update is relatively simple, the raster editing required is straightforward. For major changes, such as a new hydrographic survey, the raster editing required is likely to be quite time consuming.

NOAA plans to accumulate changes between chart editions (e.g., changes to navigational aids and features) in the ANCS II NIDB, making the NIDB principally a data base of changes rather than all chart source data. Raster images of the changes are to be produced through the normal production path in ANCS II and integrated by raster editing with the raster image of the chart. Operating ANCS II as a changes-only system in parallel

with a full raster data-base effort promises to be an inefficient and expensive use of ANCS II.

While the raster data-base approach may lead to faster turnaround times for new editions of some paper charts in the short term, there are questions about its overall efficiency. Moreover, this approach does not advance NOAA toward the goal of a single unified vector-based master digital nautical data base. The additional effort required to maintain the raster data base may increase the time required to attain this goal.

SETTING A NEW COURSE

It is questionable whether it is necessary to capture all possible chart data attributes during the initial ANCS II loading process. For example, all attributes not absolutely required for the paper chart production process, such as archival source data information, could be added at a future date without much loss in functionality. An efficient approach would be to retract the plan to maintain a raster data base and use all available resources to push the population of a digital nautical data base (such as the ANCS II NIDB) to fruition as quickly as possible, eliminating as many of the attributes as is consistent with safe and accurate paper chart production. This, of course, means providing sufficient attribution concerning change information to maintain NOAA's high standards of quality assurance and control. This approach would move NOAA closer to the ultimate goal of a fully attributed digital nautical data base, while it brings a fully automated chart production and updating system on-line as quickly as possible. Full attribution of the data can be performed later.

Additional avenues exist to leverage resources outside NOAA to help in populating the digital nautical data base. The power of geographic data standards to enable the integration of diverse data sets is tremendous. (See Kottman, 1992, for an introduction to digital geographic information exchange standards.) The adoption of universal geographic data formats and exchange standards can open avenues to accelerated loading of the digital nautical data base.

For example, some of the data are routinely collected by or for the U.S. Army Corps of Engineers in the form of project surveys. Incorporating such survey data into the NOAA master data base in digital form can help load the data base and lead to shorter production times for new large-scale charts. This merely requires agreement on data standards between NOAA and the Corps of Engineers.

State coastal management and port agencies have also been collecting data for their local areas, and NOAA might consider forming alliances with these agencies to incorporate available data, where accuracies are sufficient, into the master digital nautical data base. State and local governments are likely to be receptive to partnership agreements with NOAA (see Chapter 5), under which the partner might digitize NOAA charts coveting its geographic domain in return for digital updates in the future. Such agreements would require established guidelines for digitization and procedures for disseminating digital updates.

SUMMARY

NOAA is to be commended for initiating the development of an automated digital nautical chart production and management system. However, the agency now appears to be focused on a raster data-base maintenance project in an effort to speed up paper chart production. Maintenance of a separate raster image data base threatens to divert limited resources from the population of a vector-based master digital nautical data base and is not an efficient way to effect the improvements in chart production time that NOAA envisions. A more fruitful course for NOAA to follow into the digital information future lies in focusing on a lean approach to attribution and a full effort at vector digitization.

REFERENCES

Kottman, C.A. 1992. Some Questions and Answers About Digital Geographic Information Exchange Standards. Second edition. Intergraph Corporation, Reston, Virginia.

McCarty, T. O. 1991. Data Collection Experiences for an Automated Nautical Charting System. Unpublished Intergraph White Paper. Reston, Virginia.

5

NAUTICAL INFORMATION AS A COMPONENT OF A MARINE GEOGRAPHIC INFORMATION SYSTEM

The National Oceanic and Atmospheric Administration (NOAA) is in the process of producing a digital data base of the information appearing on its current nautical charts. When completed, this data base will simplify and speed nautical chart updating and production. This data base can also serve effectively as a key component of a broader marine geographic information system (GIS) with the potential of providing a wide range of coastal and marine environmental information products.

As a result of the ongoing information science and technology revolution, GIS and related technologies, such as Global Positioning Systems and remote sensing, have emerged as premier tools to organize, analyze, and display coastal data for uses other than the traditional safe navigation of marine commerce. Yet both the traditional and the new users can be satisfied by the same data base.

Information on the NOAA nautical charts serves well as the base layer for coastal zone and marine resource GIS applications, in the same way as a U.S. Geological Survey (USGS) quadrangle map is often used as the base map for land resource GIS applications. Critical nautical chart features for these purposes include shoreline, culturally and navigationally important landmarks, critical soundings and depth curves, shoals, wrecks, obstructions, boundaries of regulated areas, and fixed and floating aids to navigation. When the charts are digitized, these features become available for sophisticated spatial queries in the GIS. When the charts are scanned into raster files they can be used as a visual backdrop to add value and relevance to the project-specific data under investigation. Together, the two map representations form a powerful data base for managing the coastal zone.

The needs of local, state, and federal resource managers for digital data from nautical charts are significant and growing. Given that there are 30 coastal states, including those bordering the Great Lakes, and more than 450 coastal counties, the growing number of GIS installations under development by private and public agencies constitutes a significant demand for coastal data. If NOAA does not provide data products, these users must find other ways to obtain the necessary data, often in a variety of incompatible formats and at a significantly higher cost. If NOAA is able to address the needs of these nontraditional users of nautical data, unnecessary duplication of effort can be avoided and better resource management decisions can be made.

INFORMATION FOR COASTAL MANAGEMENT

Dealing effectively with coastal environmental degradation and resolving future land-use conflicts will require an intelligent balance between many competing demands. Engineers, scientists, planners, managers, decisionmakers, and the public need timely access to understandable information to assist in making difficult choices (Williams et al., 1991). Coastal management issues such as habitat modeling, carrying capacity analysis, fisheries assessment, pollution monitoring, and emergency contingency planning (including oil spill response) require vast quantities of data to be assimilated.

Given that most of the information pertaining to the marine environment has a spatial component, a GIS provides a means to aggregate and analyze the disparate data generated by public and private sources. Such systems are rapidly replacing the traditional cartographic techniques that have typified most coastal mapping and resource inventory projects and that are now being applied to coastal management efforts worldwide (Ricketts, 1992). Effective use of these increasingly sophisticated spatial analysis tools is, in turn, dependent on the availability of high-quality data bases that characterize the physical and cultural resources of the coastal zone.

Data-base development costs can be orders of magnitude higher than the cost of software and hardware involved in developing a coastal GIS (Haddad and Michener, 1991). To build affordable data bases, organizations usually rely on automating the production of existing paper map series or integrating derivative digital products that are maintained by federal agencies. The ubiquitous USGS quadrangle (quad) map series provides a rich base map upon which many land-based GIS users center their data-base development efforts. Land-based features are emphasized on the quads; however, coasts are the dynamic junction of land and water. The topographic and hydrographic surveys of NOAA's National Ocean Service, as well as NOAA nautical charts, provide the only comprehensive U.S. data base that depicts marine features from the shoreline seaward with an acceptable level of accuracy.

EXAMPLES OF GIS APPLICATIONS TO COASTAL RESOURCE MANAGEMENT

Many GIS developers in the 30 coastal states are digitizing elements of the NOAA nautical charts, NOAA topographic and hydrographic surveys, and USGS quadrangles to form digital base maps. The following examples provide a small but representative sample of how NOAA chart information is used in conjunction with project-specific data to support coastal decisionmaking in several states. These examples illustrate the advantages of using GIS for coastal resource management; however, the availability of a fully attributed nautical information data base would have saved time and money in all these cases.

The Coastal and Marine Assessment program at the Florida Marine Research Institute has invested considerable resources to convert NOAA nautical chart information to a format for use in a GIS. The Florida Marine Research Institute is mandated to manage, protect, and enhance Florida's marine resources. To accomplish this objective, it developed the Marine Resources Geographic Information System, which uses the latest in raster and vector technologies to synthesize a broad range of cultural and marine resource information. Many

of the most useful data bases in the Marine Geographic Information System are derivative products of NOAA nautical charts. These data bases have been used to support a variety of projects, including fisheries management, marine mammal research, oil spill response planning, site selection for testing of explosives, and diving operations in the Florida Keys. Appendix G provides some details of these examples.

In response to the *Exxon Valdez* oil spill, the State of Alaska and federal agencies developed a uniform digital coastline to track oil impacts, manage cleanup activities, and conduct natural resource damage assessment studies. The Alyeska Pipeline Company has developed a graphical resource data base to assist in its response to future oil spills and help meet state and federal spill contingency planning requirements. The Alaska Department of Fish and Game utilizes the SEAPLOT nautical charting and navigation system on several of its vessels engaged in fisheries research. The U.S. Fish and Wildlife Service utilized a digital bathymetric contour map to aid in its assessment of injury to sea otters from the *Exxon Valdez* oil spill. Details of these projects are given in Appendix G.

Louisiana has about 40 percent of the nation's coastal wetlands. They represent a renewable natural resource base that is valued at more than $1 billion annually and include 25 percent of the nation's fish harvest, its largest fur harvest, the highest concentration of waterfowl, and the country's largest recreational marine fishery. Recent studies indicate that coastal Louisiana has one of the world's most rapidly changing shorelines with retreat rates exceeding 20 meters per year in some areas. Wetland habitats protected by outer coast deposits are being replaced by open water at a rate of 65 square kilometers per year. Various agencies and universities in Louisiana are studying these ecosystems to better understand their origin and evolution and the impact of human activities on environmental response.

As an example, personnel at the Center for Coastal, Energy and Environmental Resources at Louisiana State University are performing comprehensive studies of coastal change using repetitive NOAA shoreline position and bathymetric survey data. Further details are given in Appendix G.

MEETING USER REQUIREMENTS

It is useful for NOAA to look at the information on its nautical charts in terms of comprising several data bases and to establish a process for marketing them by theme or geographical area to GIS users from the NOAA digital nautical data base of the future. Several data themes on existing nautical charts could easily be made available as data bases ready for use in a GIS. Users will need to be made aware of the existence of NOAA digital data through technical presentations and a formal marketing program. The USGS has taken this approach with its popular Digital Line Graph files. These files reflect the cartographic information extracted from 1:100,000 and 1:24,000 map sheets for the United States. Digital Line Graph information can be easily exchanged and directly imported to a GIS because it is in a standard format. Experience with the Digital Line Graph files has shown that they are of very high quality, in both their cartographic information and their attribute data (Dangermond, 1990).

Many of the needs of nonnavigation users can be met with some additional design considerations at very little additional cost to NOAA. The fundamental data themes such as shoreline, bathymetry, and aids to navigation are already planned as elements of NOAA's digital nautical data base. Marine GIS users need the files to be designed and created as data bases, not just graphic layers. Older NOAA digital shoreline products contained the cartographic representation as graphics. This was adequate for reproducing the shoreline as drawn on the chart, but the shoreline recorded in the digital file was interrupted by other map features such as text labels, compass roses.

Naturally, GIS users need the data to be free from errors. Older NOAA shoreline data products contain significant errors, such as wild points, missing data, and duplicate data. The quality control processes used to validate the data need to be clearly described, so that users will be assured that they can use the data immediately, without having to make an unexpected investment in data cleansing. Nontraditional users also need the data base to be complete. A data base that is completely populated for only some charts in a region or partially populated for some data features is much less useful.

After implementing greater data accuracy and quality reporting, NOAA needs to be less cautious and more open with its data holdings. NOAA has many data sets that represent data in some stage of processing, which may not be suitable for navigation purposes but can be very useful for marine GIS purposes. Some marine GIS users need older data for time-series studies, as well as data displayed on the most recent charts. NOAA does not plan to digitize data that are not displayed on the most recent charts. Older data not in digital form could be digitized and stored in the digital nautical data base or made available in analog form to users who would return the results of their digitizing to NOAA.

NOAA should participate in the spatial data clearinghouse efforts being coordinated by the Federal Geographic Data Committee and adopt standards that are compatible with the Federal Data Transfer Standard under development by this committee.

BEYOND THE DIGITAL NAUTICAL DATA BASE

There are additional needs of nontraditional users that go beyond the planned elements of NOAA's digital nautical data base. Some of these could be accommodated through a modest collaborative effort. For instance, a state or local agency might perform a detailed large-scale survey, producing more detailed shoreline or bathymetry data than are shown on any nautical chart. While these detailed data might not be necessary or even useful for the production of existing or planned nautical charts, such data could be a logical extension of the digital nautical data base and could be built on the spatial framework of nautical chart data. The digital nautical data base would serve as the vehicle for dissemination of these data to potential users. NOAA could bring data from other contributors into the digital nautical data base by assisting in the development of format and quality standards and by providing consulting services to potential data contributors.

Cartographic consistency between map series is an important issue for builders of coastal zone GIS data bases. Since shoreline depictions on NOAA nautical charts and USGS quadrangle map products do not match, the GIS analyst is faced with a significant challenge

(Needham and Lanzer, 1993). While there are some cases when different maps portray the same shoreline differently for justifiable reasons (e.g., different tidal data), there are other cases in which the depictions simply reflect two different agencies drawing the shoreline with independent sources and methods. For instance, NOAA maps the shoreline at a scale of 1:40,000, while the USGS maps it at 1:24,000. NOAA and the USGS should develop ways to more closely coordinate their depictions. A priority should be placed on accuracy and currency of these depictions. This will require a greater emphasis on acquiring data from other sources (e.g., other agencies) and, where necessary, collecting new data. A digitized attributed shoreline should be a fundamental data theme that is jointly maintained by NOAA and the USGS and made available through the digital nautical data base (see Appendix H).

For NOAA nautical chart data to have widespread utility, they need to be made available in a format that is appropriate for nautical charting, electronic charting systems, and GIS. In the future the format issue will be resolved if nautical chart information is produced by using the Spatial Data Transfer Standard (Federal Information Processing Standard 173).

Users also need data elements that are similar to, but not exactly the same as, those in NOAA's planned data base. Among these are the shoreline drawn with respect to different tidal data (higher high water, lower low water, etc.) and bottom samples. Although these data elements are not in the nautical charting data base, they might be available from other NOAA programs. The shoreline shown on the nautical charts represents the line of contact between the land and a selected water elevation. At the present time, the shoreline on NOAA nautical charts approximates the mean high water line. In areas affected by tidal fluctuations, this line of contact is usually the mean high water line. In confined coastal waters of diminished tidal influence, the mean water-level line may be used. However, for charting purposes (i.e., safety of navigation and maritime boundary determination) the low water line is more critical. It would be valuable if both of these data elements could be supplied for use in a GIS.

With respect to these nonnavigation users, NOAA needs to be less cautious and more open with its data holdings. NOAA has many data stores that represent data in some stage of processing. While unverified data are clearly not suitable for navigation purposes, they can be enormously useful for a marine GIS.

When a new chart is produced, traditional users are notified through Notices to Mariners and other means. A similar service could be provided for the planned digital data holdings to be reported to the nonnavigation users.

Most elements of the digital nautical data base are useful for environmental studies and coastal zone management; however, the following data elements have the highest priority for many nontraditional users: shoreline position (consistent with USGS), bathymetry (denser than on charts, especially near shore), aids to navigation, bottom types, managed areas (special areas), scanned and edge-matched master charts, and a digital coast pilot.

Bringing together data from separate programs may be the biggest challenge. Agencies that use NOAA data for purposes other than navigation do not distinguish between the separate mandates of the various NOAA programs, such as the Nautical Charting Program and the Coastal Zone Management Program or programs established under the Oil

Pollution Act of 1990. Users expect that NOAA should facilitate its activities by making nautical chart data (and other data) readily available in a usable format.

To meet these needs, NOAA would have to broaden its responsibilities beyond the mandates of the separate programs to include the needs of the coastal zone research and management community and other marine GIS users. Managers of the Coastal Zone Management Program and spill contingency plans could, in turn, facilitate marine GIS activities by supporting the transfer of their data to NOAA. Data from all NOAA programs could be managed through a well-designed digital nautical data base for general distribution to a variety of users.

SUMMARY

The digital nautical data base developed and maintained by NOAA as its core mission in nautical charting can also serve effectively as a key component of a broader marine GIS, providing a wide range of coastal and marine environmental information products to fulfill NOAA's mandate for marine environmental stewardship. NOAA has a clear statutory mandate and the expertise to be the lead agency for coordination and maintenance of such a master nautical data base.

The format and content of NOAA data can be made amenable for use with a marine environmental GIS at very little additional cost to NOAA. To facilitate use of nautical chart information in a GIS, efforts should be made to adopt the Spatial Data Transfer Standard developed by the Federal Geographic Data Committee. NOAA and the USGS should seek a closer coordination between their depictions of the shoreline.

This information would serve the nation's growing concerns about marine and coastal environmental quality and avoid duplication of effort by other public (federal and state) agencies.

REFERENCES

Dangermond, J. 1990. A review of digital data commonly available and some of the practical problems of entering them into a GIS. Pp. 222-232 in D. J. Peuquet and D. F. Marble (eds.), Introductory Readings in Geographic Information Systems. Taylor & Francis, Inc., Bristol, Pennsylvania.

Haddad, K. D., and W. K. Michener. 1991. Design and implementation of a coastal resource geographic information system: administrative considerations. Pp. 1958-1967 in Proceedings of the Seventh Symposium on Coastal and Ocean Management/ASCE. Charleston, S.C.

Needham, E. L., and E. L. Lanzer. 1993. The Puget Sound Geographic Information System: a tool for coordinated environmental management. Computers, Environment and Urban Systems 17:1-23.

Ricketts, P. J. 1992. Current approaches in geographic information systems for coastal management. Marine Pollution Bulletin 25:82-87.
Williams, S. J., K. Dodd, and G. K. Krafft. 1991. Coasts in Crisis. U.S. Geological Survey Circular 1075. U.S. Geological Survey, Washington, D.C.

6

NAUTICAL INFORMATION PRODUCTS AND THEIR DISSEMINATION: TOWARD A NEW WAY OF DOING BUSINESS

Historically, the mission of the Nautical Charting Division of the National Oceanic and Atmospheric Administration's (NOAA's) National Ocean Service has been to provide nautical information to mariners by publishing charts and related information products, such as Coast Pilots (detailed navigation guides to specific areas) and tide tables. NOAA has supported this mission primarily with in-house survey and chart production activities. As described in earlier chapters, changes in technology and user demands now increasingly call for adjustments in the way NOAA defines and approaches its mission. This chapter deals with changes that NOAA could make in its relationships with the private-sector companies that produce value-added nautical information products that would improve the agency's ability to meet changing user needs for new and varied products.

Some aspects of the present system for supplying products to users are not sufficient, as demonstrated in Chapter 2. Additionally, in the future, as demand grows for more custom paper products and for a variety of digital information products (see Chapter 5), it is not likely that NOAA can adapt quickly to meet those needs, given its resource constraints and the inherent limitations of a large agency. This chapter suggests new approaches for generating and distributing new products rapidly and efficiently while meeting legal requirements and maintaining necessary standards of accuracy and quality.

The alternatives addressed in this chapter for enhancing nautical information products and services are rooted in closer alliances between NOAA and the private sector. NOAA can take advantage of the capabilities and flexibility of private commercial partners to quickly evolve and manufacture diverse nautical information products, achieve rapid and efficient distribution of these products, and possibly generate additional revenues for itself (see Chapter 7). NOAA can focus its own efforts on the maintenance, quality control, and certification of the national hydrographic data base, in support of public and private ventures to provide and disseminate products.

THE PRESENT SYSTEM OF PRODUCTION AND DISSEMINATION

The nautical chart and information product mix consists of selected presentations of nautical data sets (today, mostly paper charts), each of which is characterized by its coverage, scale, and content; accuracy; medium and format (paper, digital); and update/reissue frequency. The need for these products defines and drives the nautical

charting mission. Individual products are derived from the collection of nautical chart information by NOAA, which includes all analog (paper) and digital data records collected or archived by NOAA. In addition to NOAA's nautical chart products, private vendors produce charts, digital products, and publications to meet some aspects of user demand. Most of these products are derived from NOAA products.

NOAA Products

At present, NOAA's nautical chart and information products are paper charts, supporting publications such as Coast Pilots and tide tables, and periodic updates disseminated on paper and via radio transmissions as Notices to Mariners. Nominal print cycles for NOAA's charts range from 6 months to 12 years. In practice, new editions are triggered by the accumulation of critical corrections, significant format or regulation changes, new basic data, low shelf stock, and available resources. Critical corrections include changes to aids to navigation, obstructions and shoaling, and cultural and facility changes. Typically, 30 to 70 critical changes trigger a new edition. In fiscal year 1991, NOAA produced 351 new editions of conventional charts, or 415 new editions including small-craft and other charts.

In addition to charts, NOAA publishes a series of Coast Pilots: four volumes for the East Coast of the United States, one for the Gulf of Mexico and parts of the Caribbean, one for the Great Lakes, one for the West Coast, and two for Alaska. All are revised annually expect those for Alaska, which are revised biennially.

Commercial Products

At present, about a dozen U.S. companies are copying NOAA charts (and those published by the Defense Mapping Agency and other hydrographic agencies) for resale as value-added products. They reproduce the charts in a variety of formats, including waterproof paper, smaller paper size, and chart books containing several charts for a region. Exact numbers are not available, but sales of these products are substantial and certainly exceed NOAA's sales volume. Because they are not bound by any contractual agreements with NOAA (and NOAA, like most U.S. government agencies, cannot copyright its products), private resellers have often priced their value-added reproductions below NOAA's chart price. These practices and pricing policies have contributed to the substantive erosion of NOAA's chart sales volume over the past decade. The privately reproduced charts are sold directly, by mail order, and through chart agents.

In a similar vein, several companies in the United States and abroad are engaged in digitally reproducing NOAA and other charts, either as raster images or as vector data products. Most are sold for use with electronic chart systems on recreational and fishing vessels, though some are also being used on commercial ships. These firms supply a market that NOAA does not serve at present in any way. Exact figures are not available, but annual sales of digital hydrographic data sets are estimated to be in the tens of thousands of units

(electronically programmable read-only memory (EPROM) cartridges, laser compact disks, or magnetic diskettes).

Because of liability concerns, private resellers of both paper and digital versions of NOAA charts often include disclaimers (usually something like "not for use in navigation") on their products. This disclaimer limits the use of such charts for fulfillment of international carriage requirements for commercial shippers but generally does not dissuade boaters from using them as a sole source of navigation information.

Distribution of Products

NOAA has over 2,200 nautical chart sales agents worldwide, varying in size from small marina operators to large map stores and ship chandlers. Those that sell to recreational users generally stock non-NOAA chart products as well. In fiscal year 1991, NOAA distributed about 1.4 million charts: 900,000 to government agencies (including the Navy), 400,000 to recreational boaters, and 100,000 to commercial navigators. While government consumption of NOAA charts has been fairly steady (with some temporary declines), public sales are down 50 percent since the early 1980s (Figures 6-1 and 6-2). Likely causes of this decline are the increase (due largely to the cost recovery requirement) in the retail NOAA chart price from $4 in 1981 to over $13 in 1991, combined with growing competition from the value-added reseller market. Other factors appear to be the decrease in number of U.S. flag ships and decrease in new editions due to declining funding for these activities.

SHORTCOMINGS OF THE PRESENT SYSTEM

Three major shortfalls of the present system are highlighted below.

- There is a large demand for "custom" and value-added nautical chart and information products, both paper and digital, that is not (and cannot reasonably be) met by NOAA. Private resellers are responding to this demand, but they now do so without NOAA's active cooperation. The consequence is that "not for use in navigation" and similar legal fictions are featured prominently on commonly used products that few, if any, users buy for any purpose other than navigation. A better basis is needed for private-sector generation and distribution of value-added nautical chart products.
- The frequency of updates/revisions of charts lags significantly behind the Notices to Mariners. The current process of incorporating changes into new NOAA chart editions involves many manual operations that propagate an update through all the affected products, and the printing process often takes months as well. As a consequence, NOAA's paper product updates often are scheduled at long intervals, and, more importantly, "new" charts are months out of date (i.e., behind changes announced in Notices to Mariners) by the time

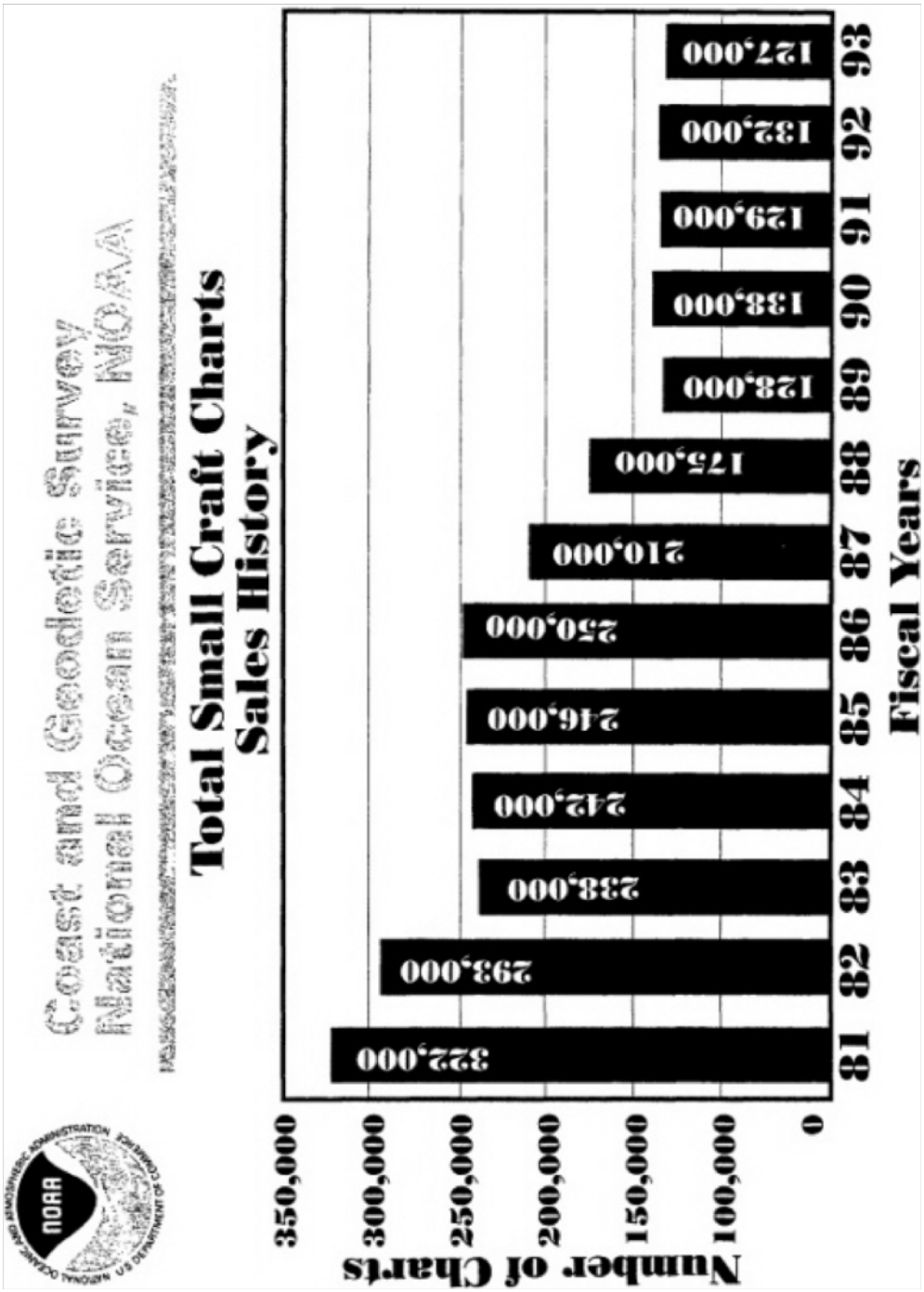

Figure 6-1 Total Small Craft Charts Sales History
Source NOAA, National Ocean Service, Coast and Geodetic Survey

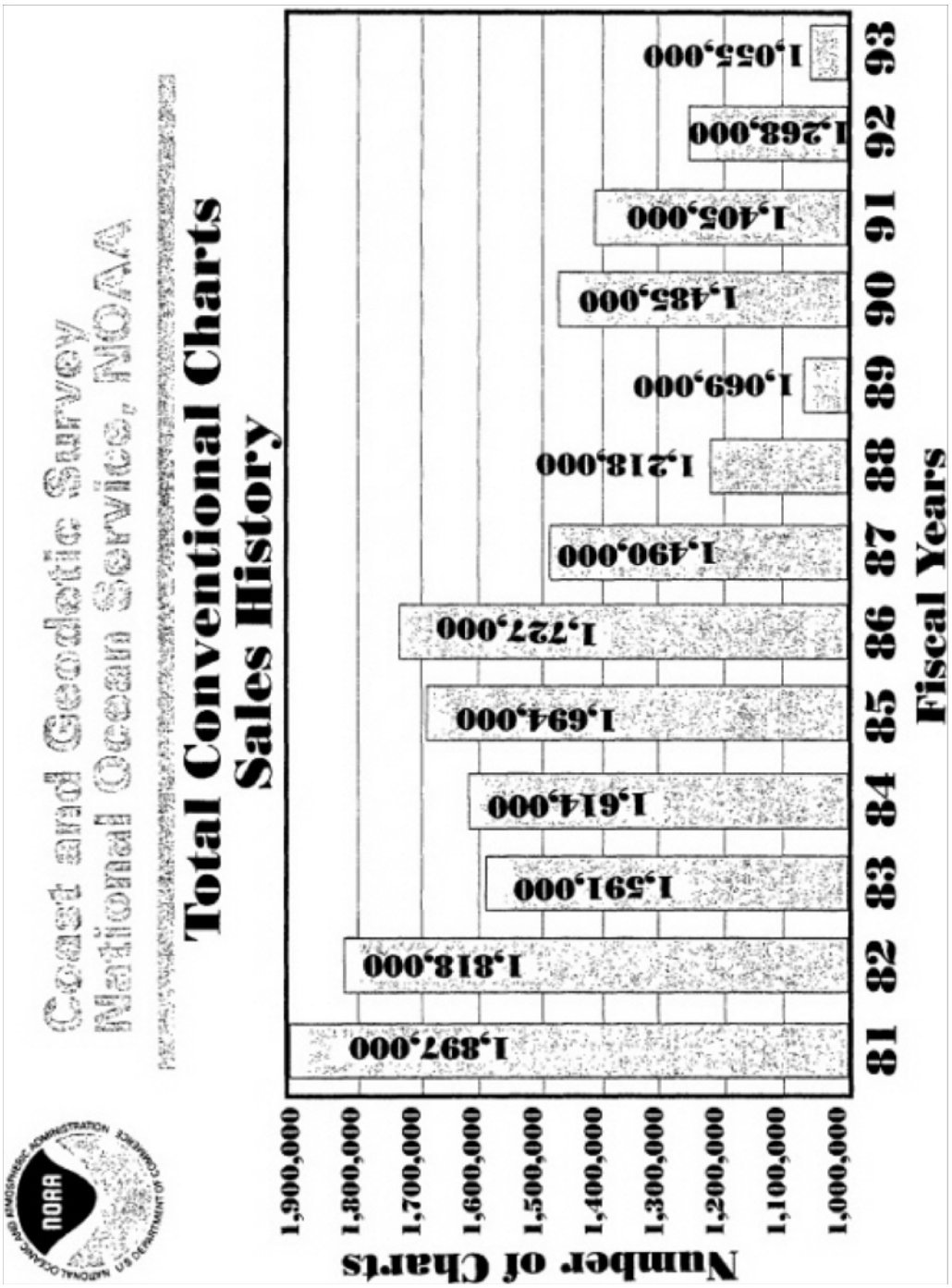

Figure 6-2 Total Conventional Charts Sales History.
Source NOAA, National Ocean Service, Coast and Geodetic Survey.

users are able to obtain them from their chart agents. The production and distribution system needs to be improved to provide for faster generation and dissemination of new editions, updates, and value-added products.

- The growing demand for digital nautical chart data products that meet legal carriage requirements cannot be met in the near future at the present rate of digitization of nautical information. This demand is likely to increase as electronic chart technology becomes standard equipment on commercial vessels. As with value-added paper chart products, the digital products offered at present by commercial ventures are inconsistent; offer limited coverage; and, without NOAA's cooperation and assistance, will not be certified for use in an official electronic chart display and information system. A better means must be found to satisfy the important and multifaceted demand for digital nautical chart data in a timely and effective way and to improve the accuracy and consistency of the digital products that NOAA now provides.

A STRATEGY FOR IMPROVEMENT

One approach to the question of appropriate public- and private-sector roles in supplying nautical information products is to assume that in the interest of efficiency, products and services ought to be delivered by private-sector operations governed by market forces unless there are sound reasons why the public sector must provide them. This is official U.S. government policy as articulated in Office of Management and Budget Circular A-76 (OMB, 1983). Maintenance of the national hydrographic data base is arguably a legitimate public-sector function. Data collection and (to a lesser extent) product dissemination also are treated as public-sector functions: NOAA now conducts surveys and prints charts. It is likely that, in the future, both functions could be served more efficiently with greater participation by the private sector.

To better and more efficiently satisfy user demands, NOAA could enter into partnerships with private companies for the printing, publishing, and distribution of nautical chart products. The advantages of this approach are extensive: NOAA can focus on its main areas of competence and responsibility of designing, building, and maintaining a data base of nautical information, and the public benefits from the wider and more rapid distribution of diverse (but quality-controlled) nautical chart products that are up to date and customized to the specific needs of user communities, such as commercial fishing and recreational boating. The rapid construction of a master digital nautical data base will ensure that NOAA's subsequent updating efforts add value to its core asset.

SUGGESTIONS FOR IMPLEMENTING THE STRATEGY

Institutional Arrangements

A variety of arrangements are possible to enlist the help of private-sector firms in the publication and distribution of nautical charts and information products. Possibilities include cooperative research and development agreements (CRADAs, as defined in the Technology Transfer Act of 1986), cooperative agreements (33 CFR 883e), contracting for the provision of services (33 CFR 883f), and licensing of data to the private sector. At the present time, NOAA lacks the legal authority to license its data. Legislation would have to be enacted to change this situation. There are also opportunities for NOAA to form data collection, printing, and data distribution partnerships with other federal agencies, and with states (see Chapter 5).

Partnerships allow NOAA to leverage others' capabilities for efficient customization, responsiveness to users, and technological efficiency. In effect, this is happening already, although on a limited scale and without NOAA's active participation. All parties will be better served with organized arrangements: user demands will be met more fully; private firms can use NOAA's participation in their efforts as a marketing tool; and NOAA can better accomplish its mission, obtain additional data, and (possibly) obtain a new source of funding (see Chapter 7).

Some federal agencies have already established successful records in using new mechanisms such as CRADAs for public/private partnerships (GAO, 1993). The Clinton administration has indicated strong commitment to support and promote better ways for the federal government to do business, including the specific partnerships described here. For this partnership approach to work at NOAA, relevant objectives will have to be incorporated into NOAA's strategic plan. Further, it is likely that some incentives would have to be provided initially to stimulate private-sector participation in what might be perceived as a risky venture. Considerations of the national interest in ensuring complete coverage of all U.S. waters—not merely those in which there is a strong interest by users—would also have to be built in to any agreements with private companies. In some cases, NOAA presently lacks the legal authority to engage in such arrangements and would have to seek legislation to permit them to take place.

Product Lines

NOAA could create partnerships of two different types--one for commercial vessel and one for small-craft charts—in order to meet the dramatically different needs of two practically and legally distinct groups of nautical chart users. Commercial vessels are defined as those of more than 1,600 tons displacement, which are now required to carry an updated NOAA chart, or International Hydrographic Organization-approved foreign equivalent, in U.S. waters. Small craft are not legally required at present to carry a chart. Both classes of users would benefit from products focused on their specific needs.

Small-Craft Chart Products

Currently, the needs of small craft are largely met by chart reprinters whose charts, in many cases, carry the generally disregarded warning "not for use in navigation." NOAA could seek partnerships with private chart reprinters and possibly collect a user fee in exchange for allowing the privately published small craft charts to carry a special version of the NOAA emblem or with a statement to the effect that the chart was created from certified NOAA data subject to update by Notice to Mariners and is intended for use in small-craft navigation.

Further, the private partner could be asked to assert its own copyright in the small-craft charts as derivative works under copyright law. These private copyrights, coupled with user preference for charts carrying the NOAA emblem, would provide significant competitive pressure on other chart publishers to also join in partnership with NOAA and pay user fees.

Following are suggested attributes of the small-craft chart process:

- Small-craft charts should be packaged in an educational folder that describes their use.
- Small-craft charts should carry the NOAA emblem with a designation that identifies the product as intended for use for nonregulated navigation.
- NOAA should explore charging private publishers of small-craft charts a modest user fee.
- NOAA's liability for small-craft charts should only extend to the accuracy of the base data or imagery supplied by NOAA. Liability for the product remains with the publisher, as it does now, but the sanctioned use of certified base data provides some protection and improves safety.
- In cooperation with the U.S. Coast Guard, NOAA should explore the promulgation of a NOAA small-craft chart carriage requirement for vessels of a certain size and displacement.

A major benefit of these small-craft chart partnerships is the innovation in product design that will likely result and the improvement in safety that is likely to come from greater and more diverse distribution of chart products.

Commercial Vessel Chart Products

A parallel set of public and private cooperative agreements could meet the needs of the regulated commercial users of nautical charts, but there are several differences that have to be accommodated. The private publisher of commercial charts would include a NOAA emblem with the statement to the effect that "this chart is approved for use in regulated navigation requiting a NOAA or International Hydrographic Organization approved chart." Private publishers would be required to print and distribute NOAA's entire suite of charts and to subject their process to periodic independent inspection to ensure that they meet rigid

NOAA specifications regarding printing quality, paper, ink, and style. Given the fact that these charts are essentially printed under contract to and under the control of NOAA, NOAA would be liable for their accuracy, as is now the case.

Following are suggested attributes of the commercial charts process:

- Commercial charts will carry not only the NOAA emblem but also a designation indicating that "this chart is approved for use in regulated navigation and meets SOLAS (Safety of Life at Sea) requirements."
- Private partners who print regulated charts should be required to print the full suite of all NOAA charts and to meet rigid NOAA specifications regarding printing quality, paper, ink, style, etc. NOAA should periodically inspect and certify the process that each of its private regulated chart publishers uses.
- Private partners who print regulated charts should be required to agree to a reasonable pricing structure in keeping with a reasonable margin of profit.
- For regulated charts, NOAA should charge a meaningful user fee to its private partners.
- Consistent with the need for NOAA to certify both the base data and the process used by the private publisher/partner, NOAA should completely indemnify the publisher and take all liability for the resulting product, much as it does now for nautical charts and as is extended to the private sector in the case of Jeppesen aeronautical charts. Legislation would be required to enable an arrangement for nautical chart products similar to the arrangement that applies to these aeronautical charts.

Digital Nautical Chart and Information Products

The legal requirements for paper charts may be modified in the future to allow use of a certified electronic chart system and data base in place of the paper chart. The Defense Mapping Agency already obtains digital nautical charts for U.S. waters from NOAA, and the Navy's requirement for paper charts may largely disappear by the end of the century. Increased use of electronic chart systems in the commercial sector, and the prospect of eventual carriage requirements for such equipment, will strengthen the requirement for NOAA to provide official digital data sets.

Partnership arrangements for producing and distributing electronic or digital chart products could be handled in much the same way as those for paper products, for both the small-craft and the commercial user segments. One significant exception is that for digital charts it is insufficient to ask the private partner to protect the products with copyright. The digital products need additional protection with licenses that restrict use of the data to the intended application. In most cases this would be a single user license per copy, but with appropriate legislation, NOAA's partnership agreements could additionally provide for digital licenses to allow the custom printing of charts to order, with a user fee paid for each chart, or for electronic on-line access to chart data, with a user fee paid on a per-transaction basis.

It will be instructive to observe the progress of foreign hydrographic offices, which in some cases are already putting in place public/private partnerships for production and

dissemination of digital nautical chart products. The Canadian Hydrographic Service is arranging a collaborative agreement for production and marketing of digital nautical charts, and the United Kingdom's Hydrographic Office is working with several commercial firms to develop standards for digital chart products.

Navy Products

Presently a major user of paper nautical charts, the U.S. Navy is moving toward digital navigation and a "paperless bridge." The Navy and the Defense Mapping Agency can obtain digital base data for U.S. waters from NOAA, as they are now beginning to do, and format these to their own requirements. Paper product needs that may arise during the transition to digital navigation can be met by private chart production partners.

Products for Other Users

As illustrated in Chapter 5, nontraditional users of nautical chart information are primarily interested in digital data. NOAA's private partner companies could serve as flexible customizers and distributors of hydrographic information for many other purposes in addition to navigation.

Legal Issues

Liability for accuracy and completeness of chart data and for its presentation is a serious concern in the preparation and distribution of nautical charts, both for traditional paper charts and for digital data sets. Following is a brief review of the legal context of nautical charts, along with a suggested approach to production and distribution that improves on the present situation.

Most maritime nations impose requirements for the carriage of up-to-date nautical charts on commercial vessels operating in their waters. For example, the United States requires all vessels over 1,600 tons operating in U.S. waters to carry charts "of large enough scale, with sufficient detail to make safe navigation of the area possible" and "corrected and updated with corrections contained in all Notices to Mariners reasonably available to the vessel" (48 FR 44534-35). Further, 33 CFR 164.33(a)(1) requires "marine charts of the area to be transitted, published by the National Ocean Service, U.S. Army Corps of Engineers, or a river authority." Charts or publications published by a foreign government may be substituted (33 CFR 164.33(b)). These regulations are promulgated by the U.S. Coast Guard and implement the requirements of the 1974 International Convention on Safety of Life at Sea. To support the correcting and updating provisions, NOAA provides updates and corrections to the agencies responsible for dissemination of Notices to Mariners (the Defense Mapping Agency and the U.S. Coast Guard).

Chartmaking by a government agency is a sovereign act. Under the doctrine of sovereign immunity, governments cannot be sued by citizens for the consequences of sovereign acts without the government's consent. In the United States, certain statutes (including the Federal Torts Claims Act and the Suits in Admiralty Act) waive sovereign immunity and permit suits against the government for civil wrongs. In the case of nautical chartmaking, the Suits in Admiralty Act allows for suits against the United States for negligence in the preparation and dissemination of nautical charts. Thus, NOAA and the Defense Mapping Agency can be held liable for damages arising from an accident that results from a faulty chart or Notice to Mariners. The negligence must generally involve a failure to exercise due care when charting obstructions. At the present time, the government is not subject to suits based on product liability theory.

Unlike the government, private parties can be sued for product liability as well as for negligence. Product liability is a form of strict liability imposed under U.S. torts law on anyone selling any product that is "defective." Under this law, private parties can be held strictly liable for damages arising from chart products they produce when these products are determined to be unreasonably dangerous for their intended use. In part because of these liabilities, government-produced charts at present are the only admissible charts in the context of carriage requirements imposed on commercial vessels.

The U.S. government, through NOAA, presently assumes responsibility for the quality of the data supporting its chart products and for the depiction of the data in the charts. (The latter issue is a point of contention in electronic charts, where the government no longer has complete control over presentation.) The U.S. government's consent to be sued for negligence in nautical chartmaking is central to the usefulness of NOAA chart products as the foundation of the legal regime that governs marine transportation. For these reasons, it is necessary that NOAA inspect, certify, and assume responsibility for the products of private publishers of NOAA's commercial chart suite, if it enters into arrangements with private companies such as those described above. Liability for the products of private small publishers would continue to be the responsibility primarily of the private firm. Because the base data used to produce the small-craft chart products now would be explicitly NOAA certified, however, the publisher's liability position would be slightly better than it is at present.

SUMMARY

The private-sector partnerships described in this chapter would allow NOAA to take advantage of the expertise in private industry to quickly evolve diverse products with effective methods of distribution, and would refocus NOAA on its distinctive competence in maintaining and certifying the nautical chart base data from which all such products are derived.

Many of the recommendations made in this chapter cannot be implemented until there are changes in legislation. However, their implementation will bring NOAA closer to compliance with other government directives, such as OMB Circular A-76. Seeking such legislative changes and pursuing these strategies successfully will require an innovative

attitude on the part of NOAA's management and some initial stimulation of private-sector involvement through incentives or other mechanisms to reduce any perception of financial risk. Changes in legislation also will be required if public/private partnerships are to become vehicles for generating additional funds to support NOAA's nautical charting activities.

REFERENCES

General Accounting Office (GAO). 1993. Technology Transfer: Implementation of CRADAs at NIST, Army, and DOE. GAO/T-RCED-93-53. June 10. GAO, Washington, D.C.

Office of Management and Budget (OMB). 1983. Circular No. A-76 (Revised). Performance of Commercial Activities. August 4. Office of Management and Budget, Washington, D.C.

7

RESOURCE CONSTRAINTS: REMOVING THE BARRIERS

In the sections that follow, the resource constraints facing the National Oceanic and Atmospheric Administration's (NOAA's) nautical charting mission are discussed and some innovative options are suggested for relieving them. The options are intended as a stimulus to NOAA to consider new approaches to solving the problems of diminishing resources coupled with additional requirements in its nautical charting mission. In many cases, NOAA would have to seek legislative action to enable it to retain revenues from these arrangements.

RESOURCE CONSTRAINTS

To some extent, discussion of programmatic matters is outside this committee's purview. However, several significant resource-related barriers, some of which are programmatic in nature, appear to impede the future progress and effectiveness of NOAA's nautical charting program. The common backdrop to these considerations is that the budget for nautical charting activities has decreased in real dollars over the past decade (see Figure 1-3), while technological and user community challenges have increased dramatically. Resource barriers constrain each of the three major functions of the nautical charting program: data acquisition, data-base management, and product generation and dissemination.

Surveying and Data Acquisition

As the backlog of survey requests has grown, the number of survey vessels and the number of days at sea have declined due to budgetary constraints. At the present level of resources allocated to surveys, resolution of the outstanding backlog of survey requests would take decades. While not all outstanding requests are of equal importance, the general significance of surveying to the nautical charting mission is clear. Surveys are costly, and to alleviate the request backlog, NOAA must identify new sources of support for survey activities and/or make more efficient use of available resources (see discussion in Chapter 3).

Data Processing and Data-Base Maintenance

A one-time investment of approximately $20 million is required to load the Automated Nautical Charting System (ANCS II) nautical information data base (NIDB) by digitizing and attributing data from NOAA paper charts. The funds for this work are not in hand at present. Once the digital nautical data base has been populated with data now contained in the paper chart suite, it can probably be maintained with existing resource levels by using automated systems under development. The NIDB would form the basis of a master digital nautical data base.

Production and Dissemination

Under the cost recovery requirement, prices for NOAA nautical charts have increased threefold in recent years, with all revenues reverting to the U.S. Treasury. Flat budgets and the inability to retain revenues from product sales have prevented NOAA from responding to user needs for timely, customized paper and digital products under NOAA's traditional in-house product development arrangement.

Production and dissemination do not pose a major resource problem so much as a challenge to accelerate the completion of a national digital nautical data base and to institute partnerships for product generation and distribution with private ventures. The automated nautical chart production system (ANCS II), together with an up-to-date digital nautical data base, would enable expedient support for new and existing products, both paper and electronic, and facilitate the formation of industry/government partnerships for production and distribution.

ALTERNATIVES FOR RESOLUTION OF RESOURCE CONSTRAINTS

The committee's inquiries and analyses, as documented in the preceding chapters, show convincing evidence that in a time of severe budget constriction it is essential to approach future efforts in nautical charting on a collaborative basis. If NOAA pursues solutions to future data collection, data maintenance, and product challenges in isolation from other federal and state agencies and from the private sector, there are risks of duplication and inefficiency. It is, therefore, imperative that NOAA work with other producers and users to ensure that nautical data can be easily exchanged or linked with other data sets as a means for strengthening the overall NOAA nautical data program and providing a multipurpose digital nautical data base.

Congress attempted to recover the costs of creating, publishing, and distributing nautical charts and the associated data base when it imposed the data-base maintenance cost recovery requirement (44 USC 1307) on NOAA's chart sales. Recent trends in chart sales suggest, however, that this will not work under the circumstances that now confront NOAA. Additional funds could be sought in direct public appropriations (as done now) or in cost recovery from the sale of products based on NOAA data.

Reliance on direct appropriations requires repeated justification of funding levels in times of increasing restrictions on public expenditures. Benefit-cost assessments (Epstein and Duchesneau, 1987; Brinkman and Caverley, 1992; Coochey, 1992) have been attempted to determine the value of chart products, but ascertaining definitive valuations remains a difficult and uncertain task. Cost recovery (charging users directly for the cost—full or partial—of producing the product) is appealing because it reduces the need for artificial estimates and lets the market help determine product value. However, this approach is complicated by the nature of the NOAA product, which is primarily information. Information has what economists call public good attributes: once it is generated and published, many users can benefit from it without diminishing its value and at virtually no additional cost. For example, NOAA charts can be copied and resold without reimbursing the government, and evidence suggests that this practice is reducing sales of NOAA-printed charts. In any event, the revenues generated by NOAA chart sales at present do not revert to NOAA but rather to the miscellaneous receipts fund of the U.S. Treasury.

In the context of these difficulties, several means for increasing the resources available to NOAA for nautical charting were considered by the committee. Further investigation of the following approaches to resolving NOAA's resource constraints might be fruitful. It is likely that the optimal strategy will be a combination of several of the options described below.

Revenue Retention/Improved Incentives Through Product Partnerships

The most attractive and economically efficient approach may be for NOAA to use royalty (or licensing) fees from public/private partnerships to increase the level of revenue that it receives from the use of its data. Several alternative routes exist within this broad approach. In most cases, legislation would have to be enacted to allow NOAA to retain revenues arising from these arrangements.

NOAA Copyright on Nautical Charts

Copyrighting nautical charts has been suggested as a means to protect the U.S. government from the effects of unauthorized reproduction of NOAA charts. Copyright is an attempt to assign ownership to information. U.S. government-produced works are not copyrighted as a matter of policy (17 USC 105). Other nations do copyright their charts, and international agreements allow copying of such charts by other national authorities. As hydrographic offices come under increasing pressure to recover costs, they will likely attempt to make stronger use of copyright. (The International Hydrographic Organization is now addressing this question.) The issue becomes even more complex with digital data sets, because unauthorized duplication may become trivially easy and inexpensive.

While copyright authority is sometimes cited as a possible source of funds for federal programs that provide an information product, it is presently contrary to existing law and

arguably counter to basic tenets of the U.S. Constitution. Further, copyright by itself would not resolve NOAA's resource constraints.

Noncopyright Revenue Retention

A related approach is to seek support in Congress for a change in the Cost Recovery Act that will enable NOAA to retain funds that it recovers from the sale of charts and other products. Such an arrangement has existed for the U.S. Geological Survey since the early 1980s. For nautical charting this would involve changing the portion of the Cost Recovery Act that affects NOAA (44 USC 1304) to enable it to keep revenues resulting from the use of its data and spend those revenues on further improvement of the data. To prevent the recovered funds from being diverted to other uses within NOAA, the Nautical Charting Division could seek a mandate for the frequency and characteristics of chart updates as well as for the rate of introduction of new charts. This is similar to the approach now used for aeronautical charts.

Cooperative Research and Development Agreements

Even without copyright on government data or retention of revenues from government chart sales, it is possible for NOAA to obtain royalties from private-sector product dissemination through "cooperative research and development agreements" (CRADAs). Under 15 USC 3710, federal laboratories may "negotiate licensing agreements . . . for . . . intellectual property developed at the laboratory . . . or . . . voluntarily assigned to the Government." Royalties received from such agreements may be disbursed by the agency to its laboratories, and 15 percent (with a ceiling of $100,000 per year) may go to individual inventors (15 USC 3710c). Other agencies' experiences may be instructive: the U.S. Geological Survey has arranged several domestic CRADAs and is actively investigating foreign CRADAs, and the U.S. Army Corps of Engineers presently earns some $12 million annually from CRADA relationships.

License Fees and Private Copyright

If NOAA is not going to be able to secure copyright protection, a linchpin for revenue retention may lie in its data base rather than its printed products. If NOAA creates chart products through arrangements with private producers, the raw data-base versions of charts may be easier for NOAA to protect (through licenses) than printed or scanned equivalents.

For example, if NOAA supplies raw, certified digital data to private printing ventures that process the data through their own image production systems to generate chart products, the products might be able to be copyrighted by the private producer since they are not mere photographic copies of NOAA's digital charts and may or may not incorporate additional

enhancements that did not originate at NOAA. The case of *West Publishing Company v. Mead Data Central* (799 F.2d 1219 (8th Cir. 1986)) suggests that copyright protection can be extended to private electronic compilations of uncopyrighted government source data. NOAA could then collect user or license fees based on privately copyrighted product sales. Such user fees are likely to be easier to apply to raw digital data than to charts themselves. NOAA does not have the legal authority to do this at present, except pursuant to a CRADA.

Other Considerations

So long as NOAA continues to print charts that are not copyrighted, there will probably be those who simply copy the public domain charts and reprint them as they do now. The market incentive to carry some sort of official NOAA approval will lead some firms to work with NOAA in producing their chart products, once NOAA makes available its participation in the kind of collaborative certification procedures and partnerships described in Chapter 6.

In summary, cost recovery through royalties, license fees, and user fees is an effective and efficient means for meeting the congressional cost recovery mandate and for improving NOAA's funding for nautical charting. However, NOAA will have to seek enactment of legislation to allow these arrangements to be implemented.

Contract Surveys

As described in Chapter 6, significant opportunity exists for NOAA to benefit from the modem resources available in the private sector and through partnerships to conduct surveys, thereby leveraging the resources available to enhance the NIDB with new data. Contract surveys of areas critical to particular users could be performed with nonfederal (or Navy) funds to NOAA specifications. Additional opportunities exist to team with other agencies of the federal government, to leverage the sum of all federal funds applied to nautical charting and surveying to the taxpayer's advantage.

Harbor Maintenance Trust Fund

The Harbor Maintenance Trust Fund is fed by maritime cargo taxes and managed by the Corps of Engineers. The Water Resources Development Act (1986), as amended by the Omnibus Budget Reconciliation Act of 1990, provides that a specified portion of the proceeds from the fund are to be transferred to NOAA for its activities related to commercial navigation. However, no mechanism was provided in the law to allow this transfer to take place. As a result, the funds earmarked for NOAA's use are now sizable but cannot be allocated or used. Recent legislation aimed at making these funds available to NOAA (the Marine Navigation Safety and Improvement Act of 1993), while well intentioned, has been rejected by the Clinton administration because, under present federal budgetary constraints,

they would count against the Department of Commerce's discretionary appropriation caps. For NOAA, therefore, such funds do not represent any "new" revenues and must be offset by reductions in expenditures elsewhere if they are specifically earmarked for nautical charting.

This fund, which is substantial, appears to offer a potential resource, however, for making the investments needed to move into the digital era in nautical charting, and NOAA could benefit from investigating alternatives to making the Harbor Maintenance Trust Fund resources available to the nautical charting program as additional revenue. If money accumulated in the Harbor Maintenance Trust Fund in the past cannot be retrieved, NOAA could at least pursue Harbor Maintenance Trust Fund resources that will accumulate in the fund in the future.

SUMMARY

The need for accurate and up-to-date nautical charts and information—both graphic and digital—is to be supported by both the changing needs of traditional navigation users and the growth of a new community of users for environmental research and coastal and marine development and regulatory purposes. Yet the activities necessary to meet these expanding needs—additional and more rapid surveys, digitization of the existing information contained in paper charts, production of new suites of customized electronic and paper products—are generally unfunded, or at least insufficiently funded.

Part of the difficulty facing NOAA's nautical charting operations is that the economic consequences of less-than-adequate support have not been substantiated and articulated in a sufficiently convincing manner. The importance of maritime trade to the United States is well established. The benefits of investing an additional $20 million or $100 million annually in improvement and maintenance of nautical charts and information are not widely recognized. Studies of the value of nautical charting programs have provided interesting insights but have not convinced congressional or senior executive branch decisionmakers of the need for additional resources.

The committee's scope did not explicitly include analysis of budgetary aspects of NOAA's nautical charting mission. Consequently, it did not examine economic studies in detail or attempt to construct an argument for a particular level of investment or effort. At the same time, it is impossible to ignore the impact of growing budgetary constrictions on the ability of NOAA to make the transition to the new technological era of digital nautical charts described in this report and soon to be imposed by international regulation. Turning the situation around requires the immediate attention of the administration and Congress. Moreover, implementing the approaches to producing and disseminating nautical information products that are described in Chapter 6 and the strategies to recover revenues described in this chapter will require innovative, flexible, and imaginative leadership within NOAA, for they embody a new way of doing the public's business.

REFERENCES

Brinkman, G. L., and S. L. Caverley. 1992. Benefit-Cost Assessment of the Canadian Hydrographic Service. Report prepared by Intercambio Limited for Canadian Hydrographic Survey, Ottawa.

Coochey, J. 1992. An Economic Analysis of the Benefits of the RAN Hydrographic Program. Unpublished study prepared for the Royal Australian Navy.

Epstein, E. F., and T. D. Duchesneau. 1987. The Use and Value of Nautical Chart Information. Unpublished study for the National Ocean Service, NOAA.

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CONCLUSIONS AND RECOMMENDATIONS

For a variety of reasons, the National Oceanic and Atmospheric Administration's (NOAA's) Coast and Geodetic Survey stands at a critical juncture in fulfilling its nautical charting mission in the face of a rapidly changing technological environment and escalating user needs for new and improved nautical information products. The ability to respond to these forces of change is likely to be limited by the realities of level or decreasing resources, which is the pattern predicted for most government agencies given current federal budgetary pressures. NOAA must, therefore, make choices regarding the allocation of its resources among the three basic tasks that go into producing nautical charts and information products: collection and certification of survey data; processing and maintenance of a nationally certified nautical information data base; and production and distribution of certified data, charts and other products.

In the course of its investigation the committee determined that the key to successfully responding to these changes is for NOAA to focus its nautical charting and information program activities on the tasks associated with processing and maintaining the nautical information data base. Management and control of the content and quality of the data that support safe navigation are core functions for the public sector. The data base defines and accommodates the information from surveys and determines the quality and timeliness of products. The private sector can assist in data collection and product distribution using modem qualified technology and techniques, but NOAA alone can perform the central functions of data management and quality control.

Following are specific conclusions coupled with recommendations that, if enacted, will facilitate the transition to a new concept of NOAA's nautical charting mission as a partnership with other federal agencies, states, and the private sector.

CHANGING NEEDS FOR NAUTICAL INFORMATION PRODUCTS

Conclusions

- NOAA faces a changing customer base for nautical information products as well as a change in product requirements of the traditional navigation customer. Nautical information is increasingly being used for coastal management, development, and regulatory purposes. This community represents a prospective market for nautical information.

Commercial and military users are in transition to digital electronic chart systems. At the same time, many recreational and other mariners will, for the foreseeable future, still rely on paper charts, with a strong demand for customized and value-added products.

- The primary requirement of all users is for nautical information that is accurate, reliable, and timely. The existing process for incorporating new information and resurveys into new editions and new charts appears to be unnecessarily slow and cumbersome. Although there are systems under development at NOAA that are designed to alleviate this problem, it is not clear when they will be operational.

Recommendations

- **NOAA should pursue nautical charting strategies that are driven by the requirements of the navigational use of chart data but that do not preclude the use of those data for the production of a variety of nautical information products, including digital data to satisfy the needs of a broad range of users**.
- **Priorities for issuing new and revised charts should be placed on those areas where the greatest uncertainty in bathymetry or other hazards to navigation pose the greatest threat to the safety of people and ships**.
- **NOAA should establish new processes aimed at minimizing the time between the acquisition of new data and the publication of those data for public use**.
- **NOAA should establish a formal ongoing mechanism for obtaining information about the changing needs of users for nautical information products**.

SURVEY ACTIVITIES

Conclusions

- The nation has a large and growing backlog of requests for new surveys and charts. At the present level of effort, the backlog cannot be reduced.
- A capability to perform surveys exists both within the private sector and in other government agencies, such as the U.S. Army Corps of Engineers and the U.S. Navy.
- Cooperative ventures with the private sector and partnerships with other agencies and/or contracting arrangements with private contractors could accommodate much of NOAA's surveying mission.

- The current prioritization process for rating requests for new surveys and requests for new charts could be improved by a more explicit application of benefit-cost analysis to ensure efficient use of constrained resources.

Recommendations

- **NOAA should facilitate private contractor participation in performing the required surveying by providing opportunities for private companies to compete for contracts to survey areas where these activities are cost-effective for NOAA and profitable for the company. NOAA should adopt as its primary surveying role the following: setting standards that take full advantage of available technology; qualifying contractors; providing quality assurance of data from them and other government collectors (e.g., states, the Army Corps of Engineers); and setting priorities for areas to be surveyed**.
- **Although the committee recommends transferring the majority of surveying to private contractors, the federal government (NOAA in cooperation with the U.S. Navy and the Army Corps of Engineers) should maintain an in-house, state-of-the-art capability for hydrographic data collection to enable it to set standards, train personnel, develop and test advanced technology, and meet national requirements**.
- **NOAA should adopt a more explicit approach to benefit-cost analysis, such as described in Appendix E, to ensure the efficiency of prioritization procedures for conducting new surveys and issuing new charts**.

DATA-BASE DEVELOPMENT AND MANAGEMENT

Conclusions

- NOAA is producing digital data bases of its current charts and is developing the Automated Nautical Chart System (ANCS II) to greatly facilitate the chart updating process. The population of the master digital nautical data base is essential to the development of a wide range of nautical information products demanded by both traditional navigational users and new users for coastal management and environmental assessment purposes.
- Many coastal states are developing data bases for use in their coastal environmental assessment, planning, regulatory, and development activities. Linkage between state and federal data bases would improve the allocation of scarce public resources for these activities.

Recommendations

- **Development, maintenance, certification, quality control, and evolution of a single digital nautical data base should be NOAA's *core mission* in nautical charting and information. NOAA should not divert its efforts into maintaining any data base that is not central to the digital nautical data base (e.g., a raster data base**).
- **The digital nautical data base developed and maintained by NOAA should be designed—insofar as is feasible—to enable its use as a component of broader marine geographic information systems. Linkages with other agencies' (and other internal NOAA) data bases and with state data bases should be fostered to improve efficiency and coverage** .
- **NOAA should collaborate with the U.S. Geological Survey on defining a single, consistent national shoreline**.

CHART PRODUCTION AND DISTRIBUTION

Conclusions

- Demand is growing for customized and value-added nautical chart and information products. There is also an emerging demand for digital products that is likely to increase rapidly with the advent of an internationally certified electronic chart display and information system (ECDIS). The private sector is capable of developing and providing value added products that accommodate new needs (like electronic charting and GISs) and better serve the large number of noncommercial users, while simultaneously generating revenue for NOAA through licensing.
- Concerns about liability and copyright are legitimate and need to be addressed; however, they are not absolute barriers to public/private partnerships in the area of nautical charts. Existing regulations governing charts may need to be revised.

Recommendations

- **NOAA should increasingly rely on the private sector for chart production and distribution activities. NOAA's in-house production resources should be concentrated on data-base development, quality control, and maintenance**.
- **NOAA should form partnerships with private companies through such mechanisms as Cooperative Research and Development Agreements (CRADAs),**

licensing, and certification arrangements, which generate revenue that can be spent on developing and maintaining the nautical information data base.

- **Implementation of recommendations regarding extensive industry participation in data collection and product production and distribution raises issues of liability and copyright. NOAA should seek resolution of these problems. Where necessary, it should seek enactment of legislation to allow the formation of partnerships with the private sector for these activities**.

RESOURCES FOR NOAA'S NAUTICAL INFORMATION PROGRAMS

Conclusions

- In order for its nautical chart and information activities to move efficiently into the digital era, NOAA will need to find additional sources of revenue to support these programs. The level and declining funding patterns of the past 5 years will not support the costs of digitization of the data base and the extensive new surveys necessary to reduce the backlog of survey requests and requests for new charts.

Recommendations

- **NOAA should explore avenues for entering into arrangements with private companies in which NOAA will obtain a share of revenues, royalties, or fees in exchange for use of NOAA-certified data in value-added nautical information products produced and distributed by the private company. Where necessary, NOAA should seek enactment of legislation to enable it to retain funds generated from arrangements with private-sector partners**.
- **NOAA should seek mechanisms that will enable it to receive as additional funding some portion of the proceeds from the Harbor Maintenance Trust Fund for use in activities related to nautical charting, as intended in the original and modifying legislation establishing this fund**.

IMPLEMENTING CHANGE

Implementation of the strategies recommended above will require innovation and openness to change on the part of NOAA's management. Existing institutional arrangements and strategies may not be adequate in the future, when the task to be completed has evolved into a new form and new technological capabilities make old approaches obsolete.

APPENDIXES

APPENDIX A

BIOGRAPHIES OF COMMITTEE MEMBERS

CRAIG E. DORMAN (*Chairman*) was previously Director of the Woods Hole Oceanographic Institution and is now serving as Deputy Director, Research and Engineering, for Laboratory Management in the Department of Defense. He spent 26 years in the U.S. Navy, retiring with the rank of Rear Admiral after serving as Program Director for Antisubmarine Warfare of the Space and Naval Warfare Systems Command. He also served on underwater demolition teams and as a U.S. Navy SEAL. His distinguished military career includes the honors of Legion of Merit, Meritorious Service Medal, and Navy Commendation and Achievement Medals, among others. Dr. Dorman serves on numerous advisory boards (including the Massachusetts Maritime Academy Board of Trustees), has served on the National Research Council (NRC) Ocean Studies Board, and currently serves on the NRC Board on Atmospheric Sciences and Climate. Dr. Dorman received his B.S. (geography) from Dartmouth College, an M.S (oceanography) from the Navy Postgraduate School, and a Ph.D. in oceanography from the Massachusetts Institute of Technology/Woods Hole Joint Program.

SAUL DINMAN is President of Custom Computer Services, a systems integration firm in Waquoit, Massachusetts. He was previously Director of Technology for NAVIONICS, a manufacturer of nautical electronic charts. Mr. Dinman is a computer industry veteran with more than 30 years of experience in computers and computer applications, specializing in data-base and local area network architecture. He has held positions at major U.S. corporations, including Digital Equipment Corporation, the Foxboro Company, RCA, and IBM, where he was responsible for computer technology in advanced control technology applications. In addition, he founded GRI Computer Corporation, a company devoted to the design and manufacture of high-performance, 16-bit minicomputers. Mr. Dinman also has extensive experience in technical communications. He was editor-in-chief of the magazine *Computer Design*, and editorial director of a group of high-technology magazines. Mr. Dinman's background includes marine applications, such as offshore drilling platform automation and research vessel instrumentation, and he is an avid amateur sailor and navigator. He holds a BSEE from Pennsylvania State University and did graduate work in applied mathematics at the Massachusetts Institute of Technology.

STANLEY K. HONEY is Executive Vice President for Technology of News Corporation Limited and was previously the founder, President, and Chief Executive Officer of Etak, Inc. His present responsibilities include managing the News Technology Group of News Corporation Limited, which develops sophisticated new media technologies. This group includes News Datacom, which develops unique technology in the fields of encryption

and media access control; News New Media, which develops CD-based electronic reference products; and Etak, Inc., which designs nationwide map data for commercial use and consumer products applications for vehicles, homes, offices, and hand-held products. Etak's digital map data bases cover 75 percent of the United States and the metropolitan areas in Germany, France, and the Netherlands. Mr. Honey's career has included experience as a research engineer in the fields of radio location, signal processing, and underwater instrumentation. He holds patents in navigation and map display, and is active as a navigator in offshore yacht racing, most recently winning awards in the 1992 Pacific Cup Race. Mr. Honey received a MSEE degree from Stanford University and a BSEE from Yale University.

VICTOR V. KLEMAS is professor of marine studies, Director of the Center for Remote Sensing, and Director of the Applied Ocean Science Program at the University of Delaware. His research areas include the application of remote sensing and geographic information systems to studies of the coastal environment and management of marine resources. He has published 65 journal articles and is a member of the editorial boards of four scientific journals. Dr. Klemas has served on a number of government advisory committees and NRC panels, including the Space Studies Board's Committee on Earth Studies, the Panel on the National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Program, and the Space Applications Board. He also consults regularly for UNESCO, UNDP, the World Bank, foreign governments, and commercial firms. Dr. Klemas holds degrees from Massachusetts Institute of Technology (B.S. and M.S. in electrical engineering) and the University of Braunschweig, Germany (Ph.D. in optical physics).

JON A. LUCY is a marine recreation specialist for the Department of Advisory Services of Virginia Institute of Marine Science and an instructor in the School of Marine Science at the College of William and Mary. An expert in all areas of marine recreation, Mr. Lucy's research focus is in sport fishery and urban waterfront studies. He has authored 30 publications on recreational uses of the sea and coasts—including a boater's weather guide, marina and waterfront utilization analyses, and characteristics of the recreational marine fishery. He sits on several regional and state advisory committees, including the Atlantic States Marine Fisheries Commission's Recreational Fisheries and Artificial Reef committees, the Northeast Regional Fishing Vessel Safety Committee, and the Virginia Boating Advisory Board. Mr. Lucy holds a B.S. in biology from the University of Richmond and an M.A. in marine science from the College of William and Mary.

HENRY E. MARX is owner and President of Landfall Navigation. He purchased the company in 1982 after many years in the corporate world in management and finance positions. His company offers an expanded worldwide nautical chart, publications, and navigation instrument inventory; a large maritime technical library; a full line of marine safety equipment; a marine purchasing service for yacht owners; a referral service for licensed delivery captains; and navigation and marine safety seminars and onboard instruction. As part of marine education efforts, Captain Marx produced an instructional videotape entitled "Loran C—A Navigator's Approach," and holds copyrights on two

navigation courses. An experienced blue-water sailor—he has sailed and raced for over 40 years—Captain Marx was a director of the Wild Goose Association, the professional LORAN C Industry Association, and holds a U.S. Coast Guard license to operate passenger-carrying vessels for not more than 50 gross tons. He received his B.S. in economics and finance from the University of Hartford, and an M.B.A. from the University of Connecticut.

JACQUES B. MICHELL is a veteran Mississippi River pilot, with nearly 20 years experience and over 4,000 pilotage transits on a variety of vessels. He is licensed as a first-class pilot of steam or motor vessels of any gross tonnage on the Mississippi River and a bar pilot for the Port of New Orleans. Captain Michell is a member of many professional and technical organizations, including the International Organization of Masters, Mates & Pilots; the American Pilots Associated and Branch Pilot organizations; and the Port Activities Committee of the World Trade Center of New Orleans. A recognized expert on navigation, safety, and aids to navigation, Captain Michell has provided expert witness testimony and consulted in cases of ship groundings and deficiencies in aids to navigation. He is also an invited lecturer on pilotage for the International Program for Port Planning and Management, Louisiana State University Ports & Waterways Institute, and the University of New Orleans, and has given presentations on navigation and shiphandling at professional symposiums and workshops.

MICHAEL A. STALZER is a ship's officer with 20 years of active sea duty, 12 as a captain and pilot. He is a retired master for Exxon Shipping Company. He holds licenses as a master (any tonnage on oceans) and pilot (unlimited tonnage, Prince William Sound, Alaska). Captain Stalzer's technical specialties include integrated vessel bridge design, and he has been actively engaged in vessel safety design considerations using electronic chart and information computer displays. He is a member of the Navigation Panel that is testing the provisional ECDIS (electronic chart display and information system) standards for the United States. Captain Stalzer holds a B.S. from the U.S. Merchant Marine Academy and a Master of Engineering from the University of Virginia. Additional professional training includes a shiphandling course in Sogreah, France, and a Marine Safety International simulator course for handling tankers. He has served as an instructor for integrated bridge system training courses.

LOWELL E. STARR is Technical Advisor for International Federal Systems of Intergraph Corporation, Reston, Virginia. Prior to this position, he spent over 33 years with the National Mapping Division of the U.S. Geological Survey (USGS), where he was Chief of the National Mapping Program from 1986 through 1991. At the USGS, he led a task force that initiated modernization of the National Mapping Program and chaired the Digital Steering Committee. This committee's efforts resulted in implementation of a new generation of advanced mapping instrumentation. Mr. Starr has served as Chairman of the Federal Interagency Coordinating Committee on Digital Cartography and on the Department of the Interior Digital Cartography Coordination Committee. He received a B.S. in geology from Kansas State College and pursued postgraduate studies at the University of Missouri.

PHILIP J. STUTES is Senior Vice President of Operations for John E. Chance & Associates, Inc., a hydrographic surveying company. He has been with the company since 1969, where he has worked in various aspects of land and offshore surveying and drilling, led special research and development projects, managed the offshore division, and served as president of a joint venture to build a private satellite positioning system. Mr. Stutes has been active in satellite positioning since its entrance into the commercial market and has participated in international symposiums on satellite surveying. Mr. Stutes is a Fellow of the American Congress of Surveying and Mapping, and a past president of the Louisiana Society of Professional Surveyors. Mr. Stutes holds a B.S. from the University of Southwestern Louisiana and an M.S. from Purdue University (both in civil engineering), and is a graduate of the Louisiana State University Executive Program.

PETER R. TATRO is presently a consultant to Science Applications International Corporation (SAIC). He was formerly Senior Vice President at SAIC, where he managed 200 scientists and engineers working on a wide variety of projects, including ocean prediction computer programs, analysis of oceanographic data and archiving, and shore-based computers providing strategic and tactical acoustic predictions for operating forces. During his 20 years of Navy service, Dr. Tatro established an in-house research group at the Naval Research Laboratory, and was a pioneer in the development and dissemination of numerical ocean and tactical forecasts. He received a BME degree from the Georgia Institute of Technology, attended the Air-Ocean Environment Curriculum of the U.S. Naval Postgraduate School at Monterey, and earned a Ph.D. degree in oceanography from the Massachusetts Institute of Technology.

APPENDIX B

OTHER AGENCIES' ACTIVITIES, ROLES, INTERESTS

Although the National Oceanic and Atmospheric Administration (NOAA) has the primary responsibility for charting the nation's waters, other federal agencies conduct activities that intersect with NOAA in this area. Following is a brief description of these other federal activities and roles.

The Defense Mapping Agency

In 1972, the Defense Mapping Agency (DMA) was established to consolidate the various unique mapping organizations in each of the nation's military departments. DMA provides mapping, charting, and geodetic information to all elements of the Department of Defense to ensure the highest state of operational readiness of the U.S military forces and their navigation, weapon, and command and control systems. DMA also has statutory responsibilities to support the civilian sector, particularly with respect to nautical information.

DMA maintains a worldwide nautical chart portfolio for defense use and produces nautical charts of waters other than those of the United States or its territories, which are the responsibility of the National Ocean Service. DMA contributes to the maintenance of the NOAA chart data base and is the largest single customer for NOAA charts.

Nautical charts require frequent correction in order to support safe navigation, and DMA has assumed the responsibility on behalf of both agencies for disseminating corrections for both sets of charts through weekly Notices to Mariners. In addition, DMA as part of an international radio warnings service is responsible for preparing coastal and high seas navigational radio warnings, and is the coordinator of two of the sixteen Navigational Warning areas that cover the world.

Although DMA's charting mission is to respond to Department of Defense requirements, DMA's statutory responsibility to the civil sector requires that it make available to the mariner in general products such as nautical charts and Notices to Mariners that enhance maritime safety. DMA provides these services through the commercial sales agent network managed by NOAA.

The production of nautical charts involves collection of data from many sources. Because DMA's charting focus is on non-U.S. waters, the majority of its charts are based on information received from the national hydrographic authorities of other nations. To facilitate this, DMA shares with NOAA the role of National Representative to the International Hydrographic Organization, which allows the United States to benefit from the free exchange of hydrographic information with 57 other countries. Further, all member

states of the International Hydrographic Organization collect data and produce charts to agreed-upon international standards, which provide quality control.

When surveys of foreign waters are required, DMA normally relies on the Navy for data collection, or may contract with NOAA, if necessary. When surveys of U.S. waters are needed, DMA will always request that NOAA take this action. If civilian priorities or a lack of resources prevent timely response, DMA takes action to satisfy the requirement, either by contracting with NOAA to put some of its reserve assets into service or by tasking the Navy to carry out the survey.

The U.S. Navy

The Navy's interest in nautical charts is linked to concerns about national security, effectiveness of weapons, and the safety of its ships and crews. Since the end of the Cold War, the focus of Navy interest has shifted from deep water to the littoral and coastal waters, where requirements for accuracy are more rigorous—particularly for driving submarines.

The Navy prefers not to use its resources to survey U.S. waters and seeks to meet its needs through NOAA. However, the Navy has a number of data collection platforms. In the future, the emphasis will be on multipurpose platforms that can collect a variety of data (e.g., geophysics, geodesy) in various locales (e.g., shallow water, deep water).

The Defense Hydrographic Initiative

In 1991, DMA, the Navy, and NOAA entered into a cooperative agreement known as the Defense Hydrographic Initiative to provide formal coordination among these agencies for collection, processing, archiving, analysis, integration, production, and distribution of hydrographic and bathymetric data. The Defense Hydrographic Initiative is also intended to serve as a link among these agencies in making and supporting the transition to digital nautical products by ensuring cooperation and continuity in research, development, production, and distribution of digital hydrographic and bathymetric products. DMA and the Navy foresee the advent of a "paperless" bridge on naval ships by the end of the century.

Each member agency agrees to participate in cooperative efforts to the extent of its respective resource availability. A Master Seafloor Digital Data Base is being developed to provide the Navy with the information necessary for advanced warfare in the future. It is hoped that this data base will be compatible with the civilian data base. However, there are different constraints involved in defense data that will require an interface to the civilian system.

Army Corps of Engineers

The Army Corps of Engineers' (the Corps) primary activity relating to nautical charting is that of a developer and provider of hydrographic data associated with engineering

surveys. To a lesser extent, the Corps' dredging, project operations and maintenance, and survey fleet are users of nautical chart products.

The Corps deploys approximately 90 hydrographic survey teams (both in-house and contract), disbursed nationally, for an effort of approximately $40-50 million annually. This survey capability is located at most of the nation's major rivers and harbors, including coastal, intracoastal, and inland waterways. Survey data products and format are more engineering in nature than NOAA nautical charts, typically large-scale (1:1,200 or 1:2,400) detail drawings of project depths and limits, and include details of significant berthing or embankment structures, navigational aids, river stabilization structures, and applicable hydraulic/hydrologic data.

Corps of Engineers' products are routinely distributed to local project (e.g., dredging) sponsors, port authorities, pilots, the U.S. Coast Guard, and NOAA's Coast and Geodetic Survey. The Corps also surveys many areas not covered by NOAA charts, such as the Mississippi, Missouri, and Ohio Rivers, and other inland waterway systems. The Corps relies heavily on private surveying and mapping firms to supplement its in-house hydrographic survey capability. Dredging contracts and other marine construction contractors also maintain an extensive hydrographic survey capability when working on Corps of Engineers' contracts.

The U.S. Coast Guard

The Ports and Waterways Safety Act (33 USC 1221) tasks the Coast Guard with the responsibility for ensuring navigation safety. In carrying out this task, the Coast Guard is responsible for aids to navigation, overseeing the nationwide dissemination of navigation safety information, and waterway management issues such as shipping safety fairways, traffic separation schemes, and Vessel Traffic Services (VTS).

The nationwide dissemination of navigation safety information is primarily in the form of Notices to Mariners, which provide mariners with specific hazard or marine safety information that is newly discovered and that normally has not previously been indicated on the charts. This requires coordination among the Coast Guard, NOAA, the Army Corps of Engineers, and occasionally the Defense Mapping Agency. Notices to Mariners issued by the Coast Guard differ from the Notices to Mariners issued by DMA. DMA's mandate is directed toward defense, and the DMA weekly Notice to Mariners contains only information affecting deep draft waters and vessels. In contrast, the Coast Guard Notices to Mariners cover all U.S. waters, regardless of water depth or vessel draft.

On a weekly basis, each Coast Guard district publishes a Local Notice to Mariners that contains information concerning aids to navigation, obstructions, channel depths, and other important safety information. The information is received from Coast Guard units, NOAA and its survey vessels, the Corps of Engineers, other federal and state agencies, and the general public. These notices are essential to all mariners to keep their nautical charts and publications up-to-date.

The Maritime Administration

The Maritime Administration (MARAD) has, as part of its mission, the identification, development, and assessment of innovative technology for improvements in efficiency, productivity, safety, competitiveness, and environmental protection of the U.S. flag merchant marine. In pursuing these concerns, MARAD is particularly interested in the progress of the electronic chart technology, which is an essential part of automated integrated navigation systems that are now under development. Of special concern are the reliability and accuracy of the underlying digital chart data base in order to provide the knowledge for these automated systems.

The U.S. Geological Survey

The U.S. Geological Survey (USGS) has broad interests in ocean mapping both in relation to its overall mission of mapping the U.S land and through other interests, such as the surveys of the seabed in the U.S. Exclusive Economic Zone (EEZ). The USGS and NOAA have operated a Joint Office of Mapping and Research in the EEZ under a memorandum of understanding since 1984.

Among the issues of interest to the USGS are the modernization of spatial mapping and data systems and the development of digital geographic information systems. The USGS is particularly interested in ensuring that standards are established regarding classification, format, and data transfer, and is involved in establishing a national spatial data infrastructure that will include a clearinghouse, metadata (to define standards and describe data heritage), and classification issues (e.g., achieving consistency in naming locales and geographic attributes) that have been resolved.

APPENDIX C-1

NAUTICAL CHART AND INFORMATION SURVEY

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington, D.C. 20418

MARINE BOARD
February 17, 1993
MB-93-189

OFFICE LOCATION
Georgetown Facility
Room HA 250
2001 Wisconsin Avenue, N.W.
Telephone (202) 334-3119
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TO: USERS OF NOAA NAUTICAL CHARTS AND INFORMATION

FROM: DR. CRAIG E. DORMAN, CHAIRMAN Craig E. Dorman / MS
COMMITTEE ON NAUTICAL CHARTS AND INFORMATION

SUBJECT: SURVEY OF NAUTICAL INFORMATION NEEDS

At the request of the National Oceanic and Atmospheric Administration (NOAA), the Marine Board[1] has convened a Committee on Nautical Charts and Information to ascertain the needs of mariners and other users for nautical charts and related information products and to identify changing requirements for these products. You (or a member of your organization) are requested to participate in a survey of national needs, trends, and opportunities in nautical charting and information by responding to the enclosed questionnaire.

NOAA produces and maintains nearly one thousand nautical chart editions, plus over four hundred bathymetric charts, nine coast pilots, and numerous miscellaneous supporting publications. Digital chart products, which use a digital data base to produce a chart directly on a video screen, are also becoming increasingly available (although not legally certified at the present time). NOAA's resources for chart updating are not sufficient to update and re-issue each of its many products annually. It is necessary to prioritize the updating process and to determine the appropriate balance between updating existing charts and producing new charts, using objective criteria for making these decisions.

Based on the responses to the attached questionnaire and other information-gathering activities, the Committee on Nautical Charts and Information will prepare a public report that provides guidance to NOAA on priorities for updating charts and producing new charts, and on the role of NOAA in meeting future demands for new kinds of nautical information products using advanced technologies.

A list of the members of the committee conducting this study and the committee's terms of reference are attached for your information. Please call Susan Garbini of the Marine Board staff at 202/334-3119 if you have any questions relating to the project. A return envelope is included for mailing the questionnaire; your response is requested no later than **May 31, 1993**. Thank you for your assistance.

Enclosures

[1] The Marine Board operates under the auspices of the National Research Council and is an independent, official advisor on ocean uses and marine affairs.

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

Nautical Chart and Information Survey

Instructions:

All respondents please complete

section A: Respondent Information and

section B: General Questions.

As appropriate to your specific field of interest, also complete

section C: Mariner Supplemental Questions,

section D: Planner/Researcher Supplemental Questions, or

section E: Data Reseller Supplemental Questions. section F: Supplemental Questions on Electronic Charts

All respondents are requested to review questions in section F and to respond if they have an interest in electronic data.

Please feel free to attach additional comments on the subject of nautical chart and information products, and return the completed questionnaire by February 22, 1993 to:

Susan Garbini
National Research Council
Marine Board
2101 Constitution Avenue
Washington D.C. 20418
phone 202-334-3119
fax 202-334-3789

A. Respondent Information

A1. Name: _____

A2. Affifliation: _____

A3. Address: _____

_____

_____

_____

A4. Phone Number: _____ Zip Code _____

Area Code

B. General Questions

All respondents: please complete the questions in this section. Skipany question that does not apply to your present or potential useof nautical charts and other nautical information products.

B1. In what capacity do you or would you use nautical charts/information? Please check all that apply.

____ recreational boating/fishing
____ commercial fishing
____ commercial piloting
____ commercial ferry operations
____ commercial cargo shipping
____ oil and gas exploration/transportation
____ other (please specify) _____

____ real estate
____ scientific research
____ coastal zone planning/policy
____ military
____ data repackaging/reselling

B2. Which of the following regions (U.S. waters) are of direct interest to you? Please check all that apply.

____ Mid-Atlantic
____ northeast Atlantic
____ southeast Atlantic
____ Gulf of Mexico
____ northwest Pacific
____ southwest Pacific
____ Alaska

____ Hawaii
____ Great Lakes
____ Mississippi River system
____ other river system(s) (please specify)
_____
____ other (please identify)
_____

B3. Do you presently use nautical chart/information products?

____ yes ___ no

If no, please skip Questions B4 through B8, and continue with Question B9.
If yes, what kind of nautical chart information products do you use?

government produced
____NOAA/NOS charts
____DMA charts
____foreign charts

commercially produced
____ Chart "books"
____ EPROM cartridges (electronically programmable memory cartridge)
____CD-ROM scanned charts (electronic data on optical disc)
____other (please specify)
_____

B4. If you use commercially produced nautical chart/information products, what are the reasons? Please indicate and rate all that apply. Use "1" for the most important, "2" for the second, etc.

____ cost

____ additional information included

____ size/format of paper product

____ convenience of book format

____digital format

____other (please specify) _____

B5. What other nautical information products do you use?

government produced

____NOAA/NOS Coast Pilots

____NOAA/NOS Tide Tables

____NOAA/NOS Tidal Current Tables

____DMA Sailing Instructions

____USCG List of Lights

____foreign publications

____other (please specify)

commercially produced

____ cruising guides

____ other (please specify)

_____

_____

B6. If you use commercial nautical information products other than charts, why do you buy these products?

____ easier to use

____ cost

____ format

____ information not available in government publications (please specify what information)
_____

____ other reason (please specify)
_____

B7. Do you update your charts and publications?

____ yes ____ no

If yes, approximately how often?

____ daily ____ monthly

____ weekly ____ annually

B8. How do you update your charts and publications? Please check all that apply.

____ Coast Guard Notices to Mariners, voice broadcasts

____ Coast Guard Notices to Mariners, local printed mailings

____ NAVTEX (Navigation Text radio receiver)

____ DMA weekly Notices to Mariners

____ DMA Navigation Information Network (NavInfoNet)

____ purchase new chart editions

B9. Do the currently available nautical chart/information products meet all of your needs?

____ yes ____ no

If not, please indicate the deficiencies.

____ information content

____ accuracy

____ currency

____ scale

____ coverage scheme

____ not available on digital media

____ other (please specify)

_____
_____

B10. What additional information would you like to see included in the standard chart/information product?

_____
_____

B11. What information presently included on charts would you like to see omitted?

_____
_____

B12. Do you have any interest in new paper nautical information products?

____ custom paper chart products

____ paper charts on waterproof paper

____ other (please specify)

_____
_____

B13. Do you have any interest in new digital nautical information products?

____vector data sets for navigation information

____raster scanned data sets for navigation information

____custom digital data sets

____other (please specify)

_____

B14. Would you purchase such images

____ from NOAA/NOS?

____ from private operations?

B15. How much would you be willing to pay for such images (or data), per standard NOAA chart equivalent?

____ US$ for NOAA/NOS-produced images

____ US$ for privately produced images

Thank you for participating in this survey effort! Your responses will assist the Marine Board in guiding NOAA/NOS and the private sector to better meet the needs of all nautical chart and information users. Please review and respond to supplemental questions as appropriate to your field of interest.

C. Mariner Supplemental Questions

Please complete the questions in this section only if you use nautical chart and information products for the purpose of navigation.

C1. Type of vessel you normally navigate.

____ sail
____ power
____ bulk carrier
____ recreational
____ general cargo
____ tug, tow, or push boat
____ tanker
____ small commercial fishing
____ other (please specify)
_____

C2. Size of vessel you normally navigate.

length over all:
____ under 18 feet
____ 19-30 feet
____ 31-65 feet
____ 65-300 feet
____ over 300 feet

displacement (grt):
____ under 500 tons
____ 500-1500 tons
____ 1500-10,000 tons
____ over 10,000 tons

C3. Years of maritime experience.

____ less than 2 years
____ 2 to 5 years
____ 6 to 10 years
____ more than 10 years

C4. Maritime licenses/certificates held.

____ U.S. Coast Guard Merchant Marine
____ Foreign Merchant marine
____ U.S. Power Squadron Certificate
____ U.S. Coast Guard Auxiliary Certificate
____ none

C5. Navigation equipment on your vessel (or that you regularly use) (please check all that apply).

____ magnetic compass
____ gyro compass
____ radio direction finder (RDF)
____ NAVTEX receiver
____ Loran-C
____ Omega
____ GPS (Global Positioning System receiver)
____ DGPS (Differential GPS receiver)
____ radar
____ ARPA (Automatic Radar Plotting Aid)
____ video plotter
____ electronic chart (ECDIS)
____ other _____

C6. If you currently use an electronic chart product, does it operate with

____ digital vector data?
____ raster scanned image data?
____ don't know

If you do not currently use an electronic chart product, do you expect to outfit your vessel(s) with such products in the next five years?

____ yes ____ no ____ may be/don't know

C7. What type of navigation do you spend most time and effort on? Please rank all that apply, using "1" for the most common, "2" for the second, etc.

____ oceanic
____ inshore
____ offshore
____ channel/waterway
____ approach
____ harbor
____ river
____ lake

C8. What do you use the chart for? Please rank all uses that apply to you, using "1" for the most common, "2" for the second, etc.

____ route planning
____ route following/monitoring and position plotting
____ avoiding hazards
____ recording trip
____ browse for interesting destinations
____ other (please specify)

_____

C9. Comments

_____
_____
_____

D. Planner/Researcher Supplemental Questions

Please complete the questions in this section only if you use, or would like to use, nautical chart and information products for the purpose of planning policy analysis, scientific research, preparing environmental assessments, or other non-navigation activities.

D1. Please describe your line of work.

____ real estate development

____ surveying properties

____ local/state coastal zone planning

____ environmental assessment

____ climate research

____ fisheries research

____ offshore minerals

____ oceanographic research (please specify field)

_____

____ other (please specify)

_____

_____

D2. What kind of data do you presently use?

____ bathymetric data, paper-based

____ bathymetric data, digital

____ nautical chart data, paper-based

____ nautical chart data, digital

D3. How do you or would you use these data? Please check all that apply:

____ basis for computer models/simulations

____ graphical presentations and diagrams

____ reference points for measurements/surveys

____ other (please specify)

_____

D4. Comments

_____

_____

_____

E. Data Reseller Supplemental Questions

Please complete the questions in this section only if you use, or would like to use, nautical chart and information products for the purpose of repackaging, reformatting and/or reselling the data.

In answering all of the following questions, assume that NOAA/NOS provides nautical chart data sets to organizations like your own.

E1. Would your company augment the base set obtained from NOAA by display or information layers from other sources?

____ yes ____ no

If yes, please describe: _____
_____

E2. Would your company provide users with calculation functions (such as distance, bearing, position fixing, forecasting, etc.) based on the geographic data provided by NOAA?

____ yes ____ no

E3. Recognizing that there are likely to be legal implications for the presentation of inaccurate geographic information, and assuming that NOAA certifies its base data to be accurate, is your company willing to assume liability for the accurate reproduction of the base data, overlays of additional data not sourced from NOAA, and/or any calculations based on the data?

____ yes ____ no

Comments: _____
_____

E4. Do you expect your company to provide systems based on NOAA data that would be used in critical applications (such as systems that can directly affect public safety, health, or welfare)?

____ yes ____ no

F. Electronic Charts Supplemental Questions

Please complete the questions in this section if you are familiar with electronic nautical data for display on video screens.

Questions F1-F6 refer to raster scanned images, in digital format, of NOAA/NOS nautical charts.

F1. If raster scanned images of nautical charts were made available, what would be your format preference?

____ TIF

____ PCS

____ other (please specify) _____

F2. What level of resolution would you prefer for raster scanned images?

____ 150 dpi

____ 300 dpi

____ 600 dpi

____ 800 dpi

____ other (please specify) _____

F3. What would be your preference for distribution media of raster scanned images?

____ 3.5 inch HD floppies

____ 5.25 inch HD floppies

____ CD-ROM

____ 3M tape cartridge (please specify preferred format, such as QIC-40)

_____

____ other (please specify)

_____

F4. With what application software would you use the raster scanned nautical date? If custom software, please describe its purpose.

_____

_____

F5. Would you purchase such images

____ from NOAA/NOS?

____ from private operations?

F6. How much would you be willing to pay for such images, per standard NOAA chart equivalent?

____ US$ for NOAA/NOS-produced images

____ US$ for privately produced images

Questions F7-F12 refer to digital vectordata sets. You may skip these questions if you are not familiar with the concept of digital vector data.

F7. Would you be likely to buy digital nautical data sets in the "seamless" DX-90 format?

____ yes ____ no ____ may be/don't know

F8. Would you be likely to buy digital nautical data sets available for single standard NOAA/NOS charts?

____ yes ____ no ____ may be/don't know

F9. What distribution media would you prefer for vector digital data sets?

____ 3.5 inch HD floppies

____ 5.25 inch HD floppies

____ CD-ROM

____ 3M tape cartridge (please specify preferred format, such as QIC-40)

_____

____ other (please specify)

_____

F10. With what application software would you use the vector data sets? If custom software, please describe its purpose?

_____

_____

F11. Would you purchase such data sets

____ from NOAA/NOS?

____ from private operations, if based on official NOAA/NOS data?

F12. How much would you be willing to pay for such data, per standard NOAA chart equivalent?

____ US$

F13. Comments

_____

_____

_____

End of Questionnaire

APPENDIX C-2

RESPONSES TO SURVEY

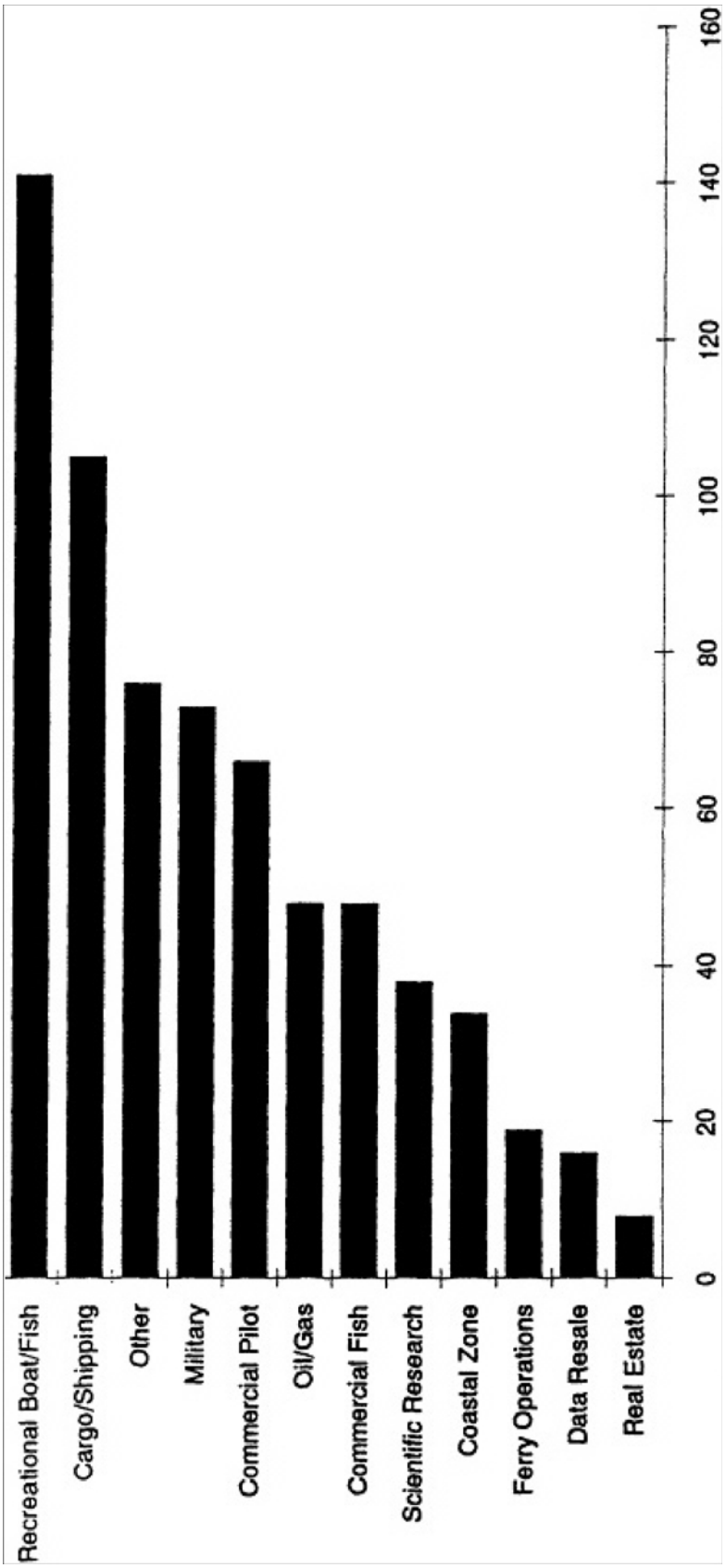

Figure C-2-1 Respondents by Primary Use

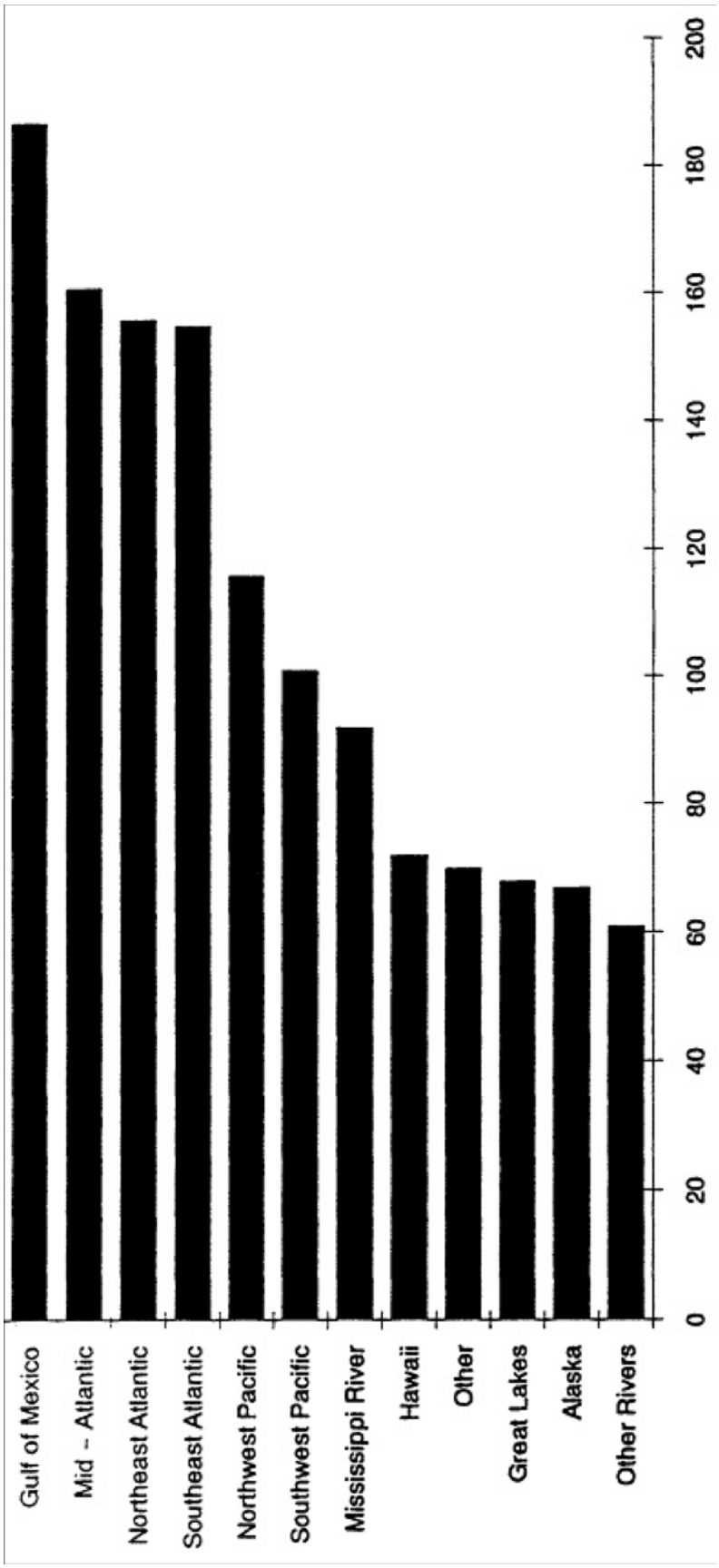

Figure C-2-2 Primary Operating Area

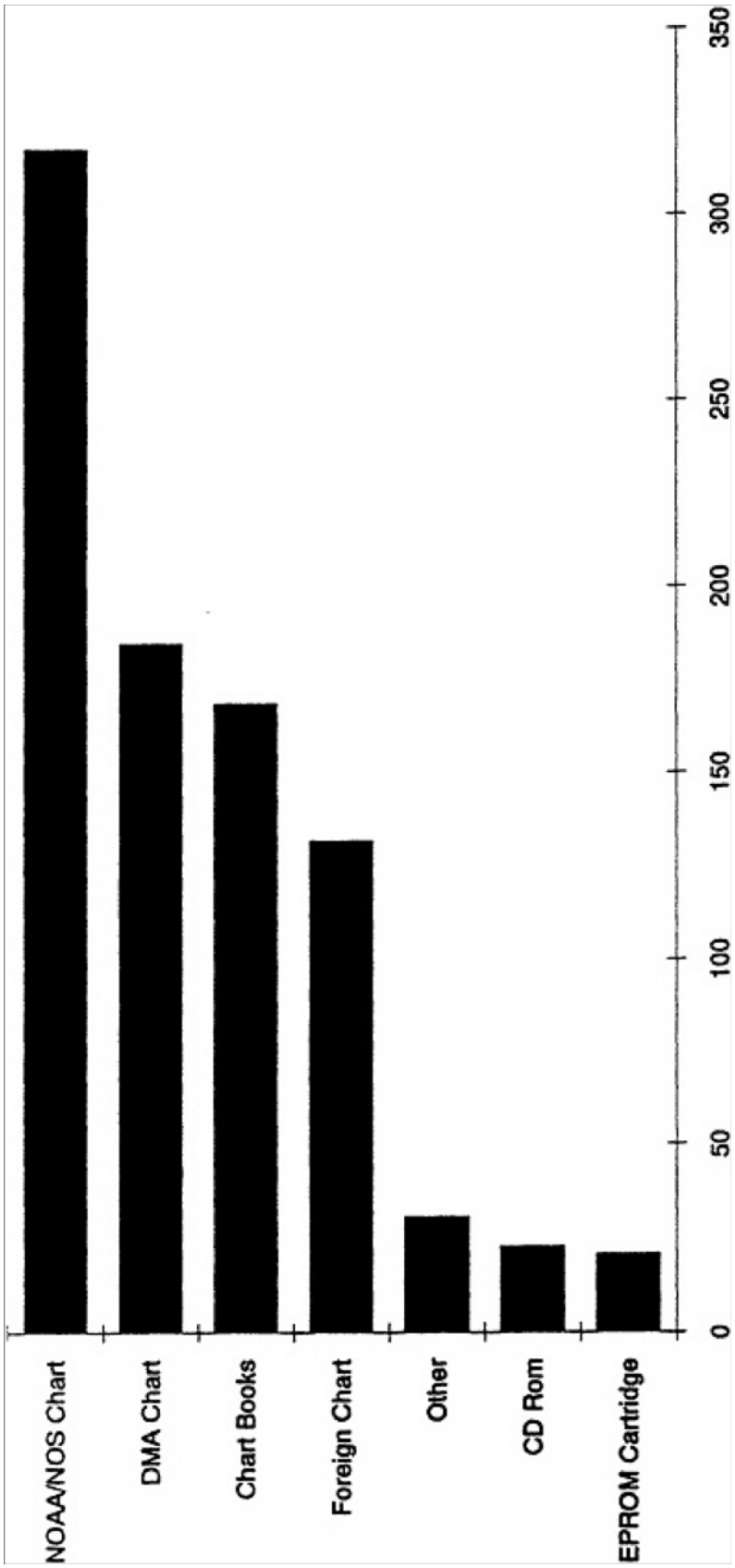

Figure C-2-3 Chart Products Used

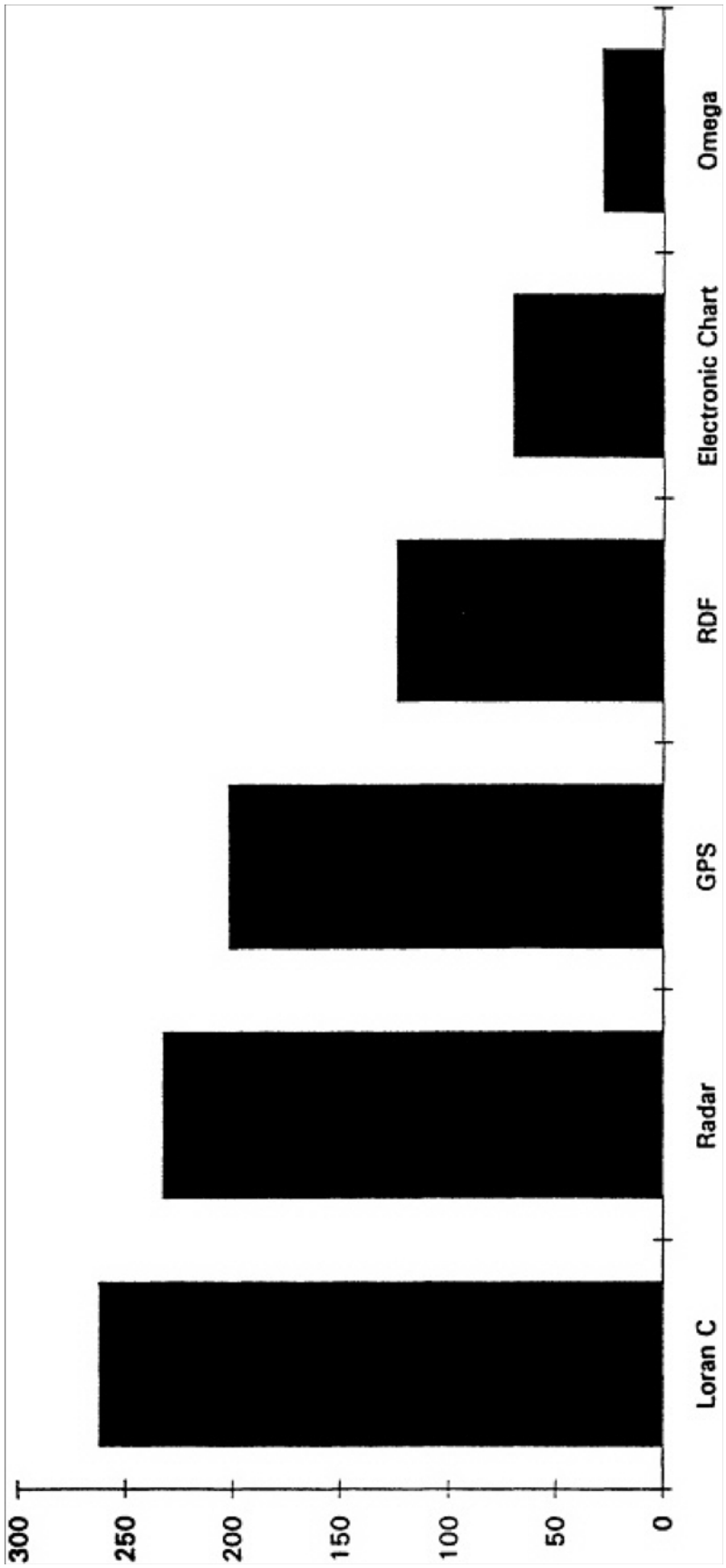

Figure C-2-4 Navigation Equipment Used

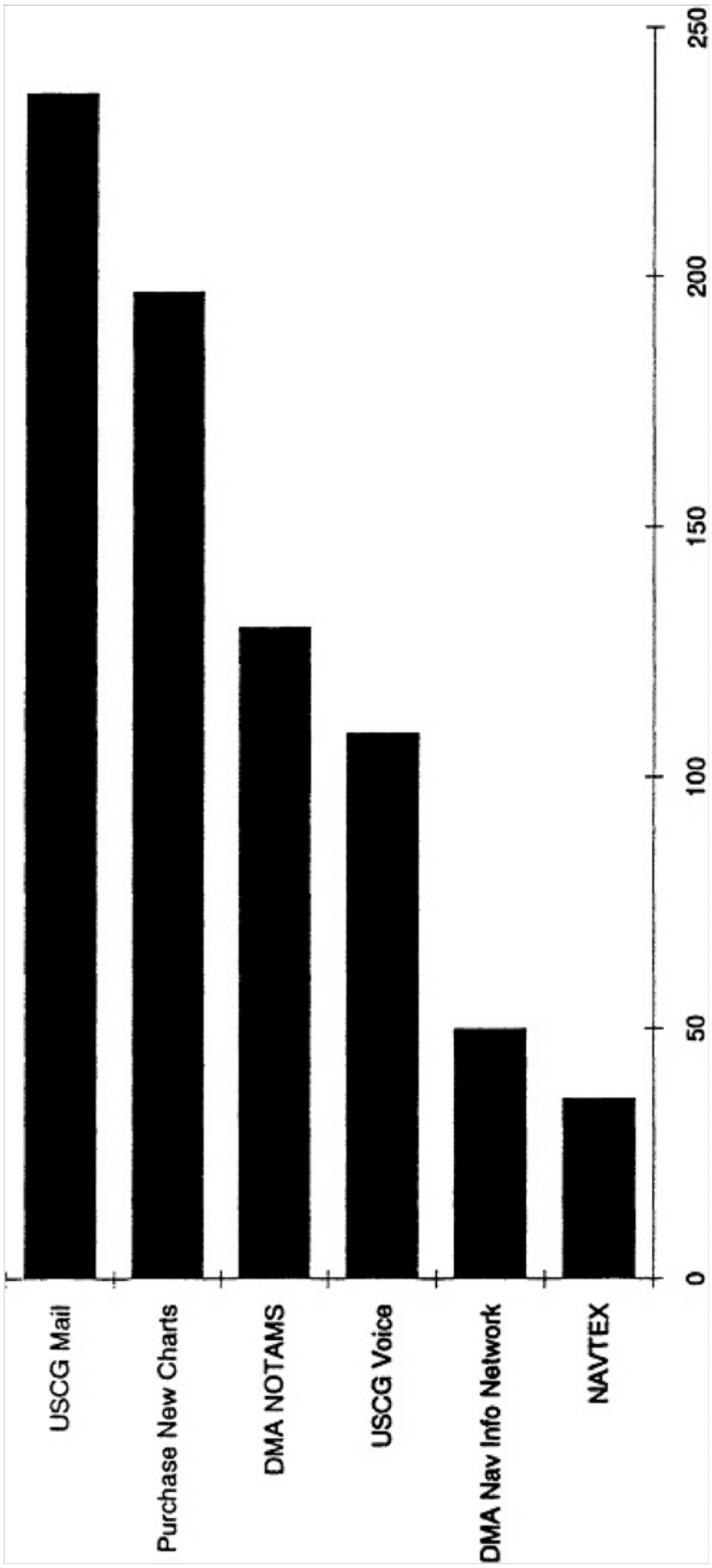

Figure C-2-5 Update Source

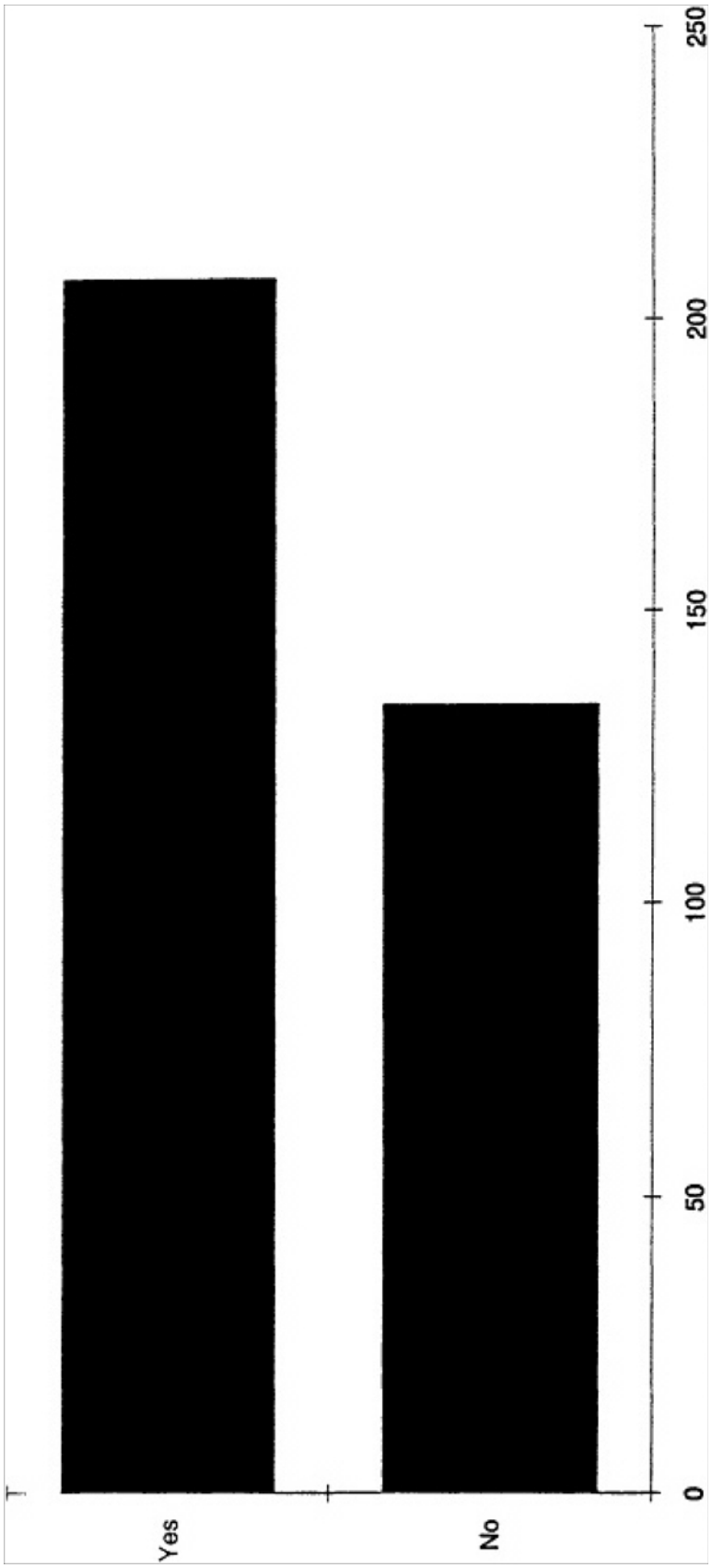

Figure C-2-6 Present Charts Meet All of Your Needs?

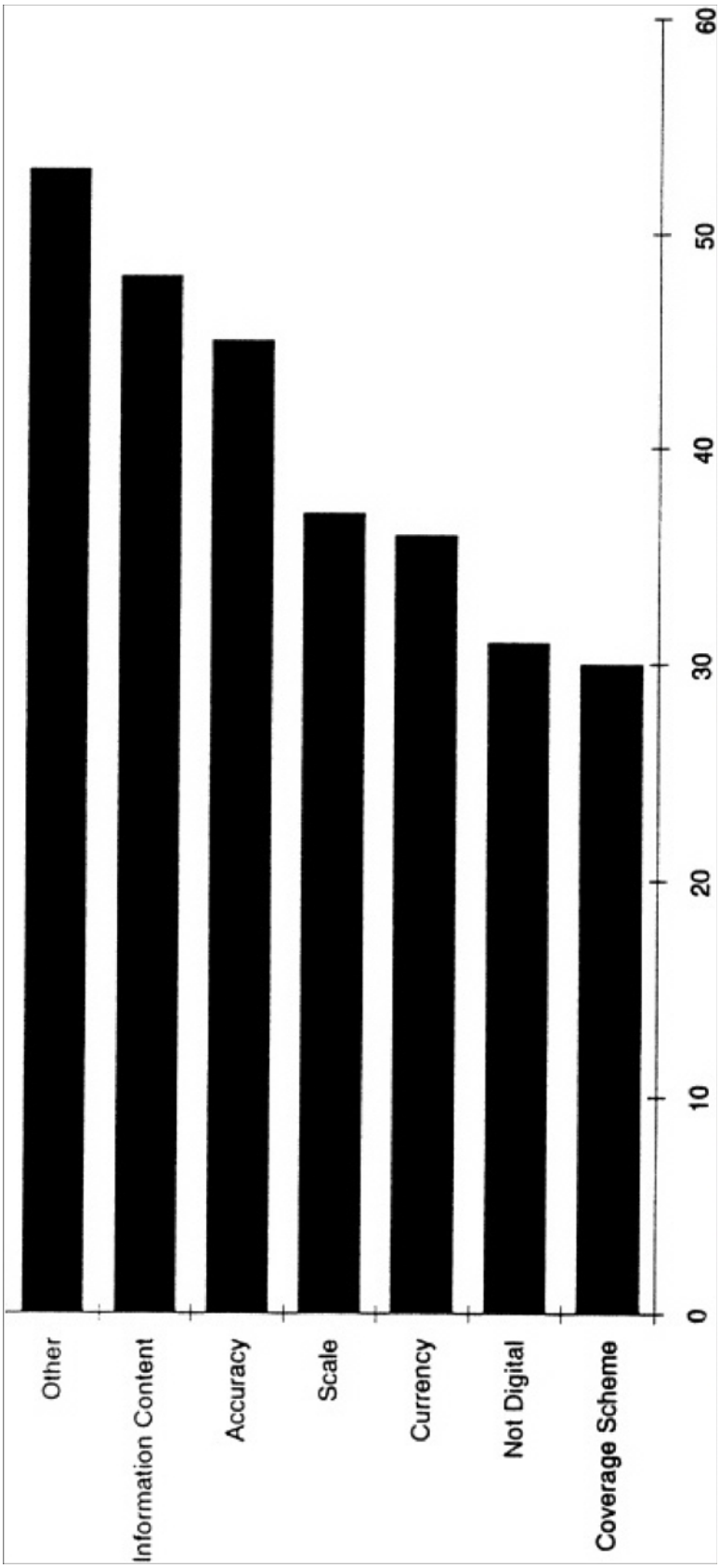

Figure C-2-7 Why Don't Charts Meet Needs?

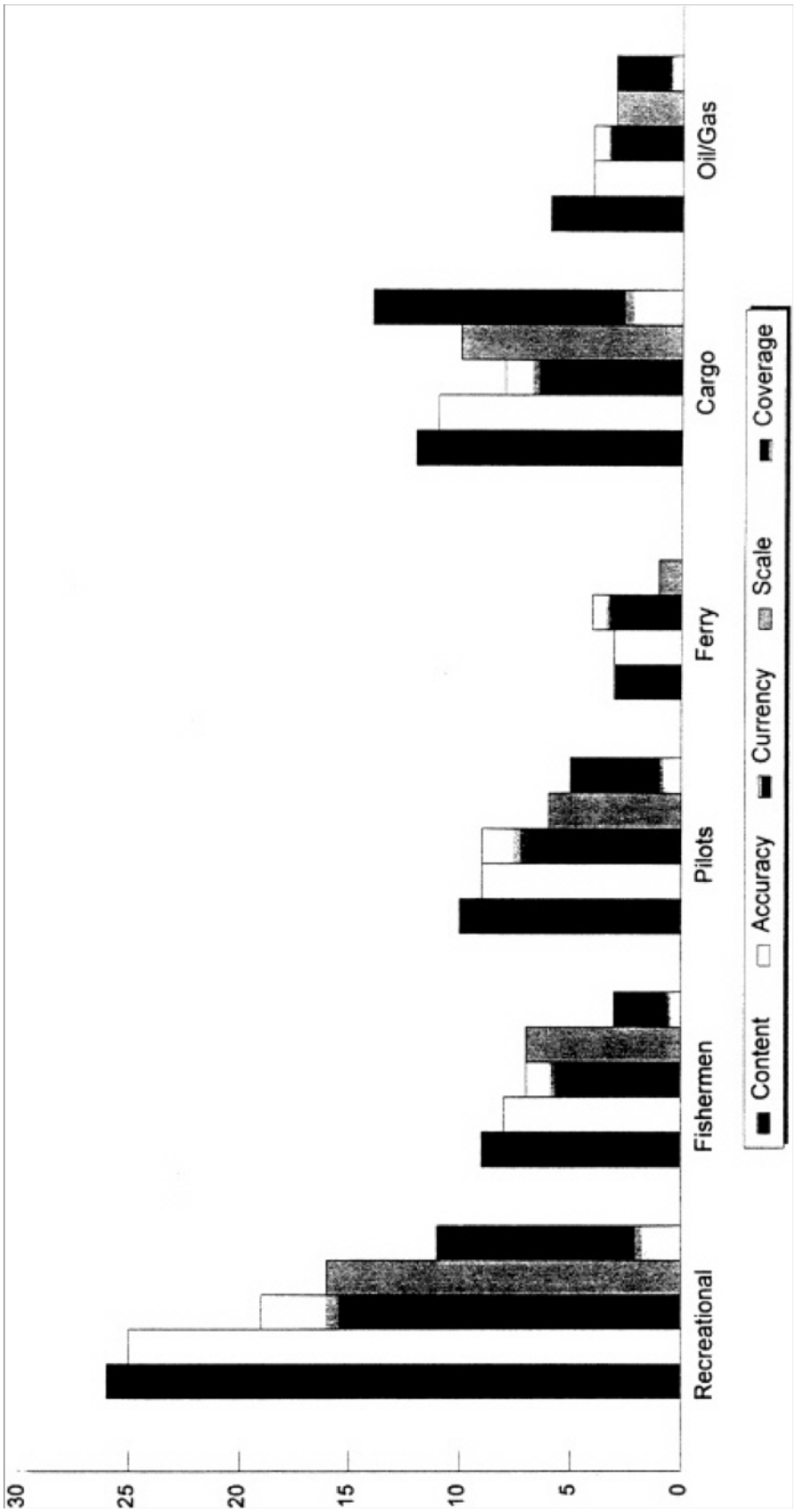

Figure C-2-8 Why Don't Charts Meet Needs?

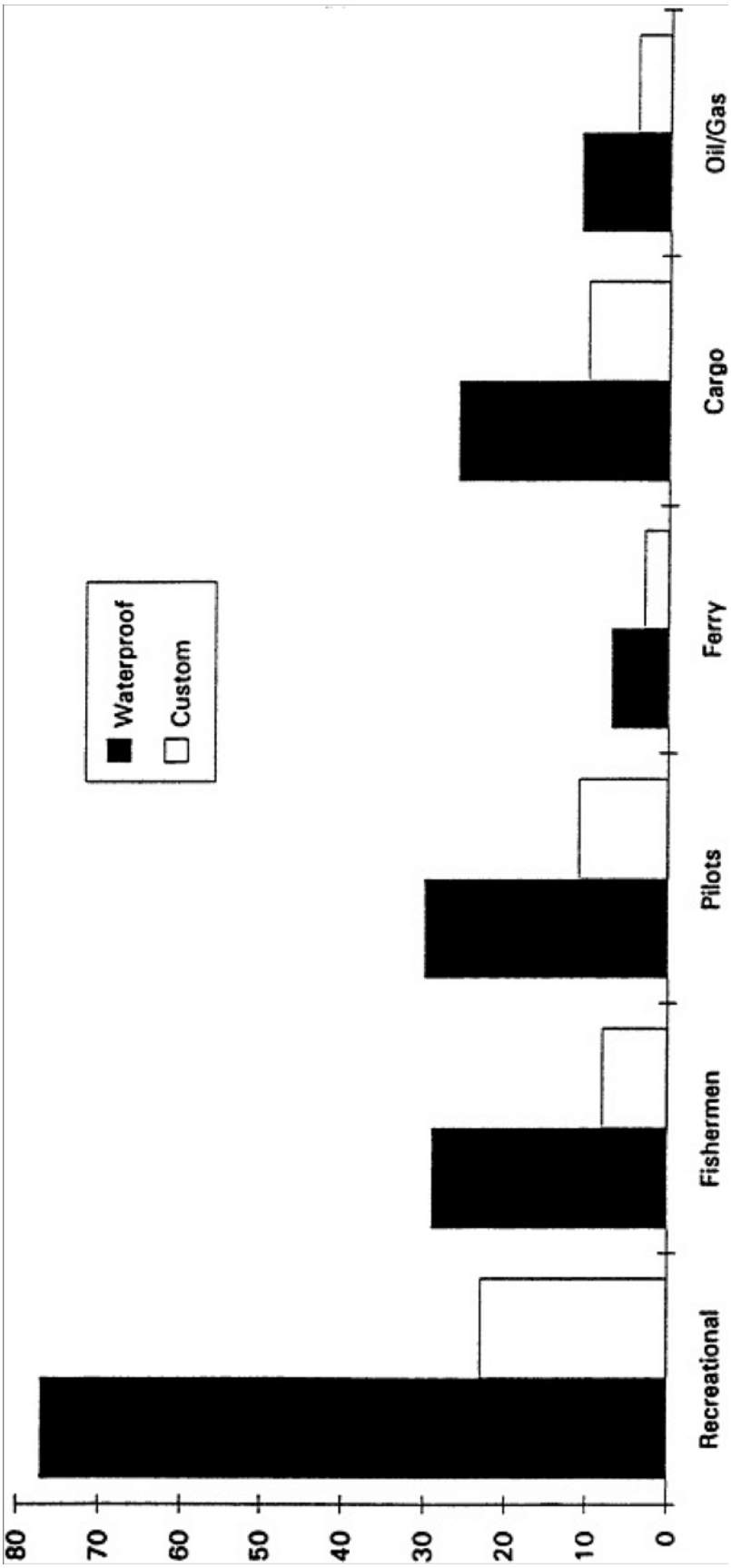

Figure C-2-9 New Paper Charts Wanted?

APPENDIX D

WORKSHOP ON THE FUTURE NEEDS OF USERS FOR NAUTICAL INFORMATION

Massachusetts Maritime Academy
Buzzards Bay

July 19-21, 1993

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington, D.C. 20418

MARINE BOARD

WORKSHOP ON THE FUTURE NEEDS OF USERS FOR NAUTICAL INFORMATION
July 19-21, 1993
Buzzards Bay, Massachusetts

OFFICE LOCATION
Georgetown Facility
Room HA 250
2001 Wisconsin Avenue, N.W.
Telephone: (202) 334-3119
Telefax: (202) 334-3789

LIST OF PARTICIPANTS

Committee Members

Craig Dorman, *Woods Hole Oceanographic Institution*
Saul Dinman, *NAVIONICS, Inc*.
Stanley K. Honey, *ETAK, Inc*.
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Jon A. Lucy, *Virginia Institute of Marine Science*
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Jacques Michell, *Associated Branch Pilots*
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Peter Tatro, *Johns Hopkins University*

Liaisons

James E. Ayres, *Defense Mapping Agency*
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Mike Hacunda, *Office of the Oceanographer of the Navy*
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David Nystrom, *U.S. Geological Survey*
Frank Parker, *U.S. Coast Guard*
Charles Schwarz, *National Oceanic and Atmospheric Administration (NOAA*)
Unable to Attend
Kenneth I. Daugherty, *Defense Mapping Agency*
John Dumbleton, *Maritime Administration*

Invited Guests

David G. Aubrey, *Woods Hole Oceanographic Institution*
Daniel J. Basta, *Strategic Environmental Assessments Division, NOAA*
Frank Bohannon, *Sunriver, Oregon*
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Mark Byrnes, *Louisiana State University*
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Chuck Killpack, *Environmental Systems Research Institute*
Alexander Landsburg, *Maritime Administration, U.S. DOT*
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Judith Powers, *Waterway Guide & Chart Books*
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NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington, D.C. 20418

MARINE BOARD **Committee on Nautical Charts and Information**

OFFICE LOCATION
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Telephone: (202) 334-3119
Telefax: (202) 334-3789

WORKSHOP ON THE FUTURE NEEDS OF USERS FOR NAUTICAL INFORMATION

Massachusetts Maritime Academy, Buzzards Bay, Massachusetts
July 19-21, 1993

SCHEDULE

Monday July 19

1815 **RECEPTION/DINNER** [Dining Hall]
Speaker: *Dr. Peter H. Cressy*, Chancellor, University of Massachusetts Dartmouth

"MARITIME EDUCATION AND ADVANCES IN TECHNOLOGY"

Tuesday July 20

0730 *Breakfast in Dining Hall*

0830 **PLENARY SESSION** [Lecture Room, Harrington Hall]

• Welcome and Workshop overview/review of objectives

-- ***Craig Dorman***

• Presentation on Results of Questionnaire

-- ***Pete Tatro***

1000 *Coffee Break*

1030 **PLENARY SESSION** (continued)

• Informational Presentations

-Description of the NOS/NCD mission and activities

-- ***Thomas Richards***

-Review nautical information technology available for users: existing, future

-- ***Gail Langran***

• Problems to be Addressed/Charge to Working Groups

-- ***Craig Dorman***

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

1230 *Lunch Break* [Dining Hall]

1315 **WORKING GROUP SESSIONS** [Classrooms, Harrington Hall]

Working Group 1: User Needs and Product Priorities

Pete Tatro/Henry Marx (co-leaders). Jon Lucy (recorder)

Working Group 2: Public and Private Sector Roles in Supplying, Products

Stan Honey/Saul Dinman (co-leaders). David Nystrom (recorder)

Working Group 3: Database Issues: Nautical Charts and Other Marine Information

Vic Klemas/Gail Langran (co-leaders). Susan Garbini (recorder)

Working Group 4: Data Collection Partnerships/Establishing Priorities for Updating Charts and Issuing New Editions

Lowell Starr/Michael Stalzer (co-leaders). Hauke Kite-Powell (recorder)

1615 *Coffee Break*

1630 **MID-TERM PLENARY** [Lecture Room, Harrington Hall]

• Working Group 1-4 presentations on scope of issues and preliminary findings. [Objective is to provide cross-fertilization among participants and working groups.]

1700 **ADJOURN**

Tours of MMA Bridge, Radar, and Oil Spill Simulators [Harrington Hall]

1830 *DINNER at Massachusetts Maritime Academy Dining Hall*

Wednesday, July 21

0730 *Breakfast in Dining Hall*

0830 **WORKING GROUP SESSIONS** [Classrooms, Harrington Hall]

Working Groups meet again and prepare written findings.

1000 *Coffee Break*

1030 **WORKING GROUP SESSIONS** (continued)

1230 *Lunch Break* [Dining Hall]

1315 **PLENARY SESSION** [Lecture Room, Harrington Hall]

Working Groups present findings

General discussion: Preliminary Conclusions and Recommendations from Workshop

Concluding Remarks/Summary by Chairman

-- ***Craig Dorman***

1600 **ADJOURN WORKSHOP**

1700 Tours of ECDIS display at Woods Hole Oceanographic Institution

1830 **RECEPTION AND CLAMBAKE at the NAS Facility at Woods Hole**

END OF WORKSHOP

APPENDIX E

PRINCIPLES OF BENEFIT-COST ANALYSIS APPLIED TO SURVEYS

The basic problem lies in determining which requested surveys are most needed, and in what order to perform them. Some surveys may be of minimal value to the nation, and therefore do not warrant the use of government resources. Similarly, other surveys are extremely valuable to the nation, because they enable more commercial activity or because they result in greater reduction of risks of accident and pollution. The known quantities in this problem (known at least with some degree of certainty for the immediate future) are the nation's survey needs and the nation's resources available to meet them. The challenge is to determine the best sequence in which to conduct the surveys. Benefit-cost analysis provides a systematic mechanism for determining an efficient answer to these questions.

Benefit-cost analysis is a tool for assessing the costs and benefits of specific projects. In general, the approach is to define a potential project, identify the costs associated with its execution, identify all benefits that will accrue if the project is carried out, and estimate these benefits in economic terms. The latter step requires calculation of net benefits if the project is undertaken minus the same measures if the project is not executed.

The alternative to conducting the project is referred to as the "baseline" case. In mathematical terms, if B is the net present value of all benefits to society from the products and processes in place in the baseline scenario, and *B*' is the net present value of all benefits to society if the project is executed, the benefit of undertaking the project is then equal to $B' - B$.

Evaluating a Single Survey

If the project in question is a hydrographic survey of a particular area, the relevant costs to consider include the costs of data collection (the actual survey), processing the survey data, and compiling the chart (paper or digital) from the processed data. The last component should be included, since many of the benefits of the survey do not accrue until the information is made available to users in the form of a chart product.

Because we are interested in benefits of a survey net of benefits that would accrue without the survey, it is not necessary to consider benefits that do not change as a result of the survey. This recognition is incorporated, for example, in the U.S. Army Corps of Engineers' approach to valuing benefits of waterways construction projects (COE, 1983). Some of the benefits considered by the Corps of Engineers are relevant to the National Oceanic and Atmospheric Administration's (NOAA's) survey projects, especially those accruing to deep-draft transportation, recreation, and fishing. Under deep-draft transportation, the Corps of Engineers includes cost reduction benefits (reductions in

transport costs due to a change in route or mode), shift of origin benefits (reductions in the total cost of producing and transporting goods), shift of destination benefits (changes in net revenue to the producer), and induced movement benefits (value of delivered commodities minus production and transportation costs). Recreational benefits are assessed by the Corps of Engineers as willingness to pay for increments in supply of recreational opportunities, measured by travel cost (TCM), contingent valuation (CVM), or unit day value (UDV) methods. Benefits to fishing include expected changes in harvest volume and cost savings.

In determining benefits of surveys, NOAA should consider a similar set of factors. In particular, the factors that presently go into calculation of survey request scores (level of use of the area by various user groups, exposure to damages from accidents) and final area rankings (topography, quality of existing surveys) should be included. (Note that benefits in the case of surveys are often actually savings, or avoided costs, associated with such things as avoided groundings.) The critical difference is that the benefit assessment works with expected economic benefits due to the survey, as opposed to nondimensional rankings. The benefits analysis thus requires use of vessel traffic statistics, statistics about likelihood of accidents with and without a new survey, statistics about expected damages in the event of an accident (which in turn depend on the nature of cargo and local environmental resources), estimates of "new" economic activity dependent on a new survey, etc. For example, software being developed by the Data Quality Working Group within the International Hydrographic Organization Committee on the Electronic Chart makes it possible to evaluate statistically the quality of existing surveys (Kielland et al., 1992). This information can be used to develop an objective measure of the improvement achievable with a new survey.

It is neither realistic nor necessary for NOAA to encompass all possible benefits in its calculation, so long as the major benefits are considered and applied consistently to all potential survey areas. This procedure should be sufficient to achieve a reasonable prioritization.

Prioritizing Among Multiple Surveys

To choose among alternative projects, the decisionmaker calculates the benefit and cost of each, and ranks projects by the ratio of benefits to costs. As long as there are projects with benefit-cost ratios above the decisionmaker's threshold level, the decisionmaker chooses to execute projects in order of decreasing benefit-cost ratio until the budget constraint is reached. This approach ensures that maximum benefits will be derived from the available resources.

For survey prioritization, this means calculating benefits and costs for all possible survey projects, and executing them in order of decreasing benefit-cost ratio. Under some simplistic assumptions, the optimal schedule of surveys then consists of performing in each time period (year) as many of the highest benefit-cost surveys as resources allow. This is only true, in general, if the expected benefits under the "survey" and baseline scenarios are the same for each future year.

This is not a particularly realistic assumption. For example, we may know that marine traffic in a particular survey area is expected to increase significantly over the next 5

years, and that the chance of a grounding without a new survey will therefore increase as well. Under these circumstances, the optimal schedule of surveys is a dynamic programming problem.

To set up the dynamic programming problem, one would estimate $B(a,t)$ and $B'(a,t)$ as benefits associated with area a in year t given a baseline or "new survey" scenario, respectively, just prior to time t. Using these values, one then formulates a dynamic programming problem to maximizes the net present value (NPV) of benefits, solving for the optimal year in which to conduct each possible survey, subject to the resource constraint.

This general problem is further complicated by the fact that information about expected benefits, survey requests, and national priorities changes with time, which implies that the optimization has to be repeated (and priorities possibly revised) each time the available information changes. Given that, for practical purposes, NOAA only needs to plan its surveys a few years ahead, and information about the longer future is quite uncertain, it is probably not necessary for NOAA to set up a dynamic programming algorithm for survey prioritization. The following section sketches an implementation that retains the valuable characteristics of a benefit-cost approach without these complications.

Suggestions for Implementation

A practical implementation of the principles described above could limit the analysis to benefits over a few years, perhaps 2 or 3. NOAA would estimate expected benefit under the baseline and "new survey" scenarios for 1 or 2 years of surveys only; choose the most beneficial surveys to perform next year; and then repeat the analysis, using any new information that may have been obtained, a year later for the following year's surveys. This limitation to near-term costs and benefits is likely to be accurate enough, and it also eliminates the difficult issue of choosing an appropriate social discount rate for the NPV calculations. The relevant unit of analysis is the potential survey area, not the individual survey request. Survey requests should still be tracked, and can help to inform the valuation of potential surveys, but they play a lesser role in prioritizing surveys under the benefit-cost scheme than they do at present.

A problem remains in the economic valuation of survey requests issued by the military. It is possible to address this issue by effectively restricting the cost calculation to "costs incurred by NOAA's survey budget." Navy requests for surveys that are accompanied by Navy funds, for example, would then move to the top of the priorities list because their cost to NOAA is low, and their benefit-cost ratio correspondingly high. The same process can accommodate requests from private parties or other government agencies for surveys that they are willing to help fund, and thereby move to a higher priority. To be effective without interfering with scheduled survey projects, this approach requires both a reserve surveying capacity that can be activated when funded survey requests arise, and a mechanism by which other agencies and private parties can share the costs of such surveys with NOAA.

The link between the survey request prioritization process and the new chart requests system should be formalized, whether the benefit-cost approach for survey prioritization is

adopted or not. If survey priorities are set by economic analysis, then the surveys should drive new chart production priorities.

Finally, it may make sense to treat requests for obstacle investigation separately from requests for full area surveys. In principle, both types of surveys could be encompassed in one analytical regime, but it may be easier in practice to treat them separately because of differences in scale of required operations. Obstacle investigation surveys should be subjected to the same kind of benefit-cost analysis as full area surveys. Treating them separately is especially reasonable if a different survey asset base is used for each type of survey.

It is possible that the priorities produced by a process such as the one described here will not be very different from those now in place, but the committee recommends that it be tested. Even if tests prove this to be the case, the benefit-cost process will be regarded as less arbitrary and therefore more readily defensible and persuasive to budgeters than the current mechanism.

REFERENCES

Kielland, P., K. Burrows, B. Ward, M. Dagbert, and R. Velberg. 1992. Toward "IHOstat": IHO approved software which evaluates the quality of bathymetric data. Hydro '92 Conference. Copenhagen, December.

U.S. Army Corps of Engineers (COE), Water Resources Council. 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. 10 March. (Supersedes principles at 18 CFR 711, 713, 714, and 716.)

APPENDIX F

U.S. ARMY CORPS OF ENGINEERS' EXPERIENCE

The U.S. Army Corps of Engineers (the Corps) is the federal government's major contractor of hydrographic surveying services. Contracts directly awarded by the Corps range between $15 million and $20 million annually for hydrographic surveying services. Another $10-15 million is indirectly contracted in the form of dredging construction contracts that require hydrographic surveys to determine daily progress. The Corps' extensive experience with contracting these services would be beneficial to the National Oceanic and Atmospheric Administration (NOAA) should it embark on a program to more fully utilize the private sector in obtaining basic field survey data.

Prior to the 1960s, hydrographic surveying was almost exclusively a government-performed function—mainly because most of the work supported dredging performed by Corps-owned dredges. After World War II, more dredging work was performed by contracts to the private sector, as were hydrographic surveys in support of these contracts (by congressional directive in some cases). Dredging companies became fully responsible for performing daily dredging progress surveys. During the 1970s and 1980s, the Corps gradually increased further its contracted services for annual project condition surveys and surveys for contract plans and specifications. As of 1993, the Corps contracted about 35-40 percent of its hydrographic surveying workload, and over half of its surveying requirements. The percentage of contracted hydrographic survey effort varies widely from district to district; some contract nearly 100 percent while others contract virtually none.

The gradual increase in contract effort over the past 20 years has resulted in numerous private surveying firms obtaining full proficiency in hydrographic surveying. It is now estimated that 20 to 30 professional service firms possess hydrographic surveying capabilities. Approximately five of these firms are capable of fielding up to ten hydrographic survey crews. Much of this capability derives from the firms' extensive experience in geophysical exploration for the offshore oil industry in the Gulf of Mexico and overseas. The demand for offshore services declined dramatically during the 1980s. Thus, most firms transitioned from oil exploration surveys to hydrographic surveying and mapping of federal river and harbor projects. An abundance of skilled personnel and resources still exists to this date. Most of these firms have one or more professional people who possess local land surveying or professional engineering registration—a Corps contracting requirement. Final drawings (i.e., hydrographic charts) require local state licensing certification by a professional land surveyor or engineer responsible for supervision of the work.

The firms that have performed hydrographic surveys for the Corps for the last 20 years are available to NOAA. Since all Corps work is performed at scales significantly larger than those used for NOAA charting, meeting International Hydrographic Organization (IHO) positional standards is not a problem for these contractors. Corps calibration specifications parallel those of NOAA and are far more stringent for measurement and payment surveys and final acceptance surveys, especially in rock cut areas where under-keel clearance certification is critical.

Brooks Act (P.L. 92-582) Contracting

Corps hydrographic survey services are procured by using P.L. 92-582 qualification-based selection methods, usually referred to as architect-engineer (A-E) contracting. This contract form has been used for all Corps surveying service contracts since its enactment.

A number of Corps publications and internal regulations on P.L. 92-582 contracting are available to NOAA. The Corps also conducts one-week training courses in A-E contracting that NOAA personnel could take. These training sessions are held throughout the country and are conducted 10 to 15 times each year. The course covers all phases of A-E contracting, although the emphasis is on design services rather than surveying services. The Corps also publishes a guide specification (USACE, 1990) for hydrographic surveying services.

A basic A-E contract with the hydrographic surveying firm is established for a 2-year period or longer. These services can be procured effectively through Indefinite Delivery Type (IDT) contracts. This method provides maximum flexibility in cases where the scope of work varies, or where priorities may unpredictably change. Delivery orders are then written against that contract for projects as they arise. This contract technique would allows rapid response to emergency survey requests such as reported channel obstructions, since orders to contractors can be initiated and executed within 24 hours. Having four to six geographically distributed IDT contracts would enable NOAA to effectively cover all areas of the country, and provide maximum flexibility for immediate survey deployment needs.

Standards for Data Collection in Contract Surveys

NOAA hydrographic survey standards are designed to comply with the IHO standards (IHO, 1987). The standards address the positional accuracy of a charted feature or sounding, accuracies of depth measurements (soundings), internal quality control checks (e.g., cross-line checks), and corrections to soundings. NOAA Coast and Geodetic Survey standards and specifications are described in the NOAA *Hydrographic Manual* (NOAA, 1976). Other internal documents and field instructions supplement this manual. All NOAA survey standards and specifications are designed to equal or exceed IHO requirements.

NOAA's use of contracted or external survey forces implies a rigid requirement that those surveys be performed to NOAA (i.e., IHO) standards and specifications. These

external hydrographic survey sources may include (1) directly contracted commercial surveyors; (2) Department of Defense or other federal agency survey forces; (3) survey vessels/ships of convenience; (4) state, local, or regional port authority surveyors; or (5) indirect third-party contracted forces of other federal agencies or organizations, including construction dredging and geophysical exploration firms.

As a contracting agency, NOAA would be responsible for the quality control oversight of field hydrographic surveys performed by private contractors or other federal agencies. In general, the degree of quality control will be a function of the experience and competence of the contractor. The recommended role is to require the contractor to perform the critical quality control functions and certify results. Such efforts are normally contained in a quality control plan that is submitted by the contractor after contract award. NOAA's role would then simply be that of performing quality assurance inspection of the contractor's quality control activities. This would take the form of intermittent visits to the job site to review and monitor survey techniques and procedures.

Cost Comparison Between Government and Commercial Hydrographic Surveys

Cost comparison data between in-house and contracted surveys are readily available from Corps records. However, a formal study comparing these costs has not been performed. Some informal cost data for both in-house and contracted work are contained in Chapter 15 ("Estimating Costs for Hydrographic Surveys") of EM 1110-2-1003, *Hydrographic Surveying* (USACE, 1991). Generally, costs for contracted surveys are competitive with government-performed surveys. Although commercial contractors' daily rates are lower and efficiencies are usually superior to those of government crews, these advantages are somewhat offset by the regulatory and administrative costs associated with government procurement and contract administration. Attempts to compare costs are usually subjective, given the intangibles that are difficult to quantify (e.g., costs associated with emergency mobilization training required of government forces).

Recent improvements in survey automation and positioning have caused the size of a typical hydrographic survey crew to drop from four or five persons to two or three, with corresponding labor cost savings. These savings are offset to some degree by higher equipment costs.

REFERENCES

International Hydrographic Organization (IHO). 1987. IHO Standards for Hydrographic Surveys. Special Publication No. 44. Third edition. Copenhagen.

National Oceanic and Atmospheric Administration (NOAA). 1976. Hydrographic Manual. Fourth edition. U.S. Department of Commerce, Washington, D.C.

U.S. Army Corps of Engineers (USACE). 1990. Hydrographic Surveying Services. Civil Works Construction Guide Specification CW-01333. December 30. U.S. Army Corps of Engineers, Washington, D.C.

U.S. Army Corps of Engineers (USACE). 1991. Hydrographic Surveying. EM 1110-2-1003. February 28. U.S. Army Corps of Engineers, Washington, D.C.

APPENDIX G

EXAMPLES OF USES OF DATA BY STATE ENVIRONMENTAL AGENCIES

GIS APPLICATIONS IN FLORIDA'S COASTAL ZONE

The Coastal and Marine Assessment program (CAMRA) at the Florida Marine Research Institute (FMRI) has invested considerable resources to convert the National Oceanic and Atmospheric Administration (NOAA) nautical chart information to GIS format. The FMRI is mandated to manage, protect, and enhance Florida's marine resources. To accomplish this objective, CAMRA manages the Marine Resources Geographic Information System (MRGIS). The MRGIS uses the latest in raster and vector technologies to synthesize a broad range of cultural and marine resource information. Many of the most useful data bases in the MRGIS are derivative products of NOAA nautical charts. The following examples provide a small but representative sample of the GIS support that CAMRA provides in Florida using NOAA chart information in conjunction with project-specific data.

Site Selection for Testing of Explosives

The U.S. Navy is considering an area off Key West, Florida, to detonate underwater explosions to gather test data for mine-clearing in the Persian Gulf. The Florida Governor's Office asked CAMRA staff to use the MRGIS for preliminary analysis of the Navy's proposal (Friel and Haddad, 1992). It was recommended that potential sites be

1. within a 60-nautical-mile radius of Key West;
2. in water approximately 25 feet deep;
3. outside the Florida Keys National Marine Sanctuary (FKNMS);
4. outside the jurisdictional boundary of the State of Florida;
5. in areas with noncritical benthic resources (e.g., sandbottom); and
6. a significant distance from cultural resources (shipwrecks).

Appropriate data bases were compiled, including digitized shoreline, bathymetry, and jurisdictional boundaries from the NOAA charts. A "depth corridor" analysis was first conducted by creating a polygon of the 18-foot and 30-foot depth arcs to focus attention on waters 25 feet deep. The polygon was then used as a "cookie-cutter" to extract just the resource information contained in that depth range. Several different versions of the maps

were created for a Navy contractor from which a rectangular study area was selected for further review. Ultimately, 25 candidate test sites were identified. The Navy contracted for "photo documentation" and further site-specific study. The MRGIS analyses provided a regional screening of areas in which minimum resource impact could be expected if explosive testing took place.

Marine Mammal Research

The manatee is one of the most endangered marine mammals in the United States—as few as 1,850 animals remain. The Marine Mammals Section of the FMRI is implementing the Manatee GIS, to use as a primary tool in research and management efforts to understand and conserve the remaining species (Ward and Weigle, 1993). The Manatee GIS is a functional node of the MRGIS and integrates manatee distribution, mortality, and migration data with several data bases that were created from NOAA nautical charts. In particular, shoreline and bathymetry are key data bases for the manatee research and management efforts. The primary data sources for these features are NOS topographic and hydrographic sheets.

To acquire a statewide shoreline base map, FMRI contracted the U.S. Fish and Wildlife Service to refine several l:40,000-scale digital shoreline files created by the National Ocean Service and convert them to ARC/INFO format. In addition, a data conversion firm was contracted to convert bathymetric data from paper NOAA charts to digital ARC/INFO format for the entire state of Florida. These core data sets are used with diverse data bases such as manatee distribution, mortality, migration, aquatic vegetation, and marinas. Preliminary findings have been used to delineate manatee protection zones, and tests are being conducted to combine environmental layers such as water temperature, vegetative cover, salinity, and bathymetry to create predicative models of travel routes and to identify high-use migration corridors.

Boat and Diver Use Patterns in the Florida Keys

For many, boating and diving are the main attractions of the Florida Keys. FMRI-South Florida Regional Laboratory and the Nature Conservancy recently completed a year-long study to estimate the number of boats that utilize the FKNMS, and specifically the level of use on individual reefs. The study relied upon a combination of aerial fly-overs, surface surveys, and GIS data base development and analysis. CAMRA's involvement began when staff wanted to see reefs and benthic communities plotted over a navigation chart to record the location of boats that were identified during aerial and surface surveys.

CAMRA staff supported the collection, storage, analysis, and display of the boat-use data using information derived from NOAA nautical charts. To facilitate the effort, CAMRA staff designed a data collection atlas Of 26 maps that display land, reefs and hardbottom, aids to navigation, and a sampling grid. Sixty-five aerial surveys were conducted on different days of the year to count and classify boat-use patterns, and these data

were supplemented by ground surveys to estimate the amount of Specific boating activities (diving, fishing, etc.). A separate map atlas was used for each day, and the data were stored as a distinct "layer" of information to allow comparisons between different days and different areas of the FKNMS. The resultant data base has been used for a variety of spatial and statistical analyses to explore correlations between boat-use patterns and benthic communities, bathymetry, boat ramps, marinas, and mooting buoys. The results of these analyses ultimately will help determine carrying capacities, create specific use zones, and further revise the FKNMS management plan.

Fisheries Management

CAMRA created the Resource Impact Map (RIM) series of eight chart-sized maps to assist managers statewide in making resource decisions. Each map includes coastline, depth contours, and aids to navigation digitized from NOAA charts. Benthic communities such as mangroves, saltmarshes, seagrasses, oyster reefs, coral reefs, hard bottom, and bare bottom are included, as are managed area boundaries. Bathymetric depth curves are shown because depth is an important controlling factor for human and marine resources. Channels and navigation aids such as buoys are displayed to help users orient themselves, like road networks on land-based maps.

The Florida Marine Fisheries Commission and the FMRI are using GIS and the RIM information to enhance Florida's fisheries (Haddad et al., 1993). For instance, the basic RIM data bases were augmented with shrimp nursery data to assist in the complex process of developing a shrimp management plan that includes closure areas. Issues relative to habitat protection, user conflict, and seafood quality vary among regions, and the maps provide a geographic presentation of these differences for policy analysis.

Oil Spill Planning and Response

Since early 1992, FMRI has been developing the Florida Marine Spill Analysis System (FMSAS), a GIS-based application to assist oil spill contingency planning, response, cleanup, and damage assessment. The FMSAS integrates a variety of information (digitized maps, scanned images, remote sensing imagery, tabular data, and photographs) with targeted analytical routines needed to implement an oil spill response strategy focused on resource protection. Many of the data shown on nautical charts have been included in the FMSAS as vector data bases. In addition, scanned nautical charts (250 dots per inch) have been integrated to provide a familiar visual backdrop for displaying the 20 other data sets in the FMSAS. The Coast Guard, NOAA, and state response officials specified this need because all responders are familiar with the basic nautical chart format.

On August 10, 1993, three vessels collided in Tampa Bay, Florida. A vessel transporting aviation fuel burst into flames while another vessel began leaking #6 oil into the Bay. Eventually, over 350,000 gallons of oil would leak out and a 10-mile stretch of popular beach would be covered in thick oil. The FMSAS in conjunction with Global

Positioning Systems (GPSs), was used to analyze the changing boundaries, logistical alternatives, resources-at-risk, and environmental sampling strategies to manage the spill. Some key features that all oil spill responders requested on the maps came from NOAA charts: shoreline, bathymetry, and aids to navigation.

More than 300 requests for information were answered by CAMRA last year to provide coastal zone management assistance. The products delivered included maps, tabular output, images, prints, digital data on a variety of media, and articles related to GIS and marine resource management authored by the staff. The vast majority of the requested products include some of the information found on nautical charts. CAMRA has invested over $100,000 in converting paper NOAA charts and digital data files to quality GIS data bases and is far from finished. Much of these funds were spent on digitizing paper maps or creating routines to convert digital NOAA data to a usable format.

GIS APPLICATIONS IN ALASKA'S COASTAL ZONE

1. ***State Coastline***: In response to the *Exxon Valdez* oil spill, the State of Alaska and federal agencies developed a uniform digital coastline to track oil impacts, manage cleanup activities; and conduct Natural Resource Damage Assessment studies. This coastline has subsequently been used for many GIS applications (both spill related and non-spill related). The source information came primarily from the most current U.S. Geological Survey 1:63,360 topographic map series. Supplemental features including small islets and post-1964 earthquake uplifted areas were derived from U.S. Forest Service timber type maps based on 1:15,840 scale aerial photography, and Exxon photo interpretation of 1:60,000 color infrared aerial photography. The coastline is normalized at the approximate line of mean high water in keeping with the U.S. Geological Survey's data.
2. ***Alyeska Contingency Plan***: The Alyeska Pipeline Company has developed a Graphical Resource Database to assist in its response to future oil spills and help meet state and federal spill contingency planning requirements. The data base consists of three base maps, which are derived from NOAA nautical charts covering the Copper River Delta, Prince William Sound, and the Kenai Peninsula/ Kodiak Island. Up to 50 layers of information can be superimposed on the base maps. Information layers include sensitive fish and wildlife habitats, shoreline types, aquaculture sites, land ownership, etc. Each object within the layer is geographically located and may have a variety of information attached to it, such as text, graphs, or pictures. The system offers ready retrieval of information needed to make informed decisions in responding to an oil spill or other disaster.
3. ***Fisheries Research***: *The* Alaska Department of Fish and Game utilizes the SEAPLOT nautical charting and navigation system developed by Ocean Tech on several of its vessels engaged in fisheries research. The system uses Ocean Tech versions of current NOAA nautical charts and has inputs for GPS, loran, and depth sounder data. Site attributes (including depth and textual information) can be geo-referenced, logged, and stored for later retrieval and display. Supplemental information including bathymetry, area boundaries,

coarse tracks, gear locations, bottom types, labels, and navigation aids can be added and used by the system for navigation, contour mapping, sorting, and printed outputs. Data from the system can be downloaded in a variety of formats for use in subsequent analysis and report preparation.

4. ***Sea Otter Research.*** The U.S. Fish and Wildlife Service utilized a digital bathymetric contour map to aid in its assessment of injury to sea otters from the *Exxon Valdez* oil spill. The map was derived from bathymetric point data provided by NOAA, National Ocean Survey for the Prince William Sound, Kenai Peninsula, and Kodiak Island areas. Bathymetric contours were generated using an ARC/INFO routine and were checked for quality against NOAA paper charts. The contours were used to plot areas of less than 20 meters depth, which are preferred sea otter feeding areas. These areas were subsequently field examined, and population estimates were obtained to derive an overall assessment of sea otter numbers. The bathymetric contour map helped to quantify potential sea otter habitat that was occupied at below-average densities due to spill mortality.

GIS APPLICATION TO COASTAL CHANGE STUDIES IN LOUISIANA

Louisiana contains about 40 percent of the nation's coastal wetlands. This represents a renewable natural resource base valued at more than $1 billion annually, and includes 25 percent of the nation's fish harvest, its largest fur harvest, the highest concentration of waterfowl, and the country's largest recreational marine fishery. Recent studies indicate that coastal Louisiana has one of the world's most rapidly changing shorelines with retreat rates exceeding 20 meters per year in some areas. Wetland habitats protected by outer coast deposits are being replaced by open water at a rate of 65 square kilometers per year. While the socioeconomic impacts of Louisiana's coastal land loss problem are extreme, coastal wetlands throughout the nation are similarly productive and fragile. With a large portion of the nation's population moving to coastal areas, concern over the future of various coastal habitats has intensified. Various agencies and universities are studying these ecosystems to better understand their origin and evolution, and the impact of human activities on environmental response.

Basic physical environmental information required for comprehensive studies of coastal change includes repetitive shoreline position and bathymetry (water depth) surveys. These data have been well documented for over 100 years, and changes in shoreline position and bathymetry can provide valuable insight into the processes affecting the origin and evolution of coastal features. Personnel at the Center for Coastal, Energy and Environmental Resources at Louisiana State University have developed comprehensive methodologies for accurate delineation, compilation and analysis of these data using CAD, computer cartography, GIS, GPS, and digital terrain modeling. Detailed descriptions of the procedures used for determining shoreline position change and bathymetry change are presented in Hiland et al. (1993).

REFERENCES

Friel, C. A., and K. D. Haddad. 1992. GIS brings new outlook to Florida Keys marine resources management. GIS WORLD 5:32-36.

Haddad K. D., G. McGarry MacAulay, and W. H. Teehan. 1993. GIS and fisheries management. Proceedings of the Eighth Symposium on Coastal and Ocean Management/ASCE 68-78.

Hiland, M.W., M.R. Byrnes, R.A. McBride, and F.W. Jones. 1993. Change analysis and spatial information management for coastal environments. MicroStation Manager March, 58-61.

Ward, L.I., and B.L. Weigle. 1993. To save a species: GIS for manatee research and management. GIS WORLD 6:34-37.

APPENDIX H

A NATIONAL COASTAL ZONE (SHORELINE) DATA BASE

A national shoreline data base should contain the most up-to-date and detailed data on shoreline, bathymetry, surficial bottom sediment, and special area delineations that are available anywhere in the nation. Development of a "National Shoreline Data Program" should adhere to the following principles:

- The data to be included should be restricted to only the key types of data elements that appear on existing charts or are in the existing data base. Other types of coastal data such as land-use, coastal wetlands, and site-specific data on sensitive habitats should *not be* considered. The national shoreline data base should serve a base map function with respect to these types of data. Nationwide efforts in development of data bases for other types of coastal data are monumental efforts in and of themselves and are already being pursued by federal, state, and local agencies.
- The program should concentrate primarily on developing and providing *derived digital data products*. Although "raw" data should always be accessible (i.e., to the small number of researchers who require them), the emphasis of the effort must be on derived digital products. Derived products include, for example, verified shoreline at different scales, isopleths of bathymetry based on the best "verified" data available. New paper chart products should not be considered except as necessary derivatives of the digital data base.
- The program should provide the most up-to-date and detailed data that are available for any coastal area of the nation, *regardless of the source*, provided that the data have passed "national" verification standards and been certified as "official." To provide does not mean only to make accessible, but rather to actively market and distribute specific digital products.
- The most important element of the program should be establishment of an *active partnership* of data transfer and acquisition of data that have already been collected by others. This will require a significant change in how resources are allocated and priorities established. This element of the program may require a training program for state and local partners and centralized support of a technical assistance function.
- Nationwide data collection efforts (i.e., the National Oceanic and Atmospheric Administration [NOAA] operations), should be targeted to specific areas of national concern and primarily at scales necessary to support the existing chart product needs, but at a significantly reduced repeat cycle nationwide. Data collection should not take place in areas

where state and local agencies, or others, have collected adequate amounts of data that can be verified and incorporated in the national data base.

The attached figure (Figure H-1) illustrates the major elements of a National Shoreline Data Base Program. Further consideration of this concept will require more detailed planning and assessment to determine the scale and scope of the changes that are required and how they may best be implemented.

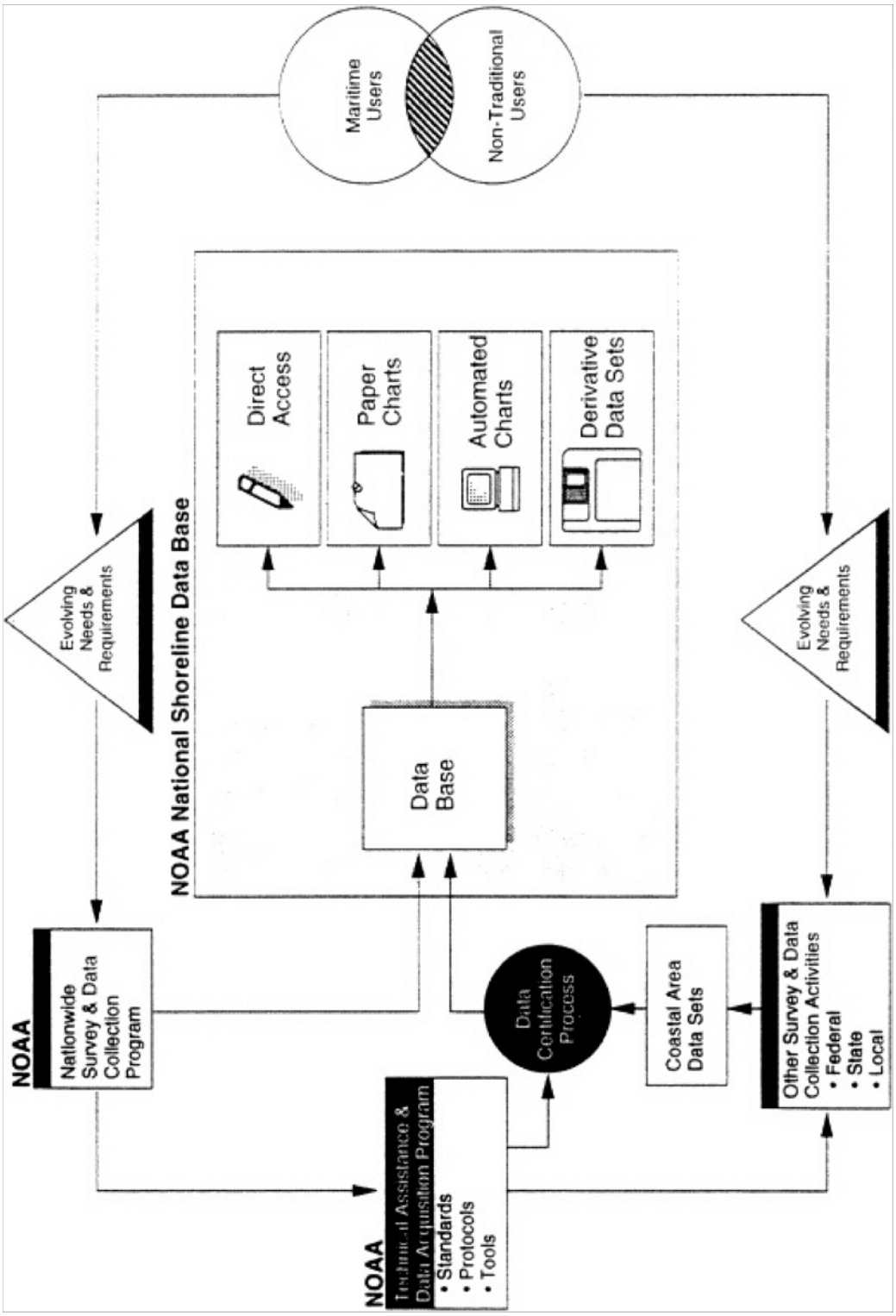

Figure H-1 Elements of a National Shoreline Data-Base Program.
Source Workshop on the Future Needs of Users for Nautical Information, Massachusetts Maritime Academy, Buzzards Bay, July 19-21, 1993.