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Six in One or One in Six Variants. Electronic Navigational Charts for Open Sea, Coastal, Off-Shore, Harbour, Sea-River and Inland Navigation

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ABSTRACT: In the paper the author tries to explain problems connected with utilization of the GIS (Geographic Information System) technology and more sensitively speaking its waterborne implementation, ie. the ECDIS (Electronic Chart Display and Information System) technology and the electronic navigational charts (ENC) in the widely comprehended maritime (open sea, coastal and harbour) and inland navigation which the author does not limit exclusively to river-reservoirs only, but widens also for channels, navigable lakes and areas which can be defined generally as sea-river navigation areas. In the paper author presents the classification of the electronic navigational charts, primary functions and performance standards for electronic chart systems for open sea, coastal, off-shore, harbour, sea-river and inland navigation.

1 INTRODUCTION

An electronic chart system, whether an Electronic Chart Display and Information System (ECDIS) or an Electronic Chart System (ECS), is primarily designed for safe navigation. But its ability to display information selectively and relate it spatially is considered a real-time GIS application in the water environment. This paper describes the potential of ECDIS for maritime, coastal, offshore and inland applications.

Information technology has significantly changed the concept of navigation, the introduction of the latest computers and communication capabilities facilitating communication with sea-going vessels on the battlefield. Networking shipowners, vessel traffic service centres, river information systems, and individual vessels in ocean, coastal and inland navigation is carried out with the latest state of-the-art technology in computers and efficient communication network systems and e-Navigation.

Most cartographic research relating to the use of "soft copy" display considered the simple reproduction of conventional charts, maps and mapping techniques on CRT devices. Although the resolution of the screen is the immediately noticeable difference between the paper and the video display medium, it is not the most important factor influencing the quality of the display. The value of the electronic chart's development is not in simply imitating the paper nautical chart, but in providing a dynamic display which successfully combines the real-time location of the ship with radar/ARPA/AIS returns and chart information. To maintain the visual simplicity of this more complex display, the data format, organization and type of chart features shown, and the way they appear on the screen, must reflect the relative importance of the information to safe navigation. Unlike the static paper chart, the electronic chart can change the display and emphasis of symbols, based on actual real-time events and the viewing scale chosen. The computer-based algorithms of the electronic chart allow it to always include the least number of symbols which are most relevant to a given situation. This paper describes the different types of electronic charts and electronic chart systems.

2 ELECTRONIC CHART SYSTEM AND ECDIS

The electronic chart system is a relatively new technology that provides significant benefits in terms of navigation safety and improved operational efficiency. More than simply a computer display, an electronic chart is a real-time navigation system that integrates a variety of information that is displayed and interpreted by the navigator. It is an automated

decision aid capable of continuously determining a vessel's position in relation to land, charted objects, aids-to-navigation, and unseen hazards. The electronic chart represents an entirely new approach to maritime navigation. There are two basic types of electronic chart systems. Those that comply with the IMO requirements for SOLAS class vessels, known as the Electronic Chart Display and Information System (ECDIS), and all other types of electronic chart systems, regarded generically as, Electronic Chart Systems (ECS).

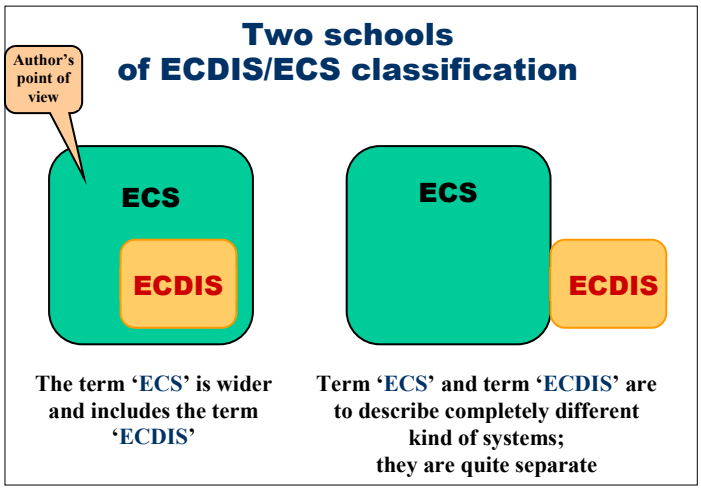


Figure 1. Two schools of ECDIS/ECS classification

ECS encompasses any electronic system that uses digital chart data. There are standards being developed for ECS by the ISO and earlier by the Radio Technical Commission for Maritime Services. ECDIS is system that is certified to meet a suite of international standards: IHO Transfer Standard for Digital Hydrographic Data S-57, IHO Specifications for Chart Content and Display aspects of ECDIS S-52, IMO Resolution A.817(19) Performance Standards for ECDIS, and IEC 61174: ECDIS - Operational and performance requirements, methods of testing and required test results. An ECDIS must use "official" ENC data to meet all of these standards and may use "official" raster data where ENC data is not yet available.

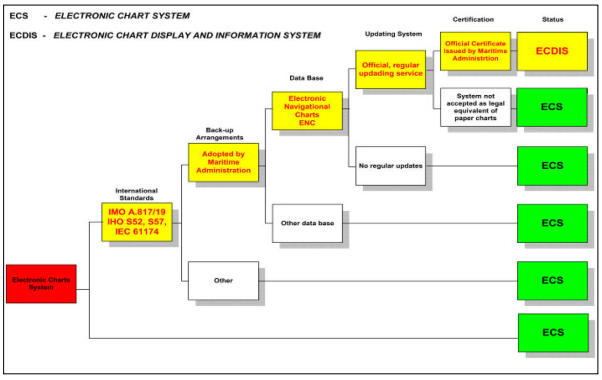


Figure 2. Classification scheme for electronic charts systems pretending to internationally standardised name of Electronic Chart Display and Information Systems (ECDIS) (Weintrit, 2001, 2009)

It is important to lay to rest right at the start the difference between ECS and ECDIS. In simple terms, an ECDIS is an ECS but an ECS is not necessarily an ECDIS! Confused? Let's try to explain.

Any ECS is a navigation system utilising computers and other electronic systems to plot and track a vessel's position. It will consist of, at least, a central computer, a library of electronic charts, a position input such as Global Positioning System (GPS) and a display screen. The electronic charts stored in the library may be in either raster or vector formats and they may be official or unofficial charts.

ECS cannot be the legal equivalent of the paper navigational chart (since it does not meet all the IMO, IHO and IEC standards for ECDIS), is already in widespread use around the world, and is characterised by being physically smaller, less sophisticated, and less expensive than fully compliant ECDIS. ECS displays different types of chart data (vector or raster) provided by hydrographic office, commercial manufacturer or user. It is intended for the use in conjunction with a current, updated paper chart. It cannot function as an ECDIS system since it does not meet the IMO standards for equipment which is a legal substitute for paper charts.

The true ECDIS system displays information from electronic navigational charts (ENC) and integrates position information from the GPS/GNSS and other navigational sensors, such as radar/ARPA, echosounder and automatic identification systems (AIS). It may also display additional navigation-related information, such as Sailing Directions, Tide Tables, etc. The ENCs themselves are as important as the system that displays them. Again confusion sometimes exists between official ENCs which have to be produced by or on behalf of a government authorised Hydrographic Office, and other commercial electronic charts which, whilst they may be able to be displayed on an ECDIS system, do not comply with the IMO regulations for use as the primary navigational chart system.

Only when official ENCs are run in a compliant ECDIS system can it be called an ECDIS. All other chart data used immediately downgrades the system to an ECS, and non-compliant, under the terms of the SOLAS regulations for use of Electronic Charts as a primary means of navigation for merchant shipping. This distinction is often over-looked by would be purchasers, but those lawyers may not be quite so ready to ignore the regulations.

ECDIS equipment is specified in the IMO ECDIS Performance Standards (IMO Resolution A.817(19), as amended by Resolution MSC.64(67) - Adoption of New and Amended Performance Standards (adopted in 1996), Annex 5 - Amendment to Resolution A.817(19) Performance Standards for ECDIS; as amended by Resolution MSC.86(70) - Adoption

of New and Amended Performance Standards for Navigational Equipment (adopted in 1998), Annex 4 - Amendments to the Recommendation on Performance Standards for ECDIS; and as amended by Resolution MSC. 232(82) - Adoption of the Revised Performance Standards for ECDIS (adopted in 2006), Revised Performance Standards for ECDIS as follows: "Electronic chart display and information system (ECDIS) means a navigation information system which, with adequate back up arrangements, can be accepted as complying with the up-to-date chart required by regulation V/19 and V/27 of the 1974 SOLAS Convention, as amended, by displaying selected information from a system electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and by displaying additional navigation-related information."

Within the ECDIS, the ENC database stores the chart information in the form of geographic objects represented by point, line and area shapes, carrying individual attributes, which make any of these objects unique. Appropriate mechanisms are built into the system to query the data, and then to use the obtained information to perform certain navigational functions (e.g. the anti-grounding surveillance).

The presentation of ENCs on the screen is specified in another IHO standard, the "Colours and Symbols Specifications for ECDIS IHO S-52", i.e. in its Appendix 2, called "ECDIS Presentation Library". This style of presentation is mandatory.

The use of ENCs in a tested approved and certified ECDIS (according to IEC 61174/2008) and with appropriate back up arrangements, is the only paperless chart option for vessel navigation.

3 ELECTRONIC NAVIGATIONAL CHART

An Electronic Navigational Chart (ENC) is a digital representation of the paper charts, a digital file that contains all the chart information necessary for safe navigation, as well as supplementary information required to plan voyages and avoid groundings (route planning and route monitoring).

ENC boasts electronic features that paper charts lack. For instance, a navigator can integrate GPS data - which tells a navigator his or her precise latitude and longitude - with ENC data. The navigator can also integrate data from Geographic Information Systems (GIS), real-time tide and current data, and wind data to enhance the capabilities of the ENC.

Table 1. Electronic navigational charts versus paper charts

Paper Chart	**Electronic Chart**
fixed scale sheet, fixed North-up orientation (usually), fixed symbol definition, fixed symbol arrangement and application with respect to North, limited paper size, limited types and amount of information, limited number of colours and combined use.	fixed display size, fixed resolution, variable display scale, variable types and amount of information, various orientation with respect to North, various symbol arrangement and application, various symbol definition, various number and use of colours.

Incorporating these features can create a fuller, more accurate picture of the marine environment. A vessel using ENCs can detect an obstruction in advance and check planned travel routes to avoid crossing hazardous areas. The electronic charting systems used to view ENCs can display warnings and regulations that pertain to areas in which a vessel transits, and can sound an alarm if the vessel's projected course veers too close to a dangerous feature.

3.1 *Types of electronic charts*

3.1.1 *Vector charts*

Vector charts are the chart databases for ECDIS, with standardized content, structure and format, issued for use with ECDIS on the authority of government authorized hydrographic offices. ENCs are vector charts that also conform to International Hydrographic Organization (IHO) specifications stated in Special Publication S-57.

ENCs contain all the chart information necessary for safe navigation, and may contain supplementary information in addition to that contained in the paper chart. These supplementary information may be considered necessary for safe navigation and can be displayed together as a seamless chart. ENCs are intelligent, in that systems using them can be programmed to give warning of impending danger in relation to the vessel's position and movement.

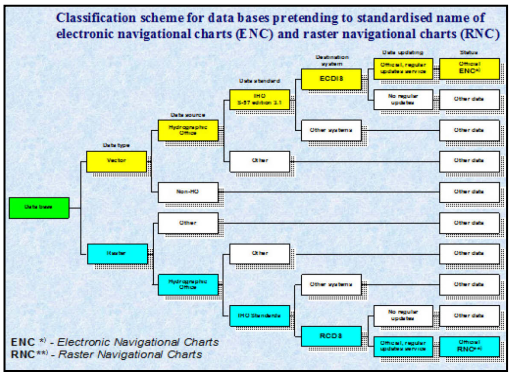


Figure 3. Classification scheme for data bases pretending to internationally standardised name of electronic navigational charts (ENC) and raster navigational charts (RNC) (Weintrit, 2001, 2009)

3.1.2 *Raster charts*

Raster navigational charts are raster charts that conform to IHO specifications and are produced by converting paper charts to digital image by scanner. The image is similar to digital camera pictures, which could be zoomed in for more detailed information as it does in ENCs. IHO Special Publication S-61 provides guidelines for the production of raster data. IMO Resolution MSC.86(70) permits ECDIS equipment to operate in a Raster Chart Display System (RCDS) mode in the absence of ENC.

Not all electronic charts are in same format; many different formats exist for electronic charts. However, two major types are now in use on merchant ships, they are vector chart and raster charts. Raster charts (RNC), in fact, are scanned paper charts into the pictures with adjustment made suitable for display on the RCDS. This RNC is also known as Admiralty Raster Chart System (ARCS Charts) which is produced by the British Admiralty (UKHO).

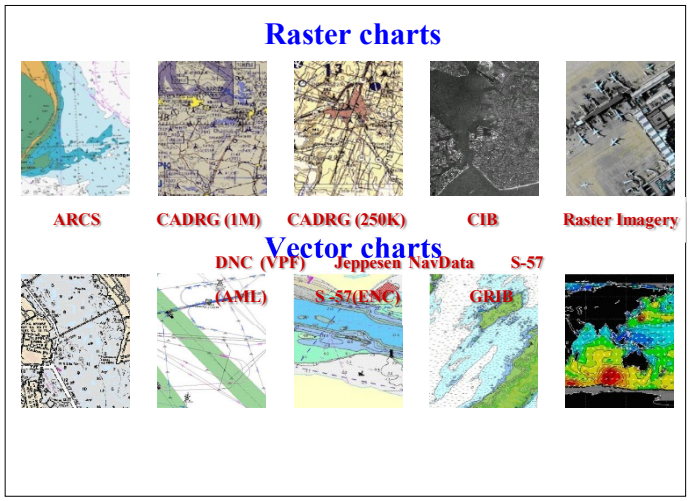


Figure 4. Various types of raster and vector charts

Table 2. The differences between raster charts and vector charts

Raster Chart (RNC)	Vector Chart (ENC)
Chart data is a digitized "picture" of a chart. All data in one layer and one format.	Chart data is organised into many separate files. It contains layer information to produce certain symbols, lines, area, colours, and other elements.
With raster data, it is difficult to change individual element of the chart since they are not separated in the data file.	With vector data, it can change individual elements with additional data.

Vector charts are digitized charts. Countries are producing unique digital charts based on their interpretation of IHO standards (i.e. S-57 standards).

4 CONFUSION OVER THE CHARTS

The by far major problem in the use of ECDIS lies in the charts to be used. The confusion appears to be complete amongst shipping lines and chart distributors and even among the various authorities around the world. You must use an ENC in order to use the system as an ECDIS. If no complete ENC coverage is available for the ships area of operations you have to use other available charts, and then your system turns into an ECS.

The ENC coverage was at this point in time very limited, and it was difficult to get an overview over which parts of the world that are covered by ENCs. It was merely stating the fact that the availability of ENCs was limited, and thus the possibility to use ECDIS in practice was limited. The confusion begins, when we start speaking about other types of charts than ENCs, in particular RNCs.

4.1 *Non-official charts*

There is a number of alternatives to the aforementioned ARCS charts. E.g. Transas and C-Map have almost worldwide coverage of vector charts where the data is based on existing paper charts. Unfortunately these charts have not obtained the status as official, because of the frequency of the updates and the lack of a controlling authority to approve the contents.

Figure 5. Summary of ENCs (Arts, 2003)

How big a part of the scales is weighed by these facts more or less depends on the flag of the ship and thus the flag state administration. The obvious advantage by using C-Map charts is therefore in the available safety features, which are inherent in the vector charts.

4.2 *Data from private data providers*

Examples of raster navigational chart producers are: NOAA, Maptech, SoftChart and Laser Plot in the United States, NDI in Canada and British Admiralty (ARCS) in England. Vector marine charts for chart plotters are produced by C-Map and Navionics. Garmin's MapSource BlueChart and Magellan's MapSend BlueNav charts are derived from Navionics vector charts. Other vector marine charts come from Passport and Transas.

If it is so expensive to produce and update ENCs, how then have private companies succeeded in building what seems to be decent world coverage? Please let's not get involved in another discussion about the legality of their products; everyone knows that SOLAS, Chapter V regulation 2.2 states that 'Nautical chart or nautical publication is 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, authorised Hydrographic Office or other relevant government institution and is designed to meet the requirements of marine navigation'. Therefore we know that only the ENCs produced by HOs may be used by commercial vessels of more than 500 GRT.

4.3 *Assessment standard ISO 19379*

In order to meet the requirement mentioned above an (international) standard for privately manufactured data was developed over the past ten years. The standard, ISO 19379, was prepared by Technical Committee ISO/TC8 (Ships and Marine Technology, subcommittee SC6, Navigation) and adopted in 2003.

ISO 19379 is the international standard that specifies the requirements for ECS databases, especially as regards the elements relevant to safety of navigation, such as content, quality and updating. The standard was developed by ISO (International Organization for Standardization), with the contribution of Hydrographic Offices, Classification Authorities, and the Marine Industry, and is being adopted by Maritime Administrations to regulate the use of ECS – in Italy, for example, it is part of the requirements for approved Electronic Chart Systems, which can replace paper charts on certain types of craft (Malie, 2003).

ISO 19379 provides guidance on production and testing of an ECS Database. It does not provide detailed coverage of the methods and techniques required for database design and development, nor does it address specific quality management procedures.

4.4 *Use of the standard*

The standard is applicable to both vector and raster charts. It is envisaged that national regulatory authorities may wish to require compliance with this standard as guidance for data used in ECS or other systems of electronic navigation in their countries. The Standard has been developed to make the ECS chart display as reliable as the official paper chart and its equivalent ENC. The aim of the working group has been to develop a standard easy to interpret but with content and accuracy levels at least equal to those of the ENC of the same area, carefully avoiding, however, any over-specification or rigid structure.

4.4.1 *Contents of the standard*

The contents of the chart are very much in line with the requirements as described in IHO S-52 (Specifications for Chart Content and Display Aspects of ECDIS, Dec. 1996).

4.4.2 *Quality*

This covers, among other items, product specification, process control and correctness and completeness of encoding.

4.4.3 *Updating*

This covers, among other items, the responsibility of the database producer to provide updates.

4.4.4 *Testing*

This covers the recommended methods of testing. Testing procedures shall ensure the accuracy and completeness of the entire data production process. The manufacturer may be required by national authorities or similar to have its testing procedures certified by an appropriate testing body. The standard does not prescribe a specific data format for privately manufactured data. Data producers are responsible for providing updates in their own format. A Performance Standard for ECS, including the display of data, was developed by the Radio Technical Commission for Maritime Services (RCTM). It should be noted, however, that some flag states have also individually developed Performance Standards for ECS.

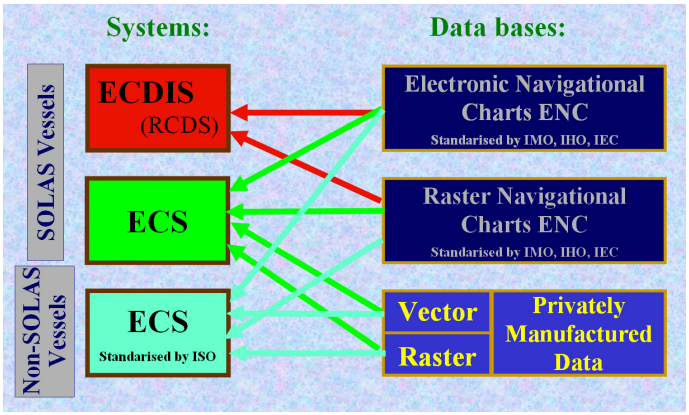


Figure 6. Relationship between electronic chart systems ECS/ECDIS and data bases (Weintrit, 2009)

4.5 *Filling the gap?*

In areas with no ENC coverage navigators have the choice either of using official raster data or privately manufactured vector data. No doubt the first option offers, next to the use of 'official' charts, the advantage that the number of paper charts carried may be considerably reduced, whereas the second requires a full set but retains full ECDIS functionality (including the alarm functions) that can only be obtained using vector charts.

4.6 *Instead of ENC?*

This option is at present preferred by several shipowners, particularly those operating their ships globally. Although most ECDIS do support privately manufactured data produced by the major manufacturers, many users prefer (for cost reasons) ECS, particularly as many of these systems nowadays (also) meet the software requirements laid down in IEC 61174 (ECDIS Operational and Performance Requirements) and are less expensive. In this case, of course, paper charts are used for primary navigation. The time consuming (IMO) mandatory passage planning however can be done using the ECS and, where applicable, copied to the paper chart.

4.7 *ENC and the private data manufacturer*

As mentioned before, there is no doubt that the number of ENCs will increase with time. Although still expensive compared with privately manufactured vector data, prices have come down considerably recently. This may move the market to purchase more ENC. Most helpful will be the support of private manufacturers in acting as value-added resellers and in providing ENC in SENC format. No doubt they will be keen to 'fill the gap' with their own data if necessary.

4.8 *Replacing paper charts*

National authorities could consider accepting privately manufactured data meeting ISO 19379 as paper chart equivalent for certain (non-SOLAS) vessels. The US and Italian governments have already amended the law to allow fishing vessels and leisure craft fitted with ECS and electronic navigational data that meets the ISO standard, to sail without paper charts in their waters.

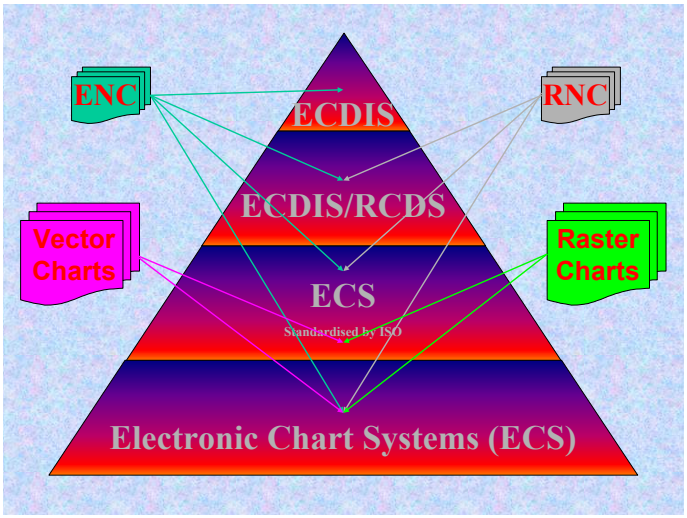


Figure 7. Relationship pyramid between electronic chart systems ECS/ECDIS and data bases (Weintrit, 2001, 2009)

4.9 *IMO MSC approved mandatory ECDIS*

In July 2008, the IMO Safety of Navigation Sub-Committee agreed to implement the mandatory carriage of ECDIS; this was approved by the IMO Maritime Safety Committee at its meeting in December 2008.

A comprehensive phase-in schedule will begin on 1 July 20-12 with mandatory carriage of ECDIS for newbuildings of passenger ships of 500gt and above and for tankers of 3000gt and above.

Mandatory carriage for existing ships will be phased in from 1 July 2014 to 1 July 2018.

5 INLAND ECDIS

ECDIS is the basic system for generation and presentation of the digital maritime charts. Charts based on the maritime standards are officially equal to analogic charts in equipment duties. Within European research and development projects, this worldwide standard was adopted to the needs of inland navigation. The Inland ECDIS standard has been continuously revised and finally passed by the Central Commission for the Navigation on the Rhine (CCNR) in summer 2001. Inland ECDIS is also recommended as the standard for digital navigational

charts by the Danube Commission, the United Nations' European Commission for Economy (UN-ECE), the European RIS platform and INA/PIANC. Inland ECDIS is currently the only standard accepted by all relevant inland navigation platforms. Co-operation between the North-American "Inland ENC community", mainly the US Army Corps of Engineers, Russia and the (European) Inland ECDIS Expert Group lead to improved and harmonized encoding rules for uniformly encoded Inland ENCs, which are written down in the "Inland ENC Encoding Guide".

Figure 8. Main European waterways

5.1 *European inland waterways*

Europe is criss-crossed by inland waterways, some of which have been in use for thousands of years to carry goods and people. The most recent addition to this network, the Rhine-Main-Danube Canal, was finished in 1992 and opened a 3,500 km long trans-European waterway from Rotterdam to Sulina on the Black Sea. Many people do not realise that cargo brought by ship to Le Havre can then be delivered by an inland vessel to Basel or to a port in Poland or in Moldova. The inland waterways traffic, almost invisible to the population, is the most efficient way to carry heavy goods over long distances.

5.2 *Electronic chart display and information system for inland navigation*

Reflections and experiments have been made in different countries with a view to facilitating inland navigation through the use of telematics. This aim was in particular pursued within the scope of the EU research and development project INDRIS (Inland Navigation Demonstrator for River Information Services). A pilot project on the river Rhine was launched in Germany in 1998 named ARGO. In ARGO and INDRIS systems, the radar image on the display in the wheelhouse is overlaid by an electronic chart. This is an approach aimed at improving safety and efficiency in inland navigation.

In the course of discussions, it turned out that only an internationally-agreed approach would be successful, since a boat master cannot be expected to employ different equipment in each country. This was the reason why the internationally-introduced ECDIS - originally developed for maritime navigation - came into view also for inland navigation. The IMO, IHO and IEC Standards for ECDIS were introduced in their compatibile versions in 1996 (latest versions between 2006 and 2008). The idea was to adopt ECDIS for inland navigation and to supplement some distinct inland features but not to change the original ECDIS standard. In this way, it will be possible to have compatibility between the original - Maritime - ECDIS and Inland ECDIS. This is important for the estuaries of the rivers, where sea vessels as well as inland vessels navigate.

In the framework of the concerted action on Inland Navigation of the European Union, an International Expert Group was requested to prepare the Inland ECDIS Standard intended especially for inland navigation. The Inland ECDIS standard adopts the regulations of the maritime ECDIS and adds requirements to it that are specific to inland navigation. The Central Commission for the Navigation on the Rhine (CCNR) passed the Inland ECDIS standard in May 2001. The standard consists of the following Sections (very similar to ISO 19379):

- Section 1: Performance Standard;
- Section 2: Data Standard;
- Section 3: Presentation Standard;
- Section 4: Operational and Performance Requirements, Methods of Testing and Required Test Results;
- Section 5: Glossary of Terms.

The Inland ECDIS Standard establishes unified rules for the use of electronic charts by vessels navigating on European inland waterways.

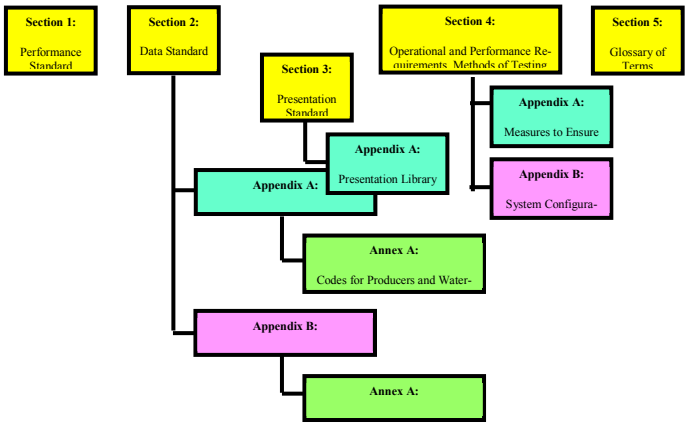


Figure 9. Structure of the Inland ECDIS standards

5.3 *Primary functions and performance of I-ECDIS*

Inland ECDIS shall contribute to safety and efficiency of inland shipping and thereby to the environment protection. It shall reduce the navigational workload as compared to traditional navigation and information methods.

Inland ECDIS (Operating System Software, Application Software and Hardware) shall have a high level of reliability and availability at least of the same level as other means of navigation, for the navigation mode as specified in Section 4 of the standard. Inland ECDIS can be designed for information mode only or for both, information mode and navigation mode. It shall use chart information as specified by Sections 2 (Data Standard) and 3 (Presentation Standard) of the mentioned Standard.

The Data Standard for Inland ECDIS is based on the "IHO Transfer Standard for Digital Hydrographic Data", Special Publication No. 57, edition 3.1 of November 2000 with all Appendices and Annexes. The Data Standard describes the necessary additions and clarifications to S-57 and the application of S-57 for the purpose of use in Inland ECDIS applications.

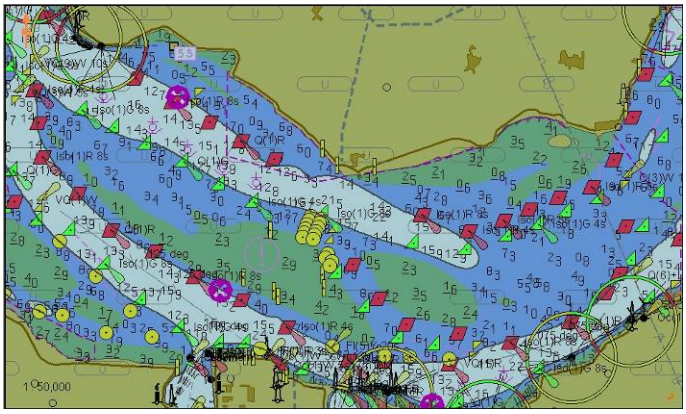


Figure 10. Simplified symbols of Sea-River and Inland Electronic Navigational Chart

The Presentation Standard for Inland ECDIS is based on the document "S-52, Specification for Chart Content and Display Aspects of ECDIS" of the IHO, Edition 5.0 of December 1996, with all Appendices and Annexes. Inland ECDIS shall facilitate simple and reliable updating of the Inland ENC. It shall provide appropriate alarms or indications with respect to the information displayed or malfunction of the equipment.

5.4 *I-ECDIS related definitions*

For the Inland ECDIS performance standard the following definitions shall apply:

- Inland ECDIS means an electronic chart display and information system for inland navigation, displaying selected information from an Inland System Electronic Navigational Chart (Inland SENC) and, optionally, information from other navigation sensors.
- Inland Electronic Navigational Chart (IENC) means the database, standardized as to content, structure and format, issued for use with Inland ECDIS. The Inland ENC complies with the IHO standards S-57 and S-52, enhanced by the additions and clarifications of this standard for Inland ECDIS. The Inland ENC contains all essential chart information and may also contain supplementary information that may be considered as helpful for navigation.
- Inland System Electronic Navigational Chart (Inland SENC) means a database, resulting from the transformation of the Inland ENC by Inland ECDIS, for appropriate use, updates to the Inland ENC by appropriate means and other data added by the boat master. It is this database that is actually accessed by the Inland ECDIS for the display generation and other navigational functions. The Inland SENC may also contain information from other sources.

Figure 11. Display Base, Standard Display, and Full Displays for two different values of Safety Contour – SeeMyDENC

- Minimum Information Density (display base) means the minimum amount of SENC information that is presented and which cannot be reduced by the operator, consisting of the information that is required at all times in all geographic areas and under all circumstances.
- Standard Information Density (standard display) means the default amount of SENC information
- that shall be visible when the chart is first displayed on Inland ECDIS.
- All Information Density (all display) means the maximum amount of SENC information. Here, in addition to the standard display, also all other objects are displayed, individually on demand.
- User-defined settings means the possibility to use and store a profile of display- and operation controls-settings.

– Integrated Display means a head-up, relative-motion picture consisting of the SENC overlaid with the radar-image with matching scale, offset and orientation.
– Navigation Mode means the use of the Inland ECDIS for conning the vessel with overlaid radar image.
– Information Mode means the use of the Inland ECDIS for information purposes only without overlaid radar image.

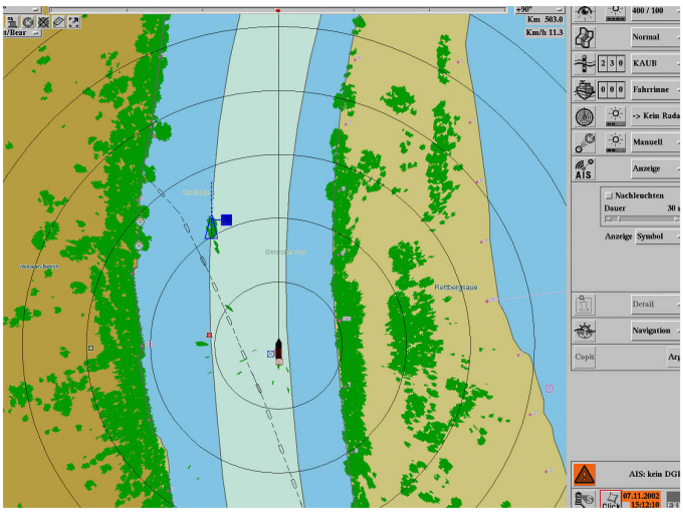


Figure 12. Inland ENC with radar picture overlay; North-up orientation of ECDIS

5.5 *Benefits of I-ECDIS*

The inland navigation software based on the SevenCs Kernel is in use all over the world. In Europe alone, some 2,800 inland vessels use it already (Gevers, 2006). The acceptance of the electronic charts by the inland skippers is not surprising, even allowing for the fact that electronic charts are not a carriage requirement for them. Electronic charts improve the safety of navigation and the efficiency of operation of the inland vessels leading to reduced costs and improved earnings. For instance, the North American skippers who use the course predictor built into the SevenCs software to prevent oversteering of their enormous barge trains, report fuel savings of up to 10%. In addition, Inland ECDIS is not labouring under the same regulatory restriction as its maritime sister. The functionalities that are already provided to inland but not to sea navigation include dynamic depth and overhead clearance adjustment or changes of channel width depending on the water level; display of the external XML files with additional information will follow in the near future.

On US waterways much more popular is CARIS' Hydrographic Production Database (HPD). The production effort focused on importing IENC data into a HPD source database, which was easily accomplished due to existing S-57 import tools. Once loaded, the source data was modified to create a seamless coverage ready for further production.

5.6 *Seamless connection*

Inland port authorities have recognised the fact that electronic charts improve their efficiency of operation as well and are supporting the production of the IENCs. The importance of inland ports like Duisburg can only increase, especially as many major seaports are experiencing a growing need to cope with overflowing ports, Rotterdam which is running out of space for its expansion being one of them. Seagoing vessels have been sailing up many large rivers for a long time, on all continents. The best example is the Mississippi, where Baton Rouge some 230 miles upstream, is a major seaport as well as an inland port. The needs of the inland navigation are not the same as those of the sea-going ships, but there are many areas where both types of vessels have to ply. Inland ECDIS and IENCs create a seamless connection between these two worlds.

5.7 *Facilitating the use of ENC on us inland waterways*

In 2001, the US Army Corps of Engineers (USACE) initiated an electronic chart program to develop and support new digital chart products for electronic navigation on the inland waterways. The program began by transforming existing digital river data and digital chart data into a new product: the Inland Electronic Navigational Chart (IENC).

Updating navigational charts, whether paper or electronic, is an essential safety element for any vessel. Numerous changes regularly occur in the river system, including channel dredging, construction, navigation aid maintenance and natural variations in the river bottom. Once significant changes occur, a new edition chart is often published. Currently, the IENC program is producing new edition electronic charts and updating them at faster pace than former paper chart program, where chart editions can be 5-to-10 years old and updates must be applied manually.

A number of potential opportunities and benefits are possible with CARIS' HPD used by USACE. First, retaining a close link between the source data and the paper chart products can significantly facilitate data maintenance and timely or simultaneous product releases. It can also facilitate closer synchronization between IENC and paper chart formats, resulting in improved consistency and version control across the entire product line.

HPD-driven approach provides improved production workflow, many more advanced tools for paper chart production and better support for the carto-

graphic framework. It also allows for a far greater level of automation, ultimately reducing manual effort. Consequently, it is more suitable for large, long term projects.

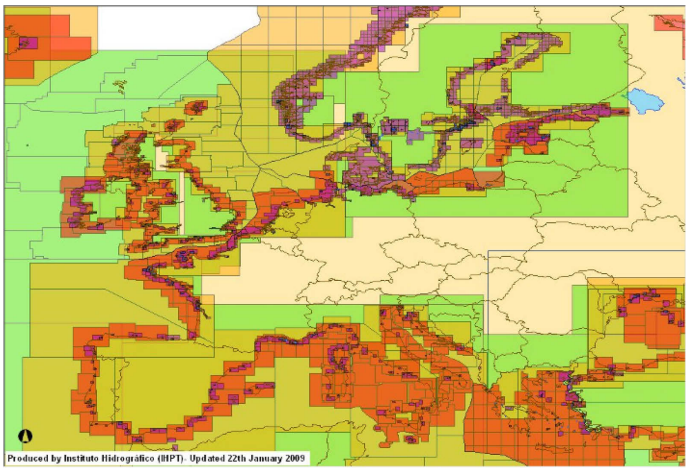


Figure 13. IC-ENC catalogue – Europe 22th January 2009

5.8 *Usace inland ENC encoding guide*

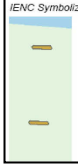
IENCs follow the S-57, Version 3.1 data exchange standard, which is recognized by software vendors and government hydrographic offices for electronic chart applications. Since S-57 is intended for deep-draft, ocean shipping, the US Army Corps of Engineers (USACE) IENC Encoding Code provides a "best fit" in some cases between river information and S-57 structure. The intent of the Encoding Guide is to provide detailed guidance on what is required to produce a consistent, uniform Inland ENC. This document provides a framework for IENC specifications by:

- Using existing IHO S-57 Edition 3.1 standard. Specifically, the:
  - Maritime ENC Product Specification (App. B1),
  - IHO Object Catalogue (Appendix A),
  - Object Catalogue (Appendix B.1, Annex A),
- Defining the mandatory requirements for safety-of-navigation on inland waterways.
- Recommending object classes, attributes, and values for encoding IENC data.

For all object classes, attributes, and attribute values that are used in conjunction with an IENC, the Encoding Guide:

- provides a basis for its creation,
- describes its relationship to the real-world entity,
- provides criteria for its proper use,
- gives specific encoding examples.

Table 3 Inland ENC Encoding Guide. Example of geographic object

Graphics	Encoding Instructions	Object Encoding
Real World  *Chart Symbol* *Image to be included at a later date* *IENC Symbolization (point)*  *IENC Symbolization (area)* 	A) Only visually conspicuous landmarks shall be encoded as landmarks. As a result the mandatory attribute CONVIS shall always be 1 (visually conspicuous). B) Castles, churches, chapels and transmitters can be encoded as CATLMK = 17 (tower), but then the type must be further made clear within the object name. C) If the landmark serves as a navigational light support, FUNCTN = 33 (light support), it must be encoded with a LIGHTS object (see N). D) If the landmark has a navigational function it has to be encoded as a building of navigational significance (see E.1.2).	**Object Encoding** **Object Class =** LNDMRK(P, A) (M) CONVIS = [1 (visually conspicuous)] (M) CATLMK = [1 (cairn), 2 (cemetery), 3 (chimney), 4 (dish aerial), 5 (flagstaff/flagpole), 6 (flare stack), 7 (mast), 8 (wind sock), 9 (monuments), 10 (column/pillar), 11 (memorial plaque), 12 (obelisk), 13 (statue), 14 (cross), 15 (dome), 16 (radar scanner), 17 (tower), 18 (windmill), 19 (windmotor), 20 (spire/minaret), 21 (large rock or boulder on land), 22 (rock pinnacle)] (O) OBJNAM = [name and/or operator/owner] (O) NOBJNM = (Refer to Section B, General Guidance) (C) FUNCTN = [33 (light support)] (M) SCAMIN = [EU: use 22000 for a point object (except 45000 for CONVIS1) and 45000 for line objects; US: 60000] (C) SORDAT = [YYYYMMDD] (C) SORIND = (Refer to Section B, General Guidance)

6 DIFFERENT TYPES OF DIGITAL CHARTS

6.1 *Electronic Navigational Chart (ENC) according to IHO format S-57*

An electronic navigational chart (ENC) is an official database created by a national hydrographic office for use with an Electronic Chart Display and Information System (ECDIS). An electronic chart must conform to standards stated in the International Hydrographic Organization (IHO) Special Publication S-57 before it can be certified as an ENC. Only ENCs can be used within ECDIS to meet the International Maritime Organisation (IMO) performance standard for ECDIS.

It is quite obvious that an official ECDIS service cannot be provided on a national level only, but requires co-operation of hydrographic services. The IHO decided to establish the Worldwide Electronic Navigational Chart Data Base (WEND).

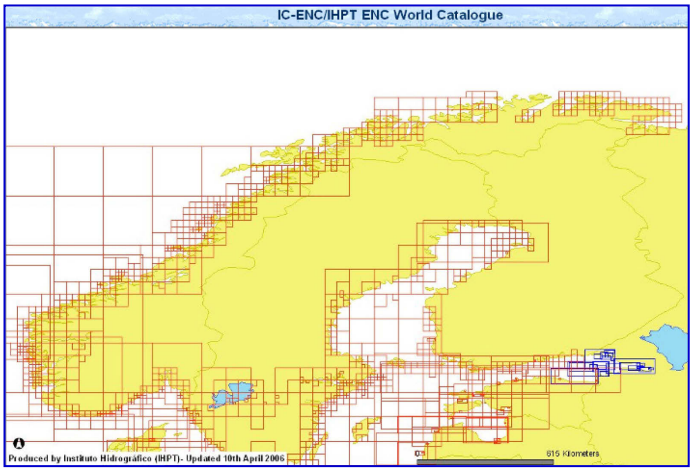
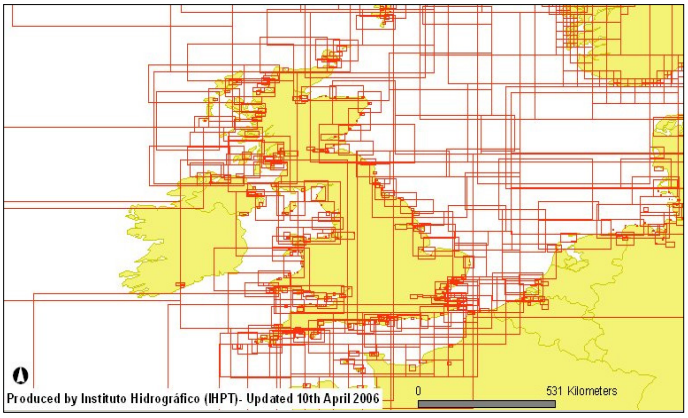


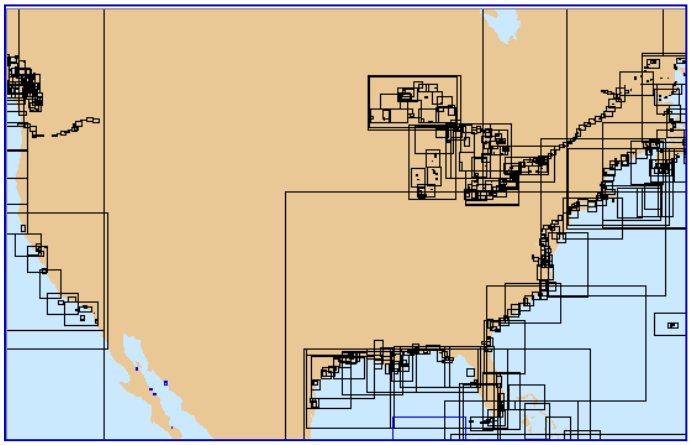
Figure 14. Norwegian (Primar) style seamless ENC cells

ENCs are available through Regional Electronic Navigational Chart Coordinating Centre (RENCs) and national electronic chart centers: e.g. Primar-Stavanger (perfect seamless ENC cells), IC-ENC

(British style ENCs). Distributors like the United Kingdom Hydrographic Office then distribute these to chart agents.

IHO Special Publication S-63 developed by the IHO Data Protection Security Working Group is used to commercially encrypt and digitally sign ENC data. Chart data is captured based on standards stated in IHO Special Publication S-57, and is displayed according to a display format stated in IHO Special Publication S-52 to ensure consistency of data rendering between different systems.

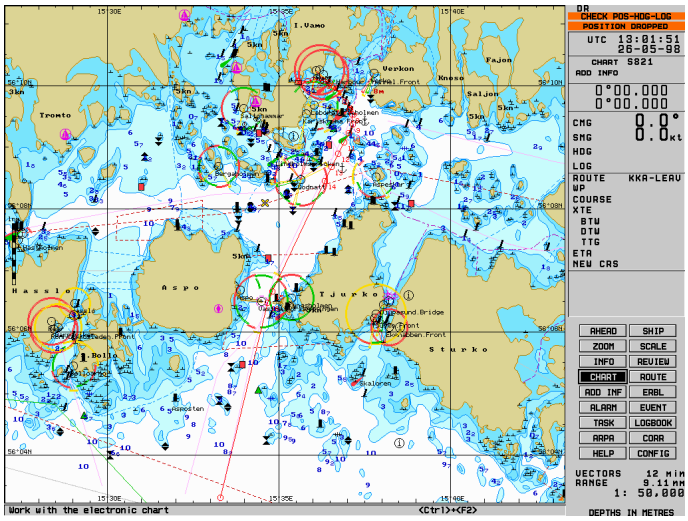




Figures 15 & 16. American/British style ENC cells

6.2 *Vector chart produced by private manufacturer*

The existence of privately manufactured data is a fact of life. It is there, its volume is still increasing and it has proved to be meeting a demand of the maritime market. It is cost-effective, economically viable and it will not disappear. The major data private manufacturers (e.g. Transas, C-Map by Jeppesen, Navionics) offer a high quality and affordable means of world-wide navigation, including an easy to access update service, sold through reliable global networks offering a round-the-clock service. There is no doubt that in the years to come the volume of ENC will increase. However, the production rate is still too slow to provide the (minimum) necessary coverage, particularly of the major shipping routes, in an acceptable time. Moreover, it is very unlikely that ENC will ever have a 100% global coverage.



Figures 17. Transas electronic chart in vector format TX-97

6.3 *Electronic Navigational Chart (ENC) with Additional Military layers (AML) for WECDIS use*

The concept of additional military layers (AML) was introduced in 1995 with the intent to define a standardized format for non-navigational data. Since 1995, various North Atlantic Treaty Organization (NATO) standardization agreement documents concerning AML data and warship electronic chart display and information systems (WECDIS) have been created. NATO has since endorsed six AML product specifications, and completed sea trials using AML datasets. However, as more nations move toward AML data production, little is known about how the data will perform as overlays within a WECDIS adhering to NATO WECDIS standards.

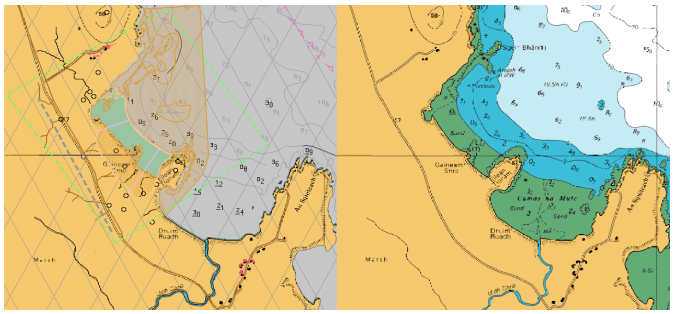


Figure 18. Additional Military Layers (AML)

Using OSI Navigation Systems' electronic chart precise integrated navigation system-military (ECPINS-M), the sophisticated electronic chart system designed to meet the specific navigational demands of the military market, the strengths and

weaknesses of how AML data interacts with other data types, primarily electronic nautical chart (ENC) data, within the WECDlS were identified. As stated in the WECDIS standard, a WECDIS means "an ECDIS as defined by the IMO, with additional functionality for navigation and conduct of warfare onboard warships." We might also consider referring to the concept of Marine Information Overlays (MIO) which have been used in the Marine Electronic Highway project, and whose use are gathering support within the e-Navigation discussion.

6.4 *Raster navigational chart (RNC)*

RNCs are raster charts that conform to International Hydrographic Organization (IHO) specifications and are produced by digitally scanning a paper chart image. The image may be either the finished chart itself or the stable colour bases used in the multicolour printing process. The resulting digital file may then be displayed in an electronic navigation system where the vessel's position, generally derived from electronic position fixing systems, can be shown. Since the displayed data are merely a digital photocopy of the original paper chart, the image has no intelligence and, other than visually, cannot be interrogated.

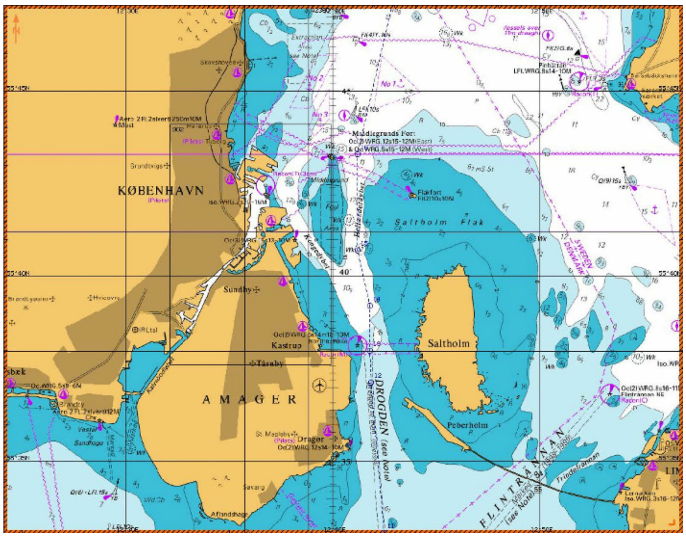


Figure 19. Raster Navigational Chart (RNC)

6.5 *Digital Nautical Chart (DNC)*

The largest of the non-S-57 format databases is the Digital Nautical Chart (DNC). The National Imagery and Mapping Agency (NIMA, now National Geospatial-Intelligence Agency - NGA) produced the content and format for the DNC according to a military specification.

The DNC is a vector-based digital product that portrays significant maritime features in a format suitable for computerised marine navigation. The DNC is a general purpose global database designed to support marine navigation and Geographic Information System (GIS) applications. DNC data is only available to the U.S. military and selected allies. It is designed to conform to the IMO Performance Standard and IHO specifications for ECDIS.

6.6 *Offshore electronic navigational chart*

In offshore industry, such as Offshore Oil & Gas, Telecommunications, Fishing, Aggregate Extraction, Diving, sometimes are used three dimensional digital nautical charts 3DNCs. In Dynamic Positioning System are used ENCs. Few screens allow officers to switch screens between radar and chart displays, cameras from the closed circuit TV system, and the vessel's "Pilot"/"Harbour Approach" display.

6.7 *Inland electronic navigational chart (I-ENC)*

The goal of the North American - European Inland ENC Harmonization Group (IEHG), formed in 2003, is to agree upon specifications for Inland ENCs that are suitable for all known inland ENC data requirements for safe and efficient navigation for European, North and South American and Russian inland waterways. However, it is intended that this standard meet the basic needs for Sea-River and Inland ENC applications, worldwide. As such, the Sea-River and Inland ENC standard is flexible enough to accommodate additional inland waterway requirements in other regions of the world.

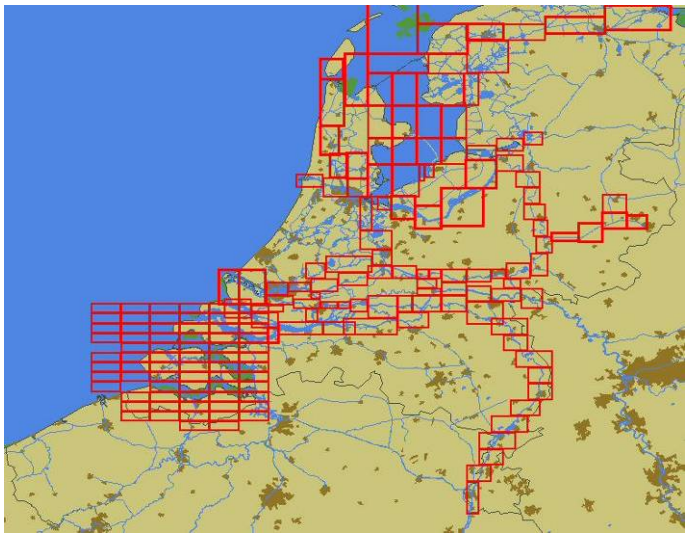


Figure 20. Coverage of seamless Inland ENC in NE Europe

7 CONCLUSIONS

Electronic Navigational Charts have improved the safety of navigation and the efficiency of operations for US and Europe's Inland Mariners who have welcomed digital technology wholeheartedly.

Inland water transport is gaining the attention of the policy-makers. So let's go forward with I-ECDIS and Inland ENC (River ENC) and Sea-River ENC.

The major advantages of Marine and Inland ECDIS electronic charts are:

- provision of information for all objects in text, graphical or video format,
- detailed and concise charts presentation in all resolutions and cut-out scales,
- simple and quick update of data (digital notices to skippers),
- presentation in various detailedness (e.g. depth) adapted to the needs of the skippers,
- provision of further information beyond shore and border zones,
- adoption to the requirements of skippers, e.g. customizing the chart display brightness to the lighting conditions in the wheelhouse, dynamic objects like locking status,
- possibility of linking with the radar display, route planning and route monitoring applications, etc.

One issue that can strike is that it seems that ECS has been adopted far more successfully inland, without mandatory requirements, but because of the added value to shipping operations. This is certainly in contrast to what we have seen on SOLAS fleet.

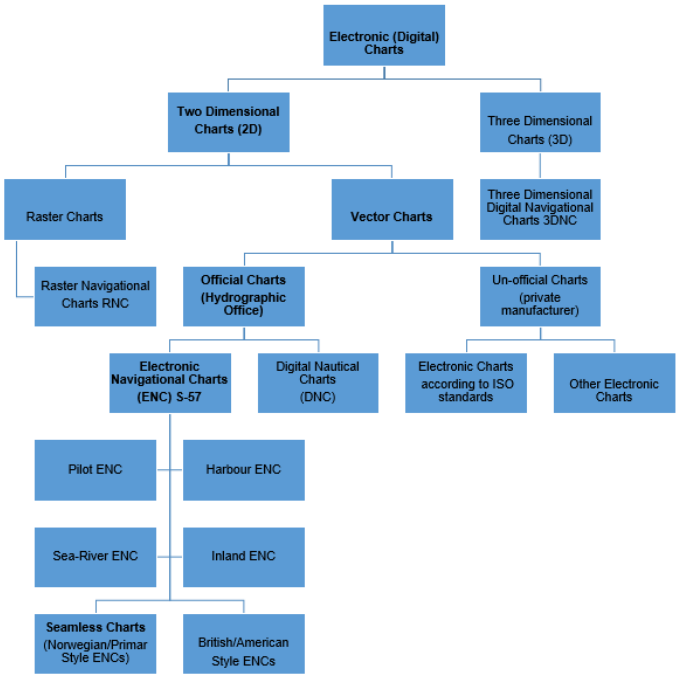


Figure 21. Electronic navigational charts general classification.

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