MARINE ELECTRONIC CHARTING:
Current Status of International Hydrographic Organisation's Achievements

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Abstract

In November 1995, the International Maritime Organization (IMO) adopted an Assembly Resolution on Performance Standards for Electronic Chart Display and Information Systems (ECDIS), specifying the minimum performance requirements for ECDIS (Resolution A19/ Res.817). The IMO Performance Standards include specific references to the IHO specifications for ECDIS (Publication S-52 and its appendices) and the IEC Standard on ECDIS testing requirements (IEC 61174). Furthermore, the chart data to be used on ECDIS are referred to as Electronic Navigational Chart (ENC), a database originating from a government-authorized Hydrographic Office and based on IHO Transfer Standard S-57.

IEC 61174 Standard and the current editions of S-52 & Appendices, and S-57 (Edition 3.0), were subsequently published over 1996-1998. From there, the scene was set for production of ENC's by Hydrographic Offices and development in parallel of ECDIS by commercial manufacturers.

This paper focuses on ENC development, explaining why it has taken longer than expected to have ENC's available on the market, detailing the current status world-wide by means of chartlets and tables, and providing expectations as regards future ENC availability.

1. BACKGROUND

The adoption by the International Maritime Organization of Performance Standards (PS) for Electronic Chart Display and Information Systems (ECDIS), in November 1995 (Resolution A19/ Res.817), paved the way for the development of not only ECDIS but also Electronic Navigational Charts (ENC). In effect the IMO PS specified that ECDIS, a GIS-like system with digital chart data and electronic positioning that is used onboard ship for safe navigation, must be used with ENCs produced by Hydrographic Offices (HOs).

According to its definition, an ENC is a "*data base, standardized as to content, structure and format, issued for use with ECDIS on the authority of government-authorized hydrographic offices. The ENC contains all the 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*". ENCs must conform to the ENC Product Specification, as contained in IHO Publication S-57 "IHO Transfer Standard for Digital Hydrographic Data", and which defines in detail the chart content of an ENC in terms of S-57 features (called "objects" and "attributes"). S-57 also specifies the data structure to be used when transferring ENCs. The current edition of S-57 is Edition 3.1, dated November 2000. Additional specifications in regard to ENC data content, its display on ECDIS and its updating are contained in IHO Publication S-52 "Specifications for Chart Content and Display Aspects of ECDIS". A sample of ENC displayed on an ECDIS is shown in Figure 1.

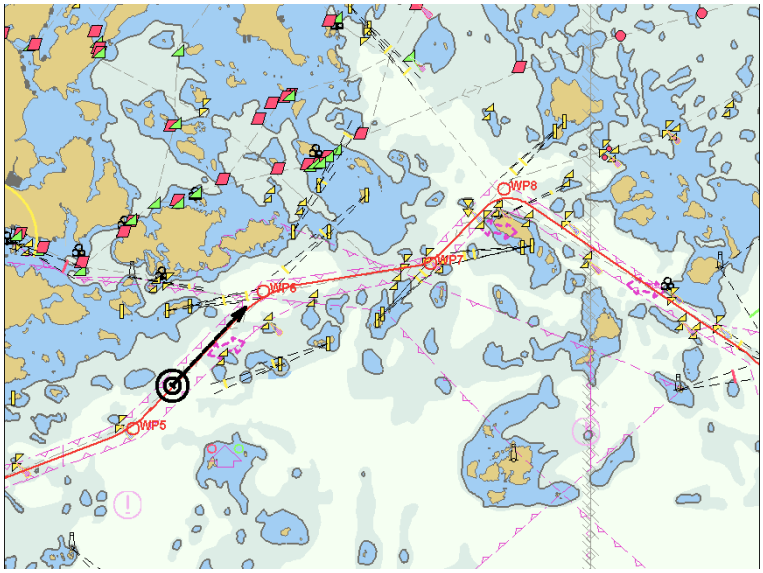


Figure 1. ENC displayed on ECDIS

It should be stressed that ENCs are vector data, as opposed to raster data. This means that every ENC feature, e.g. a coastline, is defined by a set of coordinates and identified by an individual name, thus allowing an "intelligent" management of the ENC database on ECDIS. Raster data is simply the result of chart scanning and is composed of an arrangement of pixels. The counterpart of vector data complexity is that their production is far more resource and time consuming than that of raster data.

In addition to the IMO PS and IHO Publications S-52 and S-57, the third component of the ECDIS development has been a standard of the International Electrotechnical Commission (IEC) known as IEC 61174 "ECDIS – Operational and Performance Requirements of Testing and Required Tests Results". IEC 61174 is used by type-approval agencies to certify ECDIS. The current edition of the IEC Standard was published in 1998.

Although some HOs had started producing ENC data in the early nineties, based on a previous editions of S-57, data creation on an industrial scale actually commenced after release of S-57 Edition 3.0 in 1996. However, the initial underestimation of the complexity of S-57 and the time required to get familiarized with the IHO Standard, the need to develop new software tools in the frame of ENC production as well as new working procedures, e.g. for quality control and quality assurance, and the requirement for HOs to pursue their paper chart production programmes (sometimes in conjunction with budget restrictions), have slowed down the overall process of ENC data creation. It was only in 1999 that the first ENCs appeared on the market, although a significant amount of "trial" ENC data had reportedly been previously produced. However, more and more HOs have now overcome the main difficulties and have actively embarked upon ENC production programmes.

The non-availability of operational ENC data in sufficient quantities also had an obvious negative impact on ECDIS development. Although an amendment to the IMO PS was adopted in 1998, allowing the use of Raster Navigational Charts (RNC – raster charts produced by HOs) on ECDIS where there is no ENC available, the ECDIS market mainly relies on the availability of ENC data. As a result the first ECDIS to be type-approved was logically also in 1999.

2. STATUS OF ENC PRODUCTION

2.1 General Overview

During 1999-2000, a considerable number of ENCs were created by government HOs and actually made available to mariners. This trend has even amplified in 2001 and Table 1 provides recent statistics on ENC production amongst IHO Member States. Associated with Table 1 is the colour chartlet in Figure 2, which shows the main areas in the world where ENC data has been produced. The limits, shown in red on the chartlet, are very approximate and are only intended to give a general picture of ENC data production worldwide.

Figure 2. ENC Data Production - Estimates May 2001

Table 1 – Status of ENC Data Production by IHO Member States (Estimates – May 2001)

IHO Member State	ENC Produced (No of Cells)	Equivalent Paper Charts	ENCs on the Market (with Update Service)
Australia	36	36	-
Belgium	1	1	-
Brazil	10	-	-
Canada	502	267	502
Chile	40	31	38
China	100	100	-
Colombia	7	-	-
Cuba	5	5	-

IHO Member State	ENC Produced (No of Cells)	Equivalent Paper Charts	ENCs on the Market (with Update Service)
Denmark	316	56	316[1]
Estonia	30	30	-
Finland	9	4	9[1]
France	68	-	68[1]
Germany	27	27	27[1]
India	150	-	-
Italy	56	56	-
Japan[2]	342	330	342
Korea (Rep. of)	205	275	205
Malaysia[2]	3	-	-
Mexico[3]	5	-	-
Netherlands	6	-	5[1]
New Zealand	13	13	-
Norway (NHS)	237	67	237[1]
Peru	94	94	4[1]
Poland	8	8	8[1]
Portugal	10	10	10[1]
Russia	2000	2000	29[1]
Singapore[2]	14	14	14
South Africa	30	30	-
Spain	30	30	25[1]
Sweden	52	93	52[1]
Turkey	30	30	-
Ukraine	10	10	-
UK	161	161	63[1]
USA (NOAA)	116	116	-
Totals	**4711**		**1954**

Not all IHO Member States are listed in Table 1 and ENC data may have been produced by some other Member States like Croatia, Greece and the Philippines which started ENC development projects in 2000-2001. In addition, USA-NIMA have so far produced 5,000 Digital Nautical Charts (DNC) and will eventually provide a worldwide coverage. DNCs are vector charts conforming to a format known

[1] Available from PRIMAR, the European RENC
[2] Indonesia, Japan, Malaysia and Singapore have also jointly produced 6 ENC cells in the Malacca and Singapore Straits
[3] Pending IHO Member State

as VPF and mainly intended for use by the US Navy. DNCs, which may be commercially released in future, are currently not accepted on ECDIS. More information on DNCs can be found at (www.nima.mil).

The figures in Table 1 (2nd column) indicate, in most instances, the number of "equivalent paper charts". This means that the unit used to express the geographical area covered by ENC data is the well-known paper chart. In effect, an ENC may itself be sub-divided into ENC cells and the terms “ENC” and “ENC Cell” appear to be differently interpreted as regards their geographical coverage. ENC limits may significantly vary, depending on the producing agency. An ENC cell may follow a regular gridded structure or it may follow paper chart limits.

From the above table it can be seen that, as regards operational ENC availability, Denmark, Norway and several other European HOs cooperating under PRIMAR, Canada, Japan and Rep. of Korea have taken the lead. Russia’s ENC production is also impressive, although most of their ENCs are not yet available to the general public.

According to IHO recommendations, distribution of ENCs should be made through Regional ENC Coordinating Centres (RENCs), entities established on a regional basis by several cooperating HOs to facilitate ENC distribution. The first RENC has been set up in Europe and started an official ENC service in October 1999 under the name of PRIMAR (For a graphical presentation of the ENC coverage, refer to www.primar.org).

Table 2 - Number of ENC Cells Available by Usage Band from PRIMAR

Country	Usage Band						Total
	1	2	3	4	5	6	
Denmark		20	166	112	18		316
Finland				9			9
France			33	21	8	6	68
Germany		1	4	6	16		27
Netherlands			5				5
Norway				205	32		237
Poland				4	4		8
Portugal	1	2	3		4		10
Russia			3	4	14	8	29
Spain			7	9	9		25
Sweden		40	5	2	3	2	52
United Kingdom	1	10	12	20	20		63
Totals	2	73	238	392	128	16	**849**

Figures in Table 1 reflect the overall ENC production, whatever the charting scale. The number of ENCs produced in a given scale range is not shown. However, like their counterpart paper charts, ENCs are produced at various scales, depending on the intended navigational use. Six ENC “usage bands”, roughly equivalent to scale ranges, have been defined: overview (1), general (2), coastal (3), approach (4), harbour (5) and berthing (6). ENC production strategies differ between HOs where some of them, like Australia, have decided to work “from the whole to the part”, starting with small scales, whereas others, like Norway, preferred to start with large scales. As an example, division into usage bands of the ENC cells available from PRIMAR is shown on Table 2.

The rather great number of ENCs produced (2nd column in Table 1) but not yet on the market (4th column) may appear surprising. This is because ENCs are legal products with Government responsibility on them. As a result, HOs must ensure that ENCs delivered are error-free and can be kept current, as far as possible. This implies the provision to the end-user, i.e. the mariner, of an

operational and efficient ENC updating service, the implementation of which may be costly and time-consuming.

The following HOs, at least, have also produced Raster Navigational Charts (RNCs) which can be accepted on ECDIS, pending availability of ENCs in the concerned areas: Argentina, Australia, Canada, Cuba, Iceland, New Zealand, United Kingdom (worldwide coverage) and USA (NOAA).

2.2 Europe

ENCs produced by the Hydrographic Offices of the following European countries are, or will be, distributed through PRIMAR: Denmark, Finland, France, Germany, Netherlands, Norway, Poland, Portugal, Spain, Sweden and the United Kingdom. About 850 operational ENC cells are already available from PRIMAR (see www.primar.org). Russian waters in the Baltic Sea, the Black Sea, the Caspian Sea and in the Arctic (White, Barents and Kara Seas) are now fully covered with ENC data. Also, France, Italy, Spain, Turkey and Ukraine have produced some 100 ENCs in the Mediterranean and Black Seas. ENC production in Europe is illustrated in Figure 3. It should be stressed that this picture aims at providing an indication on where ENC data has been produced or is available, whatever the charting scale. It does not claim to depict in detail the ENC production per usage band. This remark also applies to figures 4 to 7.

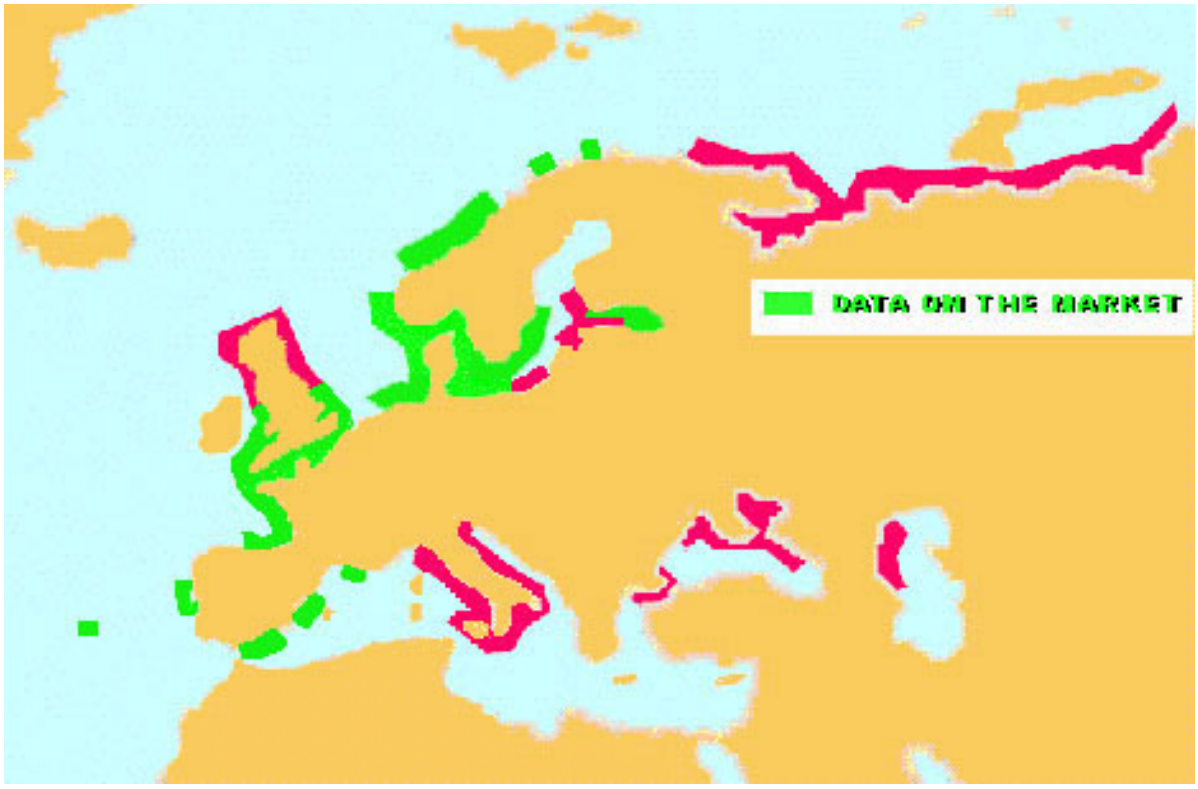


Figure 3. ENC Production in Europe (Estimates May 2001)

2.3 North America

Canada has already produced more than 500 operational ENCs on the Atlantic and Pacific coasts, the Great Lakes, along the Saint-Laurent River and in the Arctic. Their ENCs are commercialized through the company NDI (www.ndi.nf.ca/cats), which acts as a sort of RENC for Canadian data. The USA (NOAA) have produced 116 ENCs on the Atlantic coast, the Gulf of Mexico and the Great Lakes. The current status is shown in Figure 4.

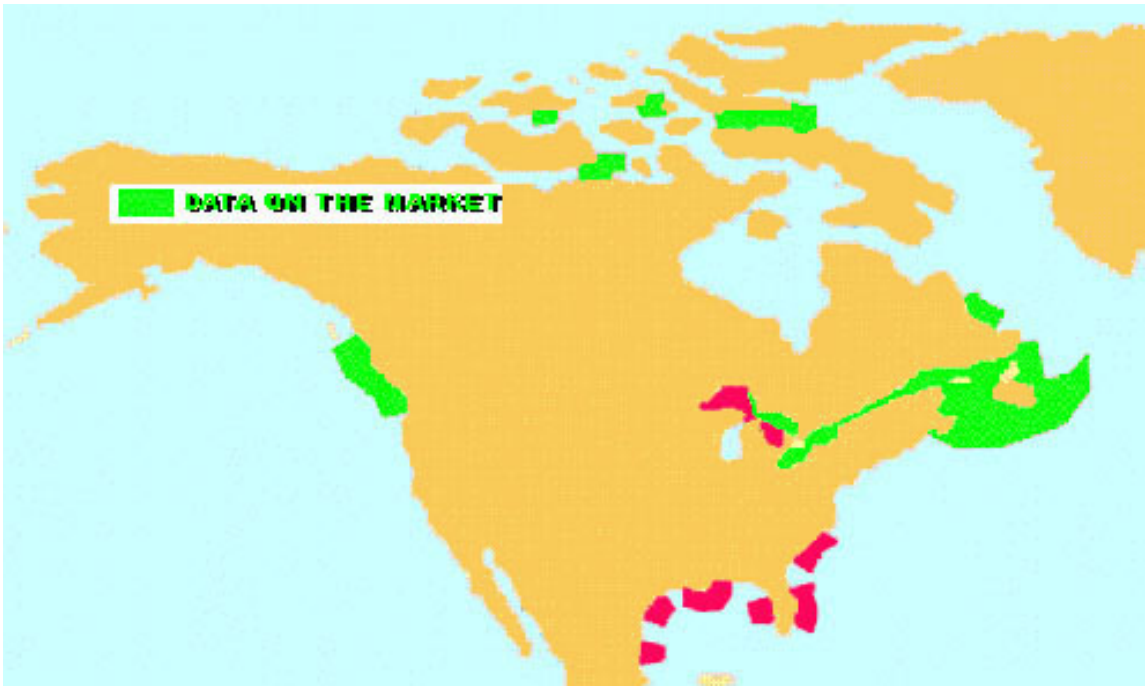
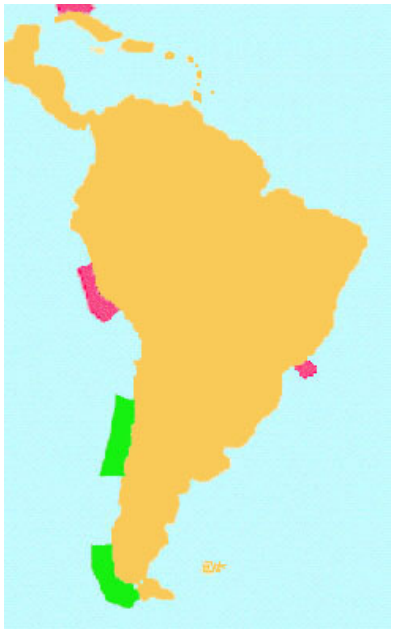


Figure 4. ENC Production in North America (Estimates May 2001)

2.4 Latin America



In the Caribbean area, in addition to the ENCs produced by USA (NOAA) on the US coast of the Gulf of Mexico, Cuba and Mexico have started ENC production. In South America, Chile has some 40 operational ENCs on the market (see www.shoa.cl). Also, Peru and Brazil have produced more than 100 ENCs in total. Colombia is reportedly starting an ENC development project. Current status is shown in Figure 5.

Figure 5. ENC Production in Latin America (Estimates May 2001)

2.5 South-East Asia

Japan has already produced some 350 operational ENCs around the Japanese archipelago (see www.jha.or.jp) and Rep. of Korea 205 ENCs covering the Korean Peninsula (see www.chartkorea.com) . Russian ENCs in the region cover Japan and Okhotsk Seas. China has produced 100 ENCs along the Chinese coast. In total it is estimated that more than 1000 ENCs have been produced in the Far East area.

Some 150 ENCs have been produced by India, covering the East and West coasts, and Nicobar, Andaman and the Lakshadweep Islands. Singapore has 14 operational ENCs covering their waters available to mariners (see www.mpa.gov.sg). In addition 6 ENCs have jointly been produced in the Singapore and Malacca Straits by Japan, Singapore, Indonesia and Malaysia. Current status is shown in Figure 6.

Figure 6. ENC Production in South East Asia (Estimates May 2001)

2.6 Australasia

Australia is leading ENC development in the region with 36 ENCs produced so far and covering the Torres Straits, the Great Barrier Reef and the approaches to major ports. New Zealand has recently started a project with 13 ENCs produced. Current status is given in Figure 7.

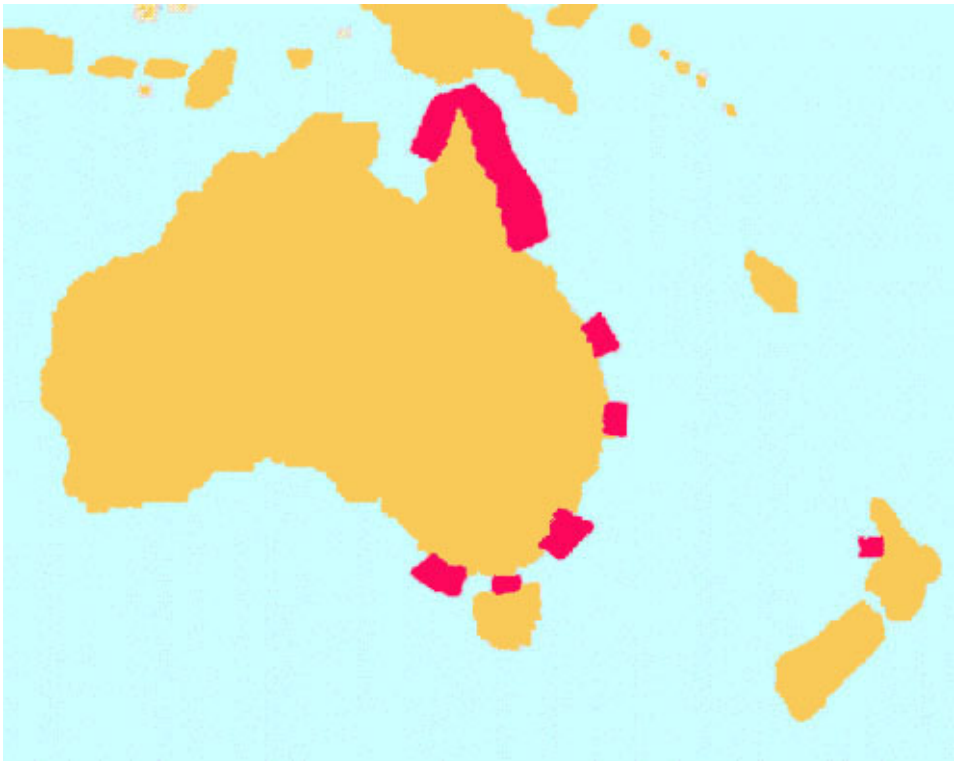


Figure 7. ENC Production in Australasia (Estimates May 2001)

2.7 Elsewhere

South Africa has recently started an ENC development project with 30 ENCs already produced. The UK Hydrographic Office has also produced some ENCs in the Red Sea and the Persian / Arabian Gulf.

3. OPERATIONS

3.1 Data Distribution - Centralised and Virtual RENCs

As stated above, ENCs are distributed through Regional ENC Coordinating Centres (RENCs). A network of RENCs based on the IHO model described in Figure 8 should eventually ensure worldwide ENC distribution.

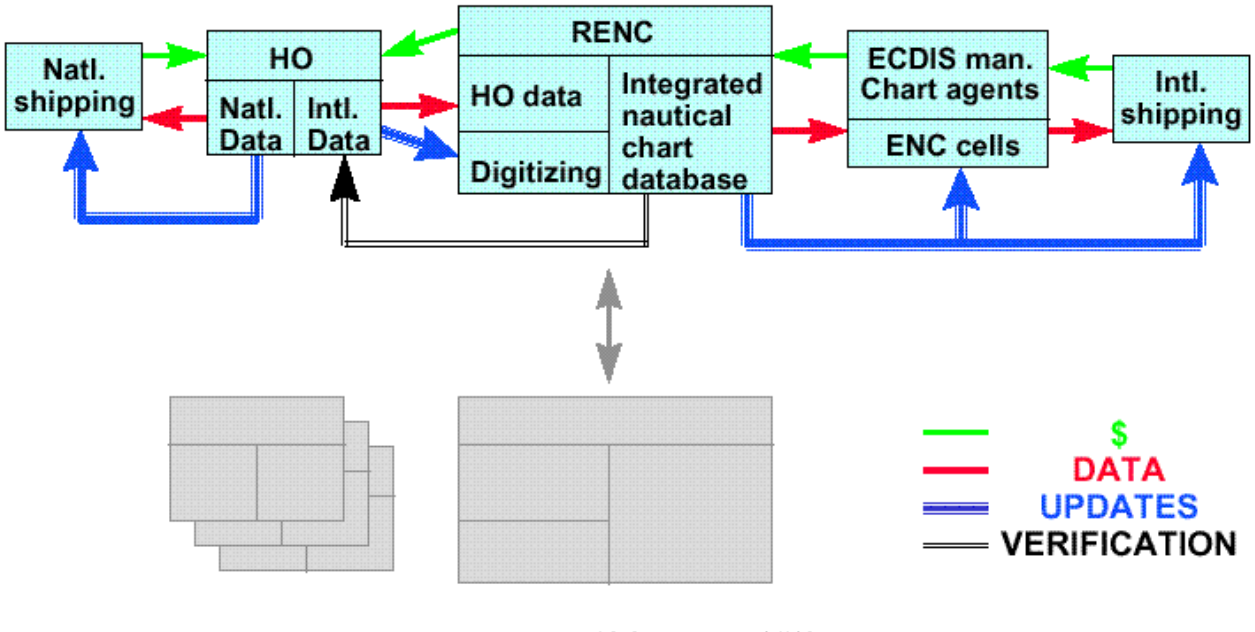


Figure 8 - IHO Model for RENCs

A RENC may be centralised, as in the case of PRIMAR, the European RENC and the sole RENC established so far. In a centralised RENC, a data centre is physically set up and staffed where ENC data originating from all cooperating HOs are collated, quality controlled, integrated into a single harmonized data base, and made available to mariners through a pool of accredited distributors. Economic operations like invoicing of end-users or payment of royalties to HOs are also monitored at the centralised RENC. Organisation of a centralised RENC is illustrated in Figure 9.

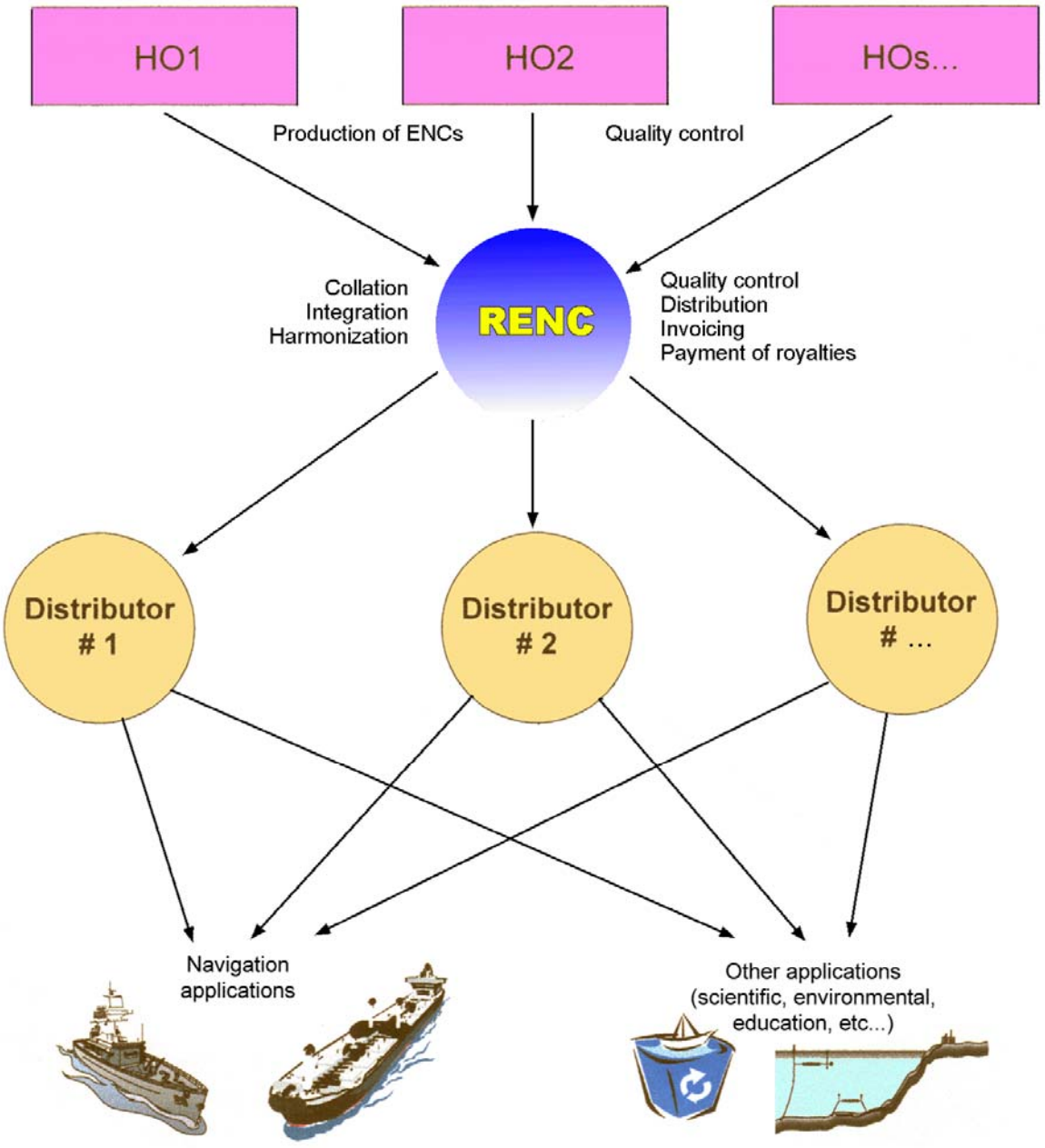


Figure 9. Centralised RENC

The concept of de-centralised or "virtual" RENCs has also been recently developed and is advocated by a number of HOs, like Italy and Japan. In a virtual RENC, ENCs and their updates would be directly delivered by the producing HOs to the end-users through commercial distributors. In other words, the "RENC" entity shown on Fig. 9 would not exist. Instead, a co-ordinating body would define the conterminous national ENC datasets of the region and would ensure that all ENCs made available are harmonized. This body would also harmonize national marketing policies. The establishment of a virtual RENC in the Mediterranean area is currently under consideration.

3.2 ENC Pricing

HOs are always torn between their duty to contribute to the safety of navigation at sea and the imposed governmental responsibility to cover costs. At present, national or RENC policies on ENC pricing vary significantly. With the ambition of the IHO to see a worldwide ENC database, some eventual

harmonisation of these prices may be expected. Below are some examples of the present level of pricing.

- Canada: US$50 per ENC per year, including updating.
- Chile: US$300 for a set of 13 ENC cells.
- Japan: US$950 per CD-ROM containing approximately 30 ENCs at small scales (General and Coastal charts) and US$450 per CD-ROM with large scale ENCs (Harbour and Approach charts). ENC updating service costs US$45 per month.
- Rep. of Korea: US$15 per ENC.
- PRIMAR - It has a three-level pricing structure to cover three different ENC cell sizes: low, medium and high, based on coverage related to size of paper chart. The medium size ENC cells are priced at US$27.80 and the associated annual updating service at US$19.20.
- Singapore: US$50 per CD-ROM containing 14 ENC cells (Harbour charts), inclusive of one year's monthly updates. Subsequently the annual subscription costs US$40.

3.3 ENC Security Schemes

A number of HOs have expressed the wish to have some form of protection of their ENC data, to prevent their illegal use or alteration. PRIMAR has already introduced an ENC security scheme which addresses the aspects of encryption, authentication and selective access to the data. It is generally agreed within the IHO that the introduction of several encryption systems would be detrimental to the whole concept of worldwide ENC distribution, and the possible adoption by the IHO of a standard security scheme is currently under consideration.

3.4 Quality Control

Quality control has been a topic of considerable debate and concern within the IHO in regard to ENC. HOs enjoy an enviable reputation for the quality of their products and do not wish to see this diminished in the new world of digital technology. In addition, as stated earlier, the ENC is a legal product under government responsibility and, increasingly, HOs appear to be concerned about their responsibility for the quality of the charts which they make available to the mariners. This has been the cause of some reluctance to make the final step of delivering ENCs. The conversion of a compiled paper chart to its digital equivalent is not only controlled by meeting the detailed ENC Product Specification of S-57, but can be assessed against an increasing number of quality control software now commercially available. A detailed list of all tests which should be applied to an ENC before it is released has recently been agreed within the IHO and included in S-57. Strict adherence to this list should bring ENCs close to error-free products.

4. FUTURE EXPECTATIONS

4.1 Establishment of New RENCs

As mentioned before only one, centralised, RENC has been created so far, in Europe. However IHO's ambition is to cover the world with a network of inter-related RENCs. Thus any user could obtain, from a particular RENC, ENC data for any part of the world. Nevertheless the establishment of a centralised RENC like PRIMAR requires considerable initial investments. This, and possibly political considerations, have contributed to slowing down the RENC creation process in some regions. It is hoped that the new concept of virtual RENC can facilitate the establishment of additional RENCs.

4.2 Interim Measures - Dual fuel ECDIS

The rather slow speed of production of the complex ENC data incited some HOs to look at interim measures to fill the gaps. Raster charts are easy, quick and comparatively cheap to produce, and

several HOs have embarked upon RNC development programmes, in particular the United Kingdom with a worldwide RNC coverage. Following an IHO proposal, the IMO decided in December 1998 to allow using on ECDIS Raster Navigational Charts (RNC) produced by HOs where there is no ENC data available [Resolution MSC.86 (70)]. This has resulted in the operation of the so-called "dual fuel" ECDIS capable of using both ENCs and RNCs. Such dual fuel ECDIS have successfully been experimented on shipping lines in the far east between Singapore and Hong Kong, and may provide an adequate solution to encourage mariners using HO-produced electronic chart data, till worldwide ENC coverage has been achieved. There is currently a plan to apply this concept to the Caribbean area where there is still little ENC data available, whereas total RNC coverage exists.

4.3 Evolution of the IHO Transfer Standard

ENCs' structure, content and format are based on IHO Standard S-57, which was developed at a time when there were no international standards available in the field of geographic information. As from 1994, the International Organization for Standardization (ISO) has been developing a series of some 20 base standards for geographic information. A number of these ISO standards are now in their final stage and the IHO is currently considering the alignment of S-57 with these ISO standards, with the objective of giving more visibility to S-57, at the international level, and making S-57 base products, like the ENC, more interoperable.

4.4 Non-navigation applications

Figure 9 illustrates the case of possible use of ENC data in applications other than for navigation, e.g. for scientific, environmental or education purposes. In fact it is believed that HOs' produced data, like ENCs, will in future find their way in various GIS applications. Integrated coastal zone management, continental shelf boundary delimitation, and emergency response to accidental pollution at sea, are typical cases where ENC-like data could be usefully applied.

5. CONCLUSIONS

ECDIS and its accompanying ENCs are moving forward towards reality. A significant amount of ENC data was created in 1999-2000 and a number of ENCs are actually available on the market. It is clear that several countries now provide ENC services, including updating, for large areas of their national waters. The year 2001 will see further national progress and some linking up of isolated areas, although large lengths of ocean routes will remain without ENC coverage for some time. The means by which the ENC services reach the market remain variable and as the business matures will no doubt take on a clearer pattern, in particular with the expected advent of virtual RENCs. Methods are available for compensating the gaps between ENC coverage, using official RNCs in the so-called "dual fuel" ECDIS. Realistic predictions of data delivery and the arrival of commercial services can be made for the not-too-distant future.

Ingénieur en Chef Michel Huet was born in Lorient, France on 6 May 1949. He followed the regular courses in the French State School for training armament engineers in Brest, from 1968 to 1972, specialising in computer sciences. He spent 17 years at the French Hydrographic Office (SHOM), at the main establishment of SHOM in Brest and aboard survey ships (Bay of Biscay, Caribbean and Southeast Pacific). His activities, throughout his career, related to computer-assisted cartography, electronics, physical oceanography and hydrography. In 1989 the IHB Directing Committee appointed him as Professional Assistant for Cartography. At the IHB, he has mainly been involved in the development of standards in the field of electronic marine cartography.