International Hydrographic Review, Monaco, LXVII(2), July 1990

THE MANAGEMENT AND DISSEMINATION OF ELECTRONIC NAVIGATIONAL CHART DATA IN THE 1990s

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Abstract

The capabilities of Electronic Charts are advancing rapidly and the growth of this new exciting technology will probably accelerate when GPS becomes available within the next few years. A considerable amount of work has been done in developing preliminary specifications and standards for the Electronic Chart and it is clear that accurate, up-to-date, Hydrographic Office chart data will be a key element to the success of these systems in the future. In anticipation of a growing demand for chart data, hydrographic and other agencies would be well advised to devote some attention to the creation of the necessary Electronic Navigational Chart Data Bases and data transfer mechanisms to manage and distribute the Electronic Navigational Chart data and updates.

This paper describes some of the work that has been done in these areas recently. An information flow model that was developed by the International Hydrographic Organization Electronic Chart Updating Working Group is presented and the new terms that were needed are defined. Trends in Electronic Chart and related developments are also analyzed to determine what the Electronic Chart might be like in the mid 1990s. The problems of managing and disseminating the Electronic Chart data are also discussed.

INTRODUCTION

The capabilities of Electronic Charts (ECs) are advancing rapidly. Advertisements in shipping and yachting magazines show that EC manufactures

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are using faster computers, faster and higher density data storage devices and higher resolution colour displays. The next major advance for Electronic Charts, and for navigation in general, will be the introduction of the very accurate Global Positioning System (GPS) in the early 1990s. Whether directly or with the aid of differential corrections, GPS will probably provide the mariner with positioning accuracies he has never had before. Only with an Electronic Chart, which clearly displays his ship at the proper scale and correctly positioned relative to charted features, will he be able to reap the full benefits of GPS. However, for such a system to be successful it must be reliable and simple to operate (and interpret) and it must display accurate, up-to-date and appropriate chart data for the intended use.

A great deal of work has been done during the past several years on specifications for Electronic Charts. The work of the International Hydrographic Organization (IHO) and the International Maritime Organization (IMO) has been directed toward the development of specifications for an Electronic Chart that is functionally equivalent to the conventional paper chart for carriage purposes under the SOLAS Convention. An Electronic Chart that meets these standards is called an Electronic Chart Display and Information System (ECDIS). The North Sea Hydrographic Commission first started working on this problem in the mid 1980s. This work continued under the IHO Committee On Electronic Charts (COE) and was eventually published by the IHO in 1987 as The Hague Specifications (officially known as IHO SP-52) dealing with the chart content of ECDIS. In the fall of 1988, IHO released 'Updating the Electronic Chart' as an appendix to IHO SP-52. Both these documents are being revised on a regular basis. However, probably one of the most significant events for advancing knowledge of Electronic Charts was the North Sea Project carried out during 1988. This COE project was funded and managed by Norway and provided an opportunity for several Hydrographic Offices (HOs) to get hands-on experience with providing data for Electronic Charts and an oppportunity for over 500 people from more than 15 countries to see six different systems in operation onboard the Norwegian Survey Ship LANCE. The official report of this project was released in March 1989. (Norwegian Hydrographic Service, 1989).

In addition to the Specifications and Updating Working Groups four other groups are carrying out research and development under the COE:

— the Data Base Working Group (DBWG), which grew out of the North Sea Project, is designing an Electronic Navigation Chart Data Base (ENCDB, see below) using an area of the southern North Sea for testing,
— the Colours and Symbols Working Group is working closely with several marine, ergonomic and perception institutes/committees from around the world to determine the optimum characteristics of the ECDIS display,
— the Definitions Working Group is preparing a Glossary of commonly used electronic chart terms, and
— the Quality of Digital Data Working Group is investigating various methods for indicating the quality of electronic chart data.

The IHO Committee on the Exchange of Digital Data (CEDD), which is primarily concerned with the exchange of digital chart data between Hydrographic Offices, is developing the DX90 data exchange format and a chart data featureobject catalog which could be used for the transfer of electronic chart data between Hydrographic Offices and the electronic chart users.

In 1988 the need for closer cooperation between mariners and hydrographers in the design of electronic charts was recognized with the creation of the IMO/IHO Harmonization Group on Electronic Charts (HGE), within the Sub-Committee on Safety of Navigation (SON), of the Maritime Safety Committee, IMO. Many of the results from the IHO/COE Working Groups are considered by the HGE which meets annually and submits the results of its deliberations to SON. The 35th session of the SON, which met in London in January 1989, accepted the HGE 'Provisional Performance Standards for Electronic Chart Display Systems' and proposed that the HGE update the Provisional Performance Standards on a yearly basis with the goal of finalized performance standards by 1993.

In the USA, the Radio Technical Commission for Maritime Services (RTCM) has produced 'Recommended Standards' for ECDIS and for Updating Electronic Charts as well as a Glossary of Terms Associated with ECDIS. These detailed and well thought out standards, some of which are in their seventh draft, have been submitted to the SON and have also been considered by the HGE.

Other agencies such as the Comité International Radio Maritime (CIRM) and the Comité Consultatif International des Radiocommunications (CCIR) are also investigating various aspects of ECDIS.

ECDIS TRENDS

A number of interesting trends have been noticeable in the various reports and papers of the past few years:

— earlier studies tended to concentrate on chart equivalence, i.e. a video duplication of the paper chart. As a result of growing experience and input from a broader group of hydrographers, mariners, manufacturers and others, the present trend (SP-52 and Provisional Performance Standards) is towards simpler, less cluttered displays that can optionally display radar and other information in addition to chart data. More consideration is being given to single operation call-up/suppression of selected sets of information (eg. soundings, light characteristics, etc.) and to other display management techniques (eg. windows).

— there is a growing awareness that writing 'Specifications' or 'Standards' for ECDIS is like shooting at a moving target due to the rapid changes that are taking place in the several enabling technologies for ECDIS. Also, there is very little practical experience with ECDIS and a wide range of opinion exists between those who use Electronic Charts regularly and those who have never seen one.

— pressure is increasing from ship owners and ship builders to treat ECDIS as a module of an integrated ship's bridge system (as opposed to ECDIS as a stand alone system). This reflects the desire of ship owners to reduce the number of highly qualified officers needed for controlling ships' operations (Froese, 1989). This approach also optimises the flow of information and offers the mariner a standardized user interface for radar, ECDIS and other displays.

— there is a growing awareness of the fact that the ECDIS display is a collection of limited resources (size, resolution, colours, symbols, windows, etc.) and that these resources will have to be allocated very carefully. It is important to remember that the primary goal of ECDIS is safe navigation which can only be achieved by the timely and clear presentation of appropriate and accurate navigation information.

— the electronic chart vocabulary is growing in response to the need to clarify and expand the description of the subject. For example, Electronic Chart or EC is now often used in the more general sense to refer to the whole range of electronic charts from the simplest to the very sophisticated while ECDIS is an Electronic Chart that meets the HGE Provisional Performance Standards; an Electronic Navigation Chart (ENC), distinct from an Electronic Chart Data Base (ECDB) has been defined and, more recently, a System ENC (SENC) has been introduced to replace the SP-52 'Ship's ECDB'.

— earlier reports dealt fairly specifically with the technical specifications for ECDIS. The two Updating Reports (IHO and RTCM) and the 35th Session of SON, however, talk about the international infrastructure that will be necessary to support the dissemination of the ENC and Updates.

The remainder of this paper will deal primarily with the last two trends although it is impossible to discuss any of these topics in isolation.

THE ECDIS OF THE MID 1990s

The ECDIS of the 1990s will depend primarily on five interrelated factors:

1. the progress of the various enabling technologies for electronic charts,
2. the progress of the regulatory and standards setting bodies,
3. the creation of electronic chart data bases,
4. the creation of organizational and technical infrastructures to deliver the data and updates to the user in an agreed format,
5. the market place.

The technologies that will influence electronic chart development are:

Positioning

GPS is expected to provide global 2-D positioning by 1991 and 3-D by 1992. However, the important question is 'With what accuracy?'. The U.S. Department of Defence (1988) states that civilian users will achieve accuracies of

100 m when the full constellation of satellites is in place and Wells *et al* (1986) estimate that this accuracy could be improved to 5 m if differential corrections are applied. Local differential correction systems already exist in some areas and plans are well underway for the establishment of regional and even global GPS differential correction networks (Kinal, 1989). These accuracies will meet the needs of most mariners. For example, the U.S. Radionavigation Plan (1988) states that, except for resource exploration, the accuracy required for safe navigation of large ships in harbours and harbour approaches is 8-20 m with a fix interval of 6-10 seconds; the coastal and ocean requirements are much less stringent. The following statement in the plan is of particular significance to ECDIS:

> 'To effectively utilise the requirements ... a user must be able to relate the data to immediate positioning needs. This is not practical if one attempts to plot fixes on a chart in the traditional way. To utilize radionavigation information that is presented at 6 to 10 second intervals on a moving vessel, some form of an automatic display is required'.

For berthing and some survey and exploration operations, underway accuracies of 1-2 m are required and it is not clear whether differential GPS will be able to provide this in the future.

A number of alternative positioning techniques to GPS are also accessible to Electronic Chart users. Loran-C is available in many parts of the world and provides, at best, 100 m accuracies in good coverage; Loran-C is therefore not suitable for harbours and harbour approaches. Starfix is a private satellite positioning system currently operating throughout most of North America (Nortrup, 1989). Starfix accuracy is about 5 m but the receivers can only be rented and the system is mainly used for survey type operations. By mid decade activities presently underway by, for example, the European Space Agency and the U.S.S.R. (GLONAS) may result in new positioning and communications systems available to ECDIS users.

A number of harbours around the world are equipped with permanent high accuracy survey type positioning systems such as Syledis; but special receivers are required to use them and, in some ports, the signals are not generally made available. A recently developed radar positioning system, called RANAV (Lyall and Michelson, 1989), has the capability of providing precise positioning to an unlimited number of ECDIS users in harbours and restricted waterways such as the St. Lawrence Seaway. RANAV uses a specially modified radar to measure ranges and bearings to dedicated passive polarized radar reflectors on shore. A computer, interfaced to the radar, computes fixes from all the measured ranges and bearings. An operational system in eastern Canada is routinely giving accuracies of 1 to 3 m.

Regardless of the positioning method used by the ECDIS, the mariner will always need some way of verifying its accuracy. One very simple technique is to optionally display the radar image on the ECDIS display; if the radar image matches the chart where, with his experience, the mariner knows it should match, he is immediately assured that his positioning is accurate.

Computer Hardware

The motto of the computer industry seems to be 'Smaller, Cheaper, Faster' and at current rates of progress this area of technology will certainly foster ECDIS development (Scientific American, 1987). The four areas to watch are: computer speed and price (Spiegelman, 1989); memory size and cost per bit, which will continue to decrease 15-20 percent annually (Andrew, 1989); size, cost and access speed of mass storage devices and; the speed, size and resolution of colour displays, especially the flat-panel, low power, colour LCD displays and the new High-Definition Television (HDTV) (Tannas, 1989). Cheaper, high resolution, full colour plotters could have a role to play onboard vessels for the creation of hard-copy versions of the ECDIS display for planning purposes or for examining the ship's track after the fact. However, it is more likely that they will be used at the Local Distribution Centres (See Fig. 1) as 'Print On Demand (POD)' stations that will use the ENCDB data to plot completely up-to-date paper charts on demand. The POD concept is being developed by the Canadian Hydrographic Service (Vachon, 1989). Raster scanners and raster-to-vector conversion systems could also have a significant impact on the creation of Electronic Navigational Chart Data Bases.

Computer Software

Systems software development is keeping pace with computer hardware. Not only is it faster and more reliable, it also offers more features, especially in the area of networking where it is becoming easier than ever before to communicate and transfer data between dissimilar hardware configurations. During the 1990s Geographic Information Systems (GIS) software availability and capability will continue to expand; a GIS core could become standard in many ECDIS. Also Spatial and Distributed Data Base Management Systems and Artificial Intelligence (eg. Expert Systems) may become commonplace (Grabowski, 1988 and Casey *et al*, 1989). All of these advances will contribute significantly, and may even be essential, to the development of both the ECDIS and the technical infrastructure that will be needed to support it.

Data Communications

The rapid growth in the positioning and computer areas is being matched by the communications industry. Dramatic changes have taken place in marine communications since the introduction of INMARSAT Standard 'A' in the mid 1980s (Fear, 1989). INMARSAT is now introducing Standard 'C', a two-way satellite data communications system employing low cost, compact receivers and simple, non-stabilized, omnidirectional antennae suitable for fitting on all sizes of vessels. Standard 'C' is significant for electronic chart users because, even at its slow 600 bit/sec., it is capable of carrying the ENC Update data volume of 1350 kbit/week estimated by the IHO EC Updating Working Group. However, the

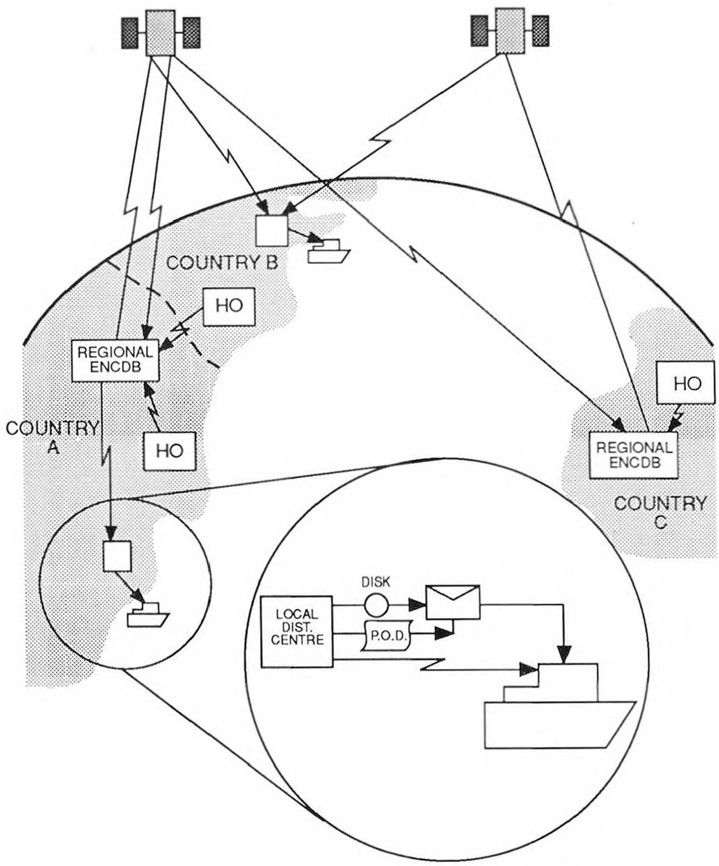

FIG. 1.— Electronic Navigational Chart Distribution System.

most important advantage of Standard 'C' is that it provides, with its Enhanced Group Call (EGC) capability, virtually world-wide broadcast coverage. As this is part of the future GMDSS (Global Maritime Distress and Safety System), there will be a carriage requirement by SOLAS for all vessels sailing beyond NAVTEX coverage to be equipped with EGC receivers by the mid 1990s. This ensures that Automatic Electronic Chart Updating will be available to most ships provided that the necessary data dissemination system is established.

INMARSAT is presently working on fully digital Standards 'B' and 'M' that will be capable of handling data rates of 16 and 6 kbits/sec. respectively. Evaluation of Standard 'M' could start in late 1992. At these data rates it is not unreasonable to consider the transmission of digital chart correction patches.

Land based telephone and packet switching networks are accessible in many parts of the world and can typically handle data rates up to a few tens of kbit/sec. Advances in data compaction and error checking software as well as improvements in interfacing hardware and line quality will increase these rates significantly in the next few years. As well, the rapid expansion of the cellular telephone networks is providing cheap reliable communications over land and near shore and the mobile satellite system MSAT could be in service by 1995. The inclusion of a data signal into the unused portion of C-Band satellite video channels has recently demonstrated that high speed (512 kbits/sec.) data transfers can be accommodated at 10% of their regular cost (MacCuaig, 1989). Data rates of 6 megabits/sec. using satellite broadcasting were achieved during the Canadian Hydrographic Office Print-On-Demand experiment (Vachon, 1989).

In the future, networks using optical-fibers and sophisticated hardware and software interfaces will be capable of transmitting data at over 100 megabits/sec. (Stix, 1990); for electronic chart advocates that translates into about 100 to 200 digital charts per second. Special data formats such as MACDIF (C.H.S., 1988), optimised for telecommunications transfer of digital chart data, will be needed. MACDIF (Map And Chart Data Interchange Format) is built upon the Open Systems Interconnect (OSI) concept of the International Standards Organization that is gradually overcoming many of the obstacles of communicating among dissimilar computer systems.

Other Factors

The ECDIS of the 1990s will also depend on the progress of the various regulatory and standards setting bodies and the availability of digital electronic chart data. As mentioned in the introduction a number of agencies are working on ECDIS standards and specifications. The guiding principle for all of this work is the assumption that ECDIS will eventually replace the paper chart on the ship's bridge. There is pressure for standards because manufacturers can not produce an 'official' ECDIS until they have standards and Hydrographic Offices will be reluctant to produce, or licence the production of, digital chart data (and accept legal responsibility for it!) until there is sufficient demand and they can be assured that the information is correctly portrayed by the ECDIS. At present less than 10% of the charts of the developed countries are in digital form.

IHO has now developed a draft international data transfer standard which will be subjected to rigorous testing with the regional test data base planned by the IHO Data Base Working Group for an area in the North Sea. In addition, two countries, Norway and the Netherlands, are starting independently to equip vessels with operational ECDIS using INMARSAT EGC for updating. The Netherlands project plans to use the existing and recently developed standards to the fullest extent possible. The IHO DBWG project may result in an operational ENCDB of part of the North Sea in the near future.

At present all electronic charts use data provided by the manufacturer or data entered by the operator via the front panel or a digitizer. Although the charts appear crude they are improving rapidly. Since so little digital Hydrographic Office data exists and it will be some time before the ENCDB Management System and data transfer formats and infrastructure are internationally agreed, it is unlikely that this situation will change significantly in the next few years. Once initial agreement on the formats, infrastructure, etc. has been reached the most likely next step will be the creation of a limited infrastructure similar to Figures 1 and 2 with a few Regional ENCDBs containing 'official' data for a few selected harbours or waterways. Outside the 'official' coverage areas unofficial manufacturers's data will have to be used. This will probably be the situation at mid-decade and Hydrographic Offices will likely be under increasing pressure to produce more digital electronic Navigational Chart Data. If Hydrographic Offices are unable to do this fast enough themselves they may have to do it under contract. Alternatively, they might introduce a licencing arrangement whereby private institutions digitize charts according to accepted standards and sell the data to the ENCDB Coordinator or even directly to the ECDIS manufacturers, vendors or users.

ECDIS Terminology and Information Flow Model

In some respects learning about Electronic Charts is like learning a new language. The word Electronic, for example, is used in a whole range of expressions that describe everything from a video display to a data base (or the data in it) as well as digital data travelling along a wire. The ECDIS language is also immature and it is important to be flexible and allow it to evolve to meet changing perceptions just as is now being done with ECDIS specifications and standards. In the following paragraphs revised definitions of some existing terms as well as some new terms are proposed. These changes and additions are necessary to adequately describe the present status of ECDIS and the present perception of the infrastructure that will be necessary to support it.

The IHO Updating Working Group report describes an information flow model that starts with the national ECDB and ends with the updated digital chart in the vessel's ECDIS, in a format compatible with the particular features of that system. A number of new terms were needed to describe this model and the definitions of some of the existing terms, which were found to be restrictive and imprecise, had to be revised. The new and revised definitions are described below and illustrated in Figures 1 and 2. It should be noted that although these figures show multiple Regional ENCDBs the proposed definitions that follow are not restricted to this view. The various terms work equally well whether the ENC is issued directly by the Hydrographic Offices or from a single super agency that coordinates the distribution of the ENCs for the entire world. The proposed new and revised Electronic Chart terms are as follows:

Electronic Chart Data Base (ECDB):

'The master data base for Electronic Navigational Chart Data (ENCD), held in digital form by the national hydrographic authority, containing chart information and other nautical and hydrographic information.'

This definition expands the previous definition to include non-chart information such as tidal data, sailing directions, etc. It should also be noted that

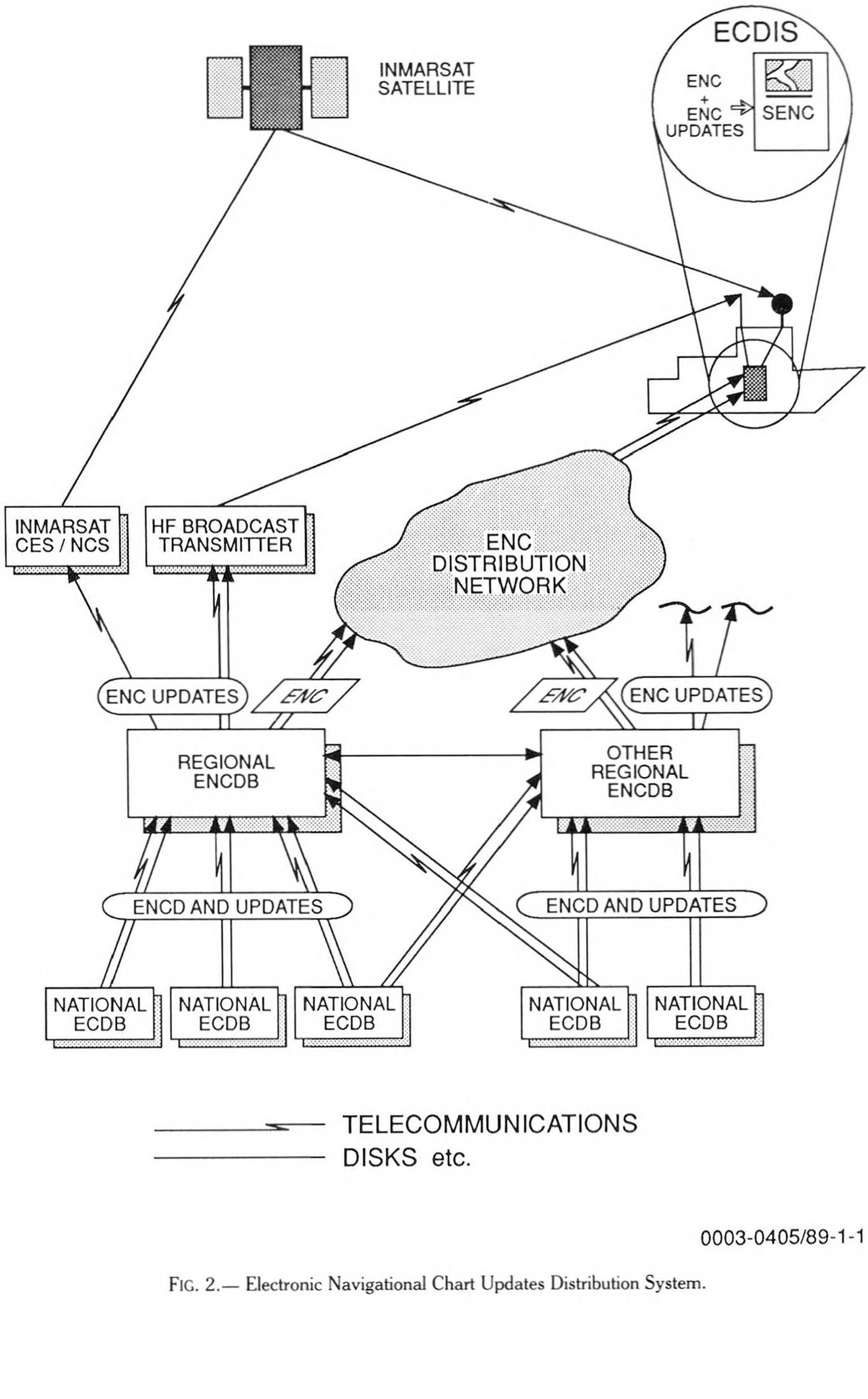

FIG. 2.— Electronic Navigational Chart Updates Distribution System.

since the ECDB is entirely internal to the national Hydrographic Office it is not standardized; that is, it is unique to each Hydrographic Office and may contain confidential national information or, indeed, it may even be part of a much larger data base used to support a number of national hydrographic or related activities.

Electronic Navigational Chart Data (ENCD):

'The national data for an ENC in a format acceptable to the ENC Coordinator.'

The ENCD is the data derived from the national ECDB as a contribution to the ENCDB. The ENCD can be delivered in any format acceptable to the ENCDB Coordinator although it would clearly be preferable to utilize an internationally agreed format.

Electronic Navigational Chart Data Base (ENCDB):

'The master data base for production and maintenance of the ENC, compiled from the national ENCD.'

The ENCDB holds all the ENCD in the form of a data base, i.e. within the framework of a data base management system. It exists solely for the production and maintenance of the ENC as opposed to the ECDB which may also be required to satisfy a number of national needs.

The need to introduce the ENCDB as a new term, distinct from the ECDB, stems mainly from the fact that the ENC is thought to cover, in general, a whole region composed of different national waters. This implies the need for a Coordinator responsible for the regional ENC and the updating service for it. It is not clear how difficult the task of harmonizing the data sets from the different countries will be. The Coordinator would be a national Hydrographic Office agreed by, for example, an IHO Regional Hydrographic Commission, but other institutional arrangements authorized by the Hydrographic Offices concerned could also be envisaged.

However, if an ENC provides national coverage only, this concept still remains useful. For example, if such a national ENC is produced by an agency authorized by the responsible Hydrographic Office, this agency would act as the 'Coordinator' and would, necessarily, maintain the ENCDB. If the Hydrographic Office itself produces the national ENC, then the Coordinator and Hydrographic Office would be one and the same, and the ENCDB could be either a separate data base of the Hydrographic Office or part of a more comprehensive ECDB. However, for compatibility and ease of coordination among Regional ENCDB Coordinators, a common ENCDB Management System would be preferred.

Electronic Navigational Chart (ENC):

'The data base, standardized as to content, structure and format, issued for use with ECDIS. The ENC is equivalent to New Editions of paper charts, and may contain additional nautical information compared with the chart. The ENC is a subset of the ENCDB developed from national hydrographic authorities' ENCD.'

The ENC structure and format would normally be optimised for transmission, not use (see SENC below), and for the particular medium via which it is to be transmitted to the user. In fact, the ENC format may change as it travels from one medium to another (eg. telecommunications and disk). It is important, therefore, that a reliable mechanism be available to check that its integrity has not been compromised whenever it changes medium or format and especially when it arrives at its destination.

System ENC (SENC):

'The data base, transformed by ECDIS from the ENC for optimum use, and updated by appropriate means. The SENC is the data base that is actually accessed for display generation and other navigational functions. The SENC contains the equivalent to the up-to-date paper chart.'

The various specifications to-date have stated that the ENC must remain unaltered and updates must be recorded separately. Also, the format and structure of the ENC will be optimised for transmission, not necessarily for efficient use by the ECDIS. The concept of a System ENC, which consists of the ENC plus ENC updates, reorganized and optimised for rapid access by the ECDIS, was therefore introduced.

Figure 1 illustrates the fact that data will have to routinely flow between ENCDB Coordinators. For example, a ship departing Montreal for Hamburg could request an ENC for the North Sea from a local distributor in Montreal who would then pass the request on to the Regional ENCDB Coordinator for, say, Eastern Canada. The Eastern Canada Regional ENCDB Coordinator, in turn, would request the data from the North Sea Regional ENCDB Coordinator. The data would then flow back through the system to the ship. Alternatively, local distributors might make requests and receive data directly to/from the various Regional ENCDB Coordinators around the world. Either scenario will clearly require a considerable amount of international cooperation and coordination.

Figure 1 also shows data flowing from the individual Hydrographic Offices directly to the nearest Regional ENCDB Coordinator. No reason exists for the data not to flow from the Hydrographic Offices to the other ENCDB Coordinators as well. For example, an Eastern Canada Regional ENCDB Coordinator might receive data from Canada, the U.S.A., France (Ile Saint-Pierre-et-Miquelon) and even Denmark if the ENCDB extended to Baffin Bay. The same network could be set up to pass information back to the Hydrographic Offices.

In the future, to speed up the delivery of up-to-date data, it is likely that automatic links between the Regional ENCDB and the individual national ECDBs will be set up. Eventually, as this process evolves, the Regional ENCDBs may degenerate into simple data communications/data transformation nodes within the worldwide network with the actual data residing in the individual Hydrographic Offices. This is similar to the structure of the present airlines reservation system.

CONCLUSIONS

Electronic Charts have progressed in the last decade from a vague notion to an accepted concept. The next decade will probably see this exciting new technology transformed into an every day reality. The main efforts of the past have been directed toward learning about and defining what the Electronic Chart should look like and how it should be used; during the next decade this effort must continue, and in addition, a considerable amount of effort will be needed to define and implement the international technical and administrative infrastructure to ensure that Electronic Charts have accurate and up-to-date data, especially if they are eventually to replace the paper chart on the ship's bridge.

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