Abstract:

The Convention for Safety of Life at Sea (SOLAS) provides that an Electronic Chart Display and Information System (ECDIS), using Electronic Navigational Charts (ENCs), meets the chart carriage requirements for shipping regulated by the Convention. It is well documented that the use of ECDIS markedly enhances maritime safety and efficiency; however, its broad employment is hindered by a lack of ENC coverage, inconsistencies between producers and problematic distribution mechanisms. The International Hydrographic Organization (IHO), an intergovernmental consultative and technical organization, has expended substantial resources in establishing standards and principles for the format, content, production and distribution of ENCs. With over a decade of lessons learned, the IHO has focused on surmounting the remaining obstacles to attaining a seamless, distributed, and readily available Worldwide Electronic Navigational Chart Database (WEND).

Introduction:

The collection of nautical information has been a part of maritime operations from the time man sought to conduct trade or warfare by sea. The nautical information obtained was difficult to collect, tedious to use but of immense value and, generally, closely held. For much of maritime history, the status of the ship’s master was derived largely on his personal knowledge of geospatial information. Over time nautical geospatial information was rendered to paper but suffered wide variations in content, format and accuracy. The status of nautical cartography and navigation was such that by the conclusion of World War I more ships had been lost to groundings than to enemy action. It was against this backdrop that the International Hydrographic Bureau (IHB), the precursor to the International Hydrographic Organization (IHO), was formed to enhance safety of navigation by, among other objectives, achieving the greatest possible uniformity in nautical charts and documents.

The last half of the twentieth century witnessed quantum leaps in all aspects of nautical cartography. The storage mechanism for the data that will become the nautical chart is a computer based data file not a copper plate. Changes to the data file can be easily applied and from this file, an accurate, up-to-date chart may be printed on demand. Print on demand eliminates the need to laboriously correct charts that were off set printed by the thousands and stored, awaiting the requisition of the mariner. The RASTER scanning of paper nautical charts to produce data files that could electronically reproduce the paper chart for displayed on a video screen enable the coupling of the chart display with the ships location derived from satellite positioning. Ultimately, the rendering of nautical information into a digital file of vector relational data provides the greatest flexibility and usability in depicting information necessary for the safe navigation of a ship. In an effort to achieve the greatest possible uniformity in electronic charting, the IHO set out in the late 1980’s to develop a standard for the transfer of digital hydrographic data between hydrographic offices and for the display of digital hydrographic data on a video screen.
The consequences of loss of life and damage to the environment, should, among other things, sound navigation practices not be adhered to, have lead to the adoption of the International Convention on Safety of Life at a Sea (SOLAS). SOLAS governs many aspects of maritime operations from ship construction to crew training. It also governs navigation and coastal states’ obligation to provide adequate nautical information to provide for safe navigation. This includes the definition of a Nautical Chart and how electronic charting may be implemented in the navigation suite.

The Nautical Chart:

SOLAS Chapter V, Regulation 2 defines a nautical chart or nautical publication as:

“A special-purpose map or book, or a specially compiled database from which such a map or book is derived, that is issued officially by or on the authority of a Government, authorized Hydrographic Office or other relevant government institution and is designed to meet the requirements of marine navigation. “

It is important to note the text highlighted by the author. The nautical chart is designed to meet the needs of marine navigation. It must, therefore, depict a certain minimum level of information but may omit other information not deemed necessary for marine navigation, most notably various information ashore not used as landmarks or marine facilities. That a nautical chart can explicitly be a database allows electronic charts to meet the legal needs of the mariner. Most importantly, the chart must be issued officially by or on the authority of a government. SOLAS Chapter V, Regulation 9 requires the governments producing nautical charts and information to ensure the greatest degree of uniformity and refers to the IHO as the competent organization to dictate the standards that would lead to uniformity.

SOLAS Chapter V, regulation 19 lays out the shipborne navigational equipment and systems all ships, irrespective of size, shall have. With respect to nautical charts, it requires:

“Nautical charts and nautical publications to plan and display the ship’s route for the intended voyage and to plot and monitor positions throughout the voyage; an electronic chart display and information system (ECDIS) may be accepted as meeting the chart carriage requirements of this subparagraph;”

Therefore, all ships must carry nautical charts and a specific type of electronic chart system, an ECDIS, may satisfy this requirement.

Electronic Chart Display and Information System (ECDIS):

An ECDIS is a computer based hardware and software suite of prescribed functionality and display qualities as delineated in the International Maritime Organization (IMO) Resolution A.817(19), Performance Standards for Electronic Chart Display and Information Systems (ECDIS). Furthermore, a certifying agency must attest that an ECDIS meets these performance standards using the International Electrotechnical Commission procedures found in IEC Publication 61174, Electronic Chart Display and Information System (ECDIS) – Operational and Performance Requirements, Methods of Testing and Required Test Results. This technical
description is offered to make evident that an ECDIS is a rigidly defined system under international standards, regulations and conventions.

The IMO is explicit in noting that an ECDIS may satisfy the chart carriage requirement because the use of ECDIS to plan, execute and monitor an international voyage results in quantifiable increases to safety of navigation and efficiencies in maritime operations. ECDIS integrates various navigation sensors and nautical information to provide continuous, real-time and accurate positioning. The mariner’s attention is no longer focused on obtaining and plotting the vessel’s position but on evaluating the current situation and determining future actions. Because the ENC database is “smart” – that is it can be interrogated for additional information, integrated with other parameters and set to respond to thresholds set by the mariner, the ECDIS can warn of dangers or indicate planned maneuvers along the projected path of the vessel. Integration of RADAR displays and Automatic Identification Systems within the ECDIS display further contributes to safety of navigation and particularly collision avoidance. These features can be used effectively in confined waters and in ports, especially during periods of poor visibility. The classification Society DNV, has found that the chance of going aground falls by 40% when using ECDIS. Also, the Canadian Coast Guard reports that a third of all grounding and collisions could be avoided by using ECDIS. Additionally, ECDIS can greatly enhance the efficiency of maritime operations. No longer must the navigator laboriously pour through Notice to Mariners, extracting pertinent changes and annotating those changes on a paper chart. Within the ECDIS, changes to the ENC are compiled and displayed through routine electronic changes received via e-mail, internet or on electronic media. For voyage planning, the necessary portfolio of charts at the appropriate scale is quite literally at the navigator’s fingertips from the ECDIS console. Additional information such as tide tables, list of lights, and sailing direction are similarly retrievable from the ECDIS console. During the voyage, the vessel’s position is continuously plotted on the chart display and logged, along with other information the mariner may wish to enter manually or automatically.

**Electronic Navigational Chart (ENC):**

The necessary “fuel” to drive an ECDIS is the Electronic Navigational Chart (ENC). Within the IMO Performance Standard, an ENC is defined as:

“The database, standardized as to content, structure and format, issued for use with ECDIS on authority of government authorized hydrographic offices. The ENC contains all chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart (e.g. sailing directions) which may be considered necessary for safe navigation.”

The IHO began its work on specifying the content, structure and format of the ENC in the late 1980’s and initially approved the ENC Product Specification, the IHO Transfer Standard for Digital Hydrographic Data and the Specifications for Chart Content and Display Aspects of ECDIS in 1992. These documents provided the content, structure and format whereby government hydrographic offices could begin encoding ENCs.
The technical aspects of content, structure and format of ENCs have evolved little since those early days. Of paramount importance is stability in the standards so that hydrographic offices could produce ENCs and software manufactures could produce code that would read and display ENCs. Minor changes occurred in 2001 and the code has been frozen since that time to facilitate ENC production and use. It is a testament to the early developers that so few changes to their standard have been indispensable. The state of the science by the new millennium was reasonably capable software suites for the encoding of ENCs offered by several manufactures and several companies highly proficient in encoding ENCs should a hydrographic office choose to outsource the production.

**ENC Coverage**

However, the production of ENCs had a very slow start. They are costly to produce and these costs are in addition to continuing the hydrographic office’s analog production and maintenance efforts. With few ENCs available there is little motivation for shipping companies to procure an ECDIS; therefore, sales of existing ENCs were minimal. Given this slow, initial production, by 2004 ENCs were available for the national waters of most developed countries. While some regional shipping routes are covered by ENCs (the North Sea and Baltic being the best examples), complete coverage of most international shipping routes was not available. In some measure, this situation was brought on by the IHO guidance issued by the Worldwide ENC Database (WEND) Committee as a set of WEND Principles that focused predominately on production in waters within national jurisdiction. Realizing this imbalance, the WEND Committee, began an initiative in 2004 to stimulate ENC production along prioritized shipping routes and in waters beyond the national jurisdiction of IHO Member States. The effort has been largely successful. The UKHO and SHOM have produced several small-scale charts covering waters where they have had historical responsibility. In the South China Sea, the East Asia Regional Hydrographic Commission has produced four small-scale charts covering the area and is distributing them free of charge. The IHO is encouraging the development of bilateral agreements between those hydrographic offices not yet capable of producing and maintaining ENCs with those hydrographic offices more advanced and resourced in ENC production.

**ENC Consistency**

As more ENCs became available for use, the ENCs encoded by different hydrographic offices displayed significant differences in appearance, despite the seemingly prescriptive nature of the ENC standards. It should be stressed that these dissimilarities are not due to bad data or encoding but rather in interpretation of the standards; however, they are none the less disconcerting to the mariner. These dissimilarities include different contour intervals or shadings, inconsistencies at cell boundaries, gaps at cell boundaries and assigning similar objects with different SCAMIN attributes. It is also important to recall that dissimilarities exist between paper charts produced to IHO standards but the mariner was accustomed to dealing with these differences as he transferred his navigation to the next paper chart. The IHO, through its Committee on Hydrographic Requirements for Information Systems (CHIRIS) has provided additional guidance to rectify many of these inconsistencies. Another important check on consistency is performed by the Regional ENC Centers (RENC). The WEND Principles encourage the formation of RENCs as distribution mechanisms for ENCs. While only two RENCs are active, they have proved...
invaluable in providing a final consistency check between ENCs they distribute and working with their member hydrographic offices to obtain a seamless appearance across national boundaries.

**ENC Availability**

Returning to the ENC coverage catalogue displayed earlier, there are several ENCs that have been produced but are not available commercially. There are a few distinct reasons for a hydrographic office going to the expense to produce an ENC but not making it commercially available.

- In some cases, the ENC encoding has been outsourced and the hydrographic office is conducting internal quality assurance checks. In these instances the non-availability should be short lived and these ENCs would become commercially available in due course.
- An ENC must be kept up-to-date. Some producers have not instituted an update mechanism; therefore, their ENCs are not yet commercially available. Effective update mechanisms are available and WEND has encouraged they be adopted.
- In other cases, the hydrographic offices have yet to grasp the business model for distributing digital data. In these cases, the WEND Committee encourages the hydrographic office to align with one of the existing RENCs as a proven mechanism for distribution. The RENCs are also creating distribution templates that one or a few hydrographic offices can adopt to create their own RENC.
- In still other cases, issues of copyright or sovereignty when an ENC covers waters of multiple national jurisdiction, that were satisfactorily managed in the paper chart era, remain unresolved in the digital era. The East Asia Regional Commission’s production of the South China Sea ENCs is an creative method of overcoming these obstacles.

**Affordable and Straight Forward Distribution**

As shipping companies, or their chart agents, began collating ENCs to cover international voyages, they were confronted with a labyrinth of pricing, media and update mechanisms. It was not uncommon for a voyage to require several individual CD and maybe an online download. Some ENCs were encrypted using the IHO standard security scheme while others were not and still others were distributed in proprietary SENC formats. This mix of encrypted, unencrypted and SENC ENCs caused problems while loading ENCs on many ECDISs. ENCs from different sources could have different update schedules and methods. And, of course, the pricing varied from free to prohibitively expensive, from the shipping company’s perspective.

Again, the WEND Committee encourages hydrographic offices to avail themselves of the services of a RENC that would streamline and simplify the distribution process. To this end the two active RENCs distribute the ENCs of twenty-six countries

**The Future**

After a painfully slow beginning ENC production appears well underway with many international voyages between major ports covered by ENCs. Several ENC producers have begun proactive production in international waters. Recent initiatives proposed by WEND would strongly encourage the countries not capable of producing
ENCs for their waters authorize another country to produce and maintain ENCs for their waters until such time as they are capable of executing this responsibility.

Similarly, most of the major ENC producers have aligned with one of the two active RENCs benefiting the final quality assurance of the ENC and streamlining the licensing and distribution mechanisms. There remain a few issues amongst major ENC producers that have not aligned with a RENC.

With the initial difficulties in ENC production and distribution, shipping companies could not employ ECDIS as a primary navigation device. But with the recent advances cited in this paper, ECDIS use should markedly increase in order to reap the quantifiable increases in safety and efficiency attributable to ECDIS use. Current discussion in IMO may lead to the regulations mandating the use of ECDIS on certain vessels within the next five to seven years. Clearly the IHO Member States must be in a position to support that use with ENCs covering the intended voyages.

Beyond the provision of worldwide coverage, readily available through a user-friendly distribution system, future ENCs must incorporate new source data collected using modern hydrographic techniques. While information regarding the age and quality of the hydrographic survey is a part of the ENC, it may not be as obvious to the mariner as the indications on a paper chart that the survey data may be sparse. That the chart is displayed on a computer screen further leads to an assumption modernity. Upgrading the dated charts with new source data requires significant resources and a national or regional priority. Only with such a priority can the IHO provide the mariner the tools necessary to enhance safety of navigation and efficiency of maritime operations.