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THE ELECTRONIC CHART SYSTEMS AND THEIR CLASSIFICATION

ABSTRACT This paper is about Geographical Information Systems (GIS) in marine, coastal and navigational applications, about Electronic Chart Display and Information System (ECDIS) – state of the art in nautical charting, international fully standardised integrated navigational tool, about different types of electronic charts and systems and about necessity to use of correct internationally agreed terminology.

This paper presents actual status of *Electronic Chart Systems* (**ECS**), *Electronic Chart Display and Information Systems* (**ECDIS**), *Raster Chart Display Systems* (**RCDS**), *Admiralty Raster Chart Services* (**ARCS**), their relations and classification of existing data bases pretending to standardised name of *Electronic Navigational Charts* (**ENC**) and *Raster Navigational Charts* (**RNC**).

INTRODUCTION

The traditional paper chart has been a fundamental tool for the navigation of ships for many centuries. However, with the advent of satellite position fixing and powerful cheap computers, a potent additional tool is now available to the mariner. The introduction of modern mapping tools such as *Geographical Information Systems* (**GIS**), *Digital Terrain Models* (**DTM**), video plotters, raster charts, numerical maps, electronic chart systems (**ECS**) and *Global Positioning System* (**GPS**) have forced the hydrographic community to depart from the traditional paper chart to the development of digital spatial data products to meet user needs. Navigational information systems **ECDIS** (*Electronic Chart Display and Information Systems*) are destined to replace paper charts based navigation, providing increased benefits for safety and efficiency. The development of ECDIS is at least as significant to mariners and to ship safety as was the introduction of radio or radar to the bridges of ships earlier last century and at least as revolutionary for navigation techniques as was the introduction of Mercator's charts four hundreds years ago [Weintrit, 1997].

GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

Geographical Information Systems (GIS) are computer-based systems which are used to store and manipulate geographical information. GIS is ideally suited to analyse the multiple and diverse datasets which are quite diverse in content, in data collection methodology, in data format and structure or in spatial type (point, line, area) [Riemersma et al., 2000].

The initial impetus for developing a marine speciality in GIS was the need to automate the production of nautical charts and to more efficiently manage the prodigious amounts of data that are now capable of being collected at sea.

The GIS can provide the data management tool for all the digital hydrographic survey data, providing the functionality to store, retrieve and query information in the underlying database. The database can contain such information as survey parameters and settings.

Geographic information has been the basic information for navigation at land and at sea as well as for military and administrative purposes since the early beginnings of our culture. Since these early days maps and charts have been used both for displaying the information and as analogue databases, containing the geo referenced data in a graphically fixed form [Hecht, 2001].

The fundamental component of any GIS system is the data. Because electronic navigational charts (ENC) are managed as a database, they are considered to be a form of the GIS, and the data will be utilised in various applications in all activities on the sea [Kanazawa, 2000]. GIS is in effect any computer-based system which display graphical information with some intelligence, and it can be argued that a integrated navigation system ECDIS is a GIS [Riemersma et al., 2000].

STATE-OF-THE-ART IN NAUTICAL CHARTING

Much is written about the power and potential of GIS for coastal zone monitoring and management, as well as how GIS offers a powerful tool in the exploration and production. Many of these contributions are significant examples deal with GIS at the regional or local level**. ECDIS demonstrates the introduction of a GIS-based capability at the global level** (the world-wide data base, international standards for system and data, global use). The relevance of ECDIS thus is at least threefold [Ward et al., 2000]:

- It is a significant contributor to safety of navigation and thus will prevent many of the groundings, which have contributed to much of the world's ocean pollution;
- It is demonstration of the need for global co-operation at the government and government agency level if such potential of GIS is to be realized fully to the benefit of the world;
- It demonstrates the immense capability, which can be unleashed by the proper and appropriate development of GIS-based systems.

WHAT IS ECDIS

ECDIS is an advanced navigation information system for use in ships. It has been developed to lighten considerably the navigation workload, freeing the mariner for other important navigation-related tasks such as maintaining a safe lookout and for collision avoidance. It is a real-time decision aid, which provides the navigator with accurate and reliable information about a ship's position and its intended movements in relation to charted navigational features. ECDIS combines satellite position fixing, ship's sensors and other data with a sophisticated electronic database containing chart information. The electronic chart database is known as an electronic navigational chart or ENC. An ENC is much more than a computer copy of a paper chart, though it can look very similar when displayed on ECDIS equipment. ENCs are sophisticated and strictly controlled vector navigational chart data bases containing high levels of textual, spatial and graphical data representing not only the material already shown on a paper chart, but also additional data and information drawn from other publications and from source survey data. ENCs are only produced by or on the authority of government-authorised hydrographic offices or relevant government-authorised organisations [Ward et al., 2000].

A typical ECDIS installation is shown in Figure 1.

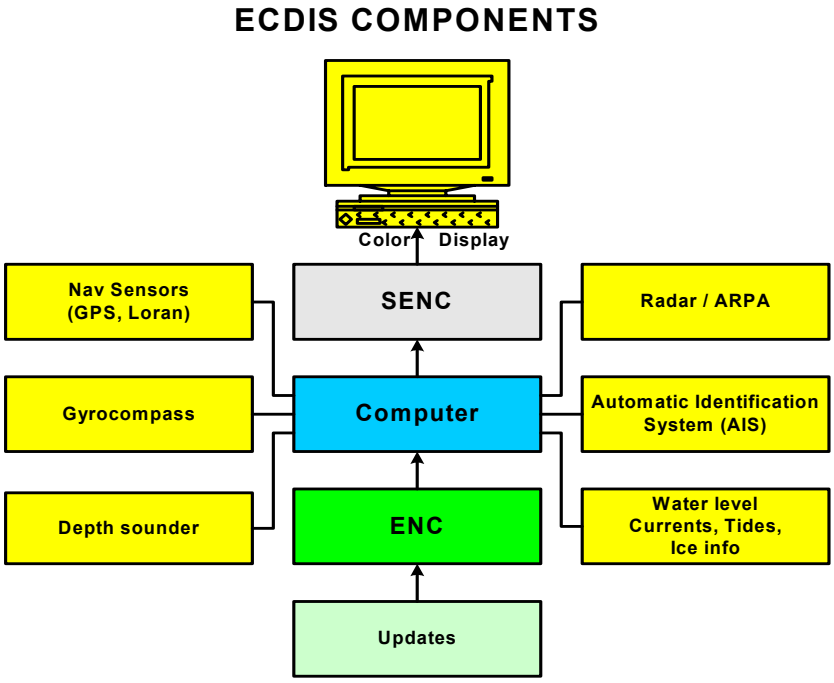

Fig.1. The typical ECDIS configuration

The best description or understanding of ECDIS is the following statement of Dr Lee Alexander: "A paper chart shows you where you were, or shouldn't be. ECDIS tells you where you are, and can safely go".

The fact that chart information is held in a data base rather than as a fixed image means that it can be analysed, manipulated and compared with other available information to provide a powerful decision making tool on the bridge of a ship. ECDIS continually analyses the ENC database and compares it with a ship's position and its manoeuvring characteristics to give timely warning of approaching dangers or notable events in the navigational plan.

ECDIS provides many other navigation and safety features including continuous voyage data recording and playback. The ship's radar signal can also be incorporated into an ECDIS and the radar image or content data displayed on screen as an overlay. This helps provide a comprehensive and fully integrated appreciation of the navigational situation and brings together the charted information with a record of the current circumstances as seen by radar. The additional information such as weather, ice reports, AIS signals, vessel position reporting and the application of observed tides can also be passed to system in real-time through telemetry links.

DEFINITIONS

ECDIS is the international fully standardised form of system of electronic charts that can legally replace a paper nautical charts. For the purpose of the standards for ECDIS the international organisations, such as IMO, IHO and IEC, adopted the following definitions:

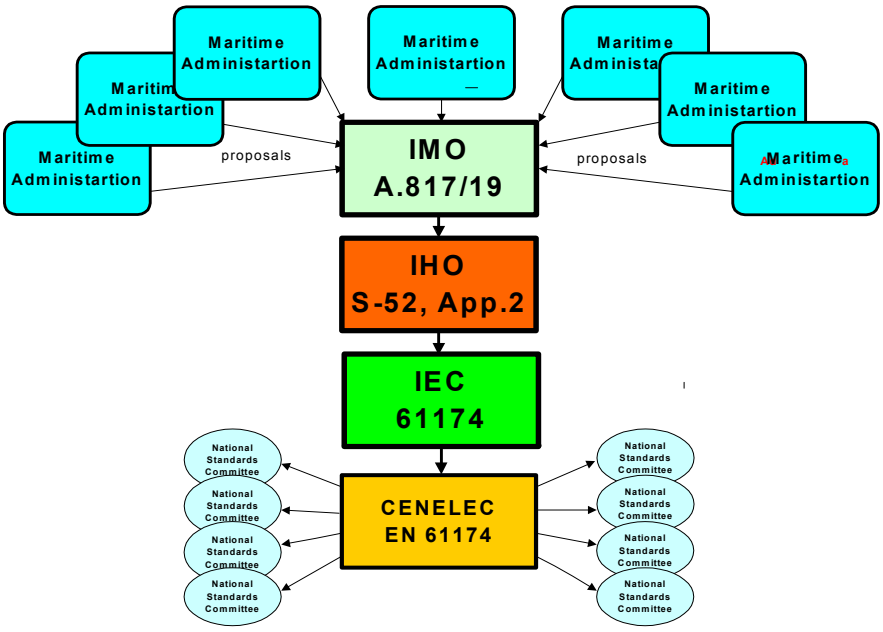

Fig.2. Definitions of ECDIS-related terms adopted by IMO, IHO, IEC, CENELEC and NSCs

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/20 of the 1974 SOLAS Convention, 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.

Electronic Navigational Chart (**ENC**) means the database, standardised as to content, structure and format, issued for use with ECDIS on the authority of government authorised hydrographic office. 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.

System Electronic Navigational Chart (**SENC**) means a database resulting from the transformation of the ENC by ECDIS for appropriate use, updates to the ENC by appropriate means, and other data added by the mariner. It is this database that is actually accessed by ECDIS for the display generation and other navigational functions, and is the equivalent to an up-to-date paper chart. The SENC may also contain information from other sources.

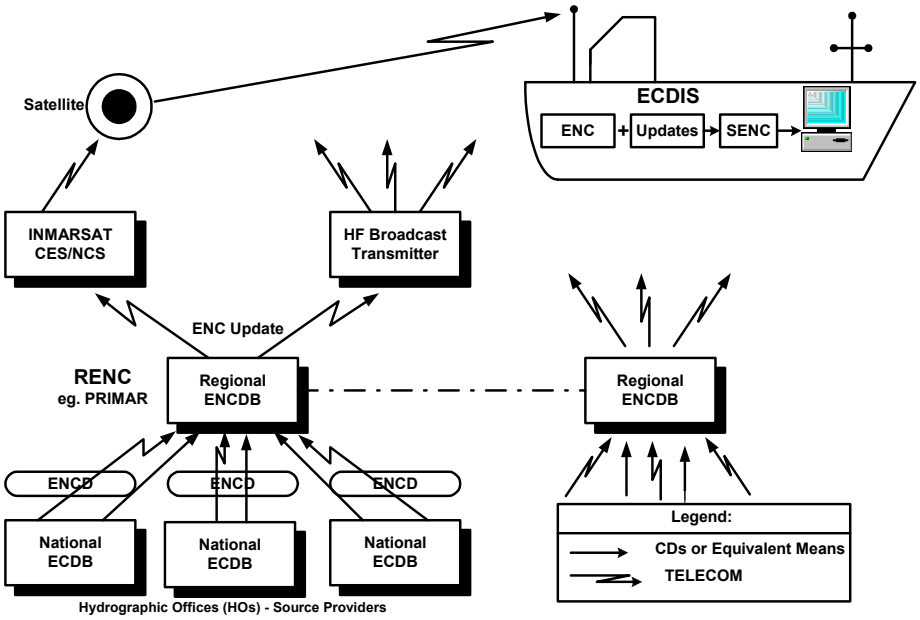

Fig.3. Updating system of the Electronic Navigational Charts (ENCs)

Electronic Chart System (**ECS**) - the generic term for equipment which displays chart data provided by hydrographic office, commercial manufacturer or user. 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. ECS is intended for use in conjunction with a current, updated paper chart.

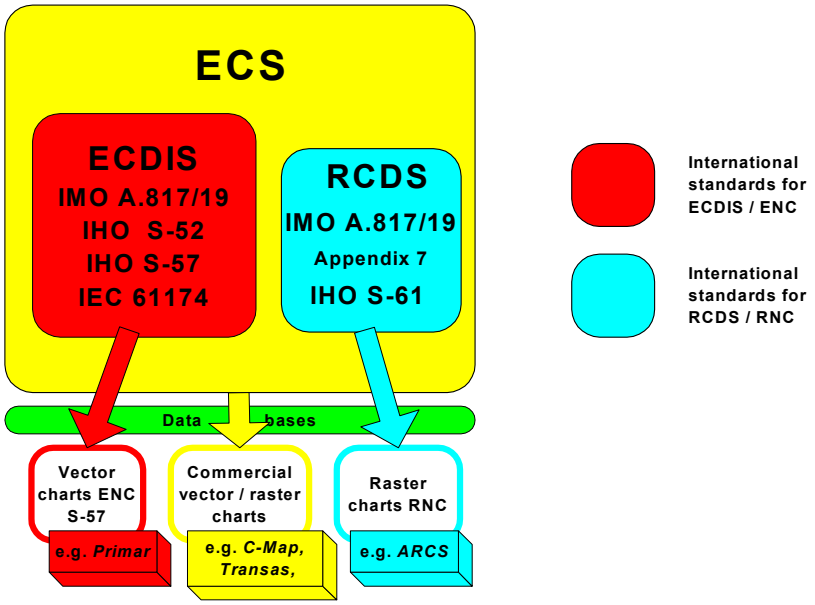

Fig.4. Classification scheme for electronic chart systems showing relations between ECS, ECDIS, RCDS and their databases.

Raster Chart Display System (**RCDS**) means a navigation information system displaying Raster Navigational Charts (RNC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring and, if required, display additional navigation-related information.

Raster Navigational Chart (**RNC**) means a facsimile of a paper chart originated, or distributed on the authority of a government-authorised hydrographic office.

System Raster Navigational Chart (**SRNC**) means a database resulting from the transformation of the RNC by the RCDS to include updates to the RNC by appropriate means.

CLASSIFICATION OF ELECTRONIC CHART SYSTEMS

This chapter of paper graphically presents actual status of *Electronic Chart Systems* (**ECS**), *Electronic Chart Display and Information Systems* (**ECDIS**), *Raster Chart Display Systems* (**RCDS**), *Admiralty Raster Chart Services* (**ARCS**), their relations and classification of existing data bases pretending to standardised name of *Electronic Navigational Charts* (**ENC**) and *Raster Navigational Charts* (**RNC**).

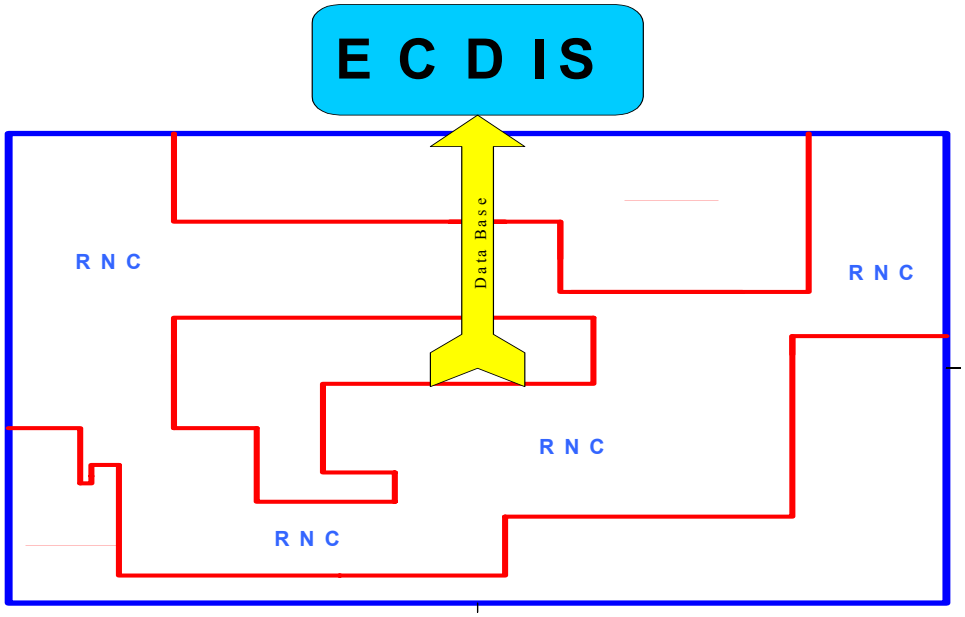

Fig. .5. "ECDIS dual fuelling" – the use of official raster charts in ECDIS has been agreed by the IMO (Res. A.817/19 – App.7) as an interim solution pending comprehensive world coverage by ENCs

On the figures 4 - 8 the Author tries to clear up some of the confusion that currently exists about the different types of electronic chart data and electronic chart systems. Author believes that using consistent and correct terminology will go a long way toward facilitating the use of ENC data in ECDIS.

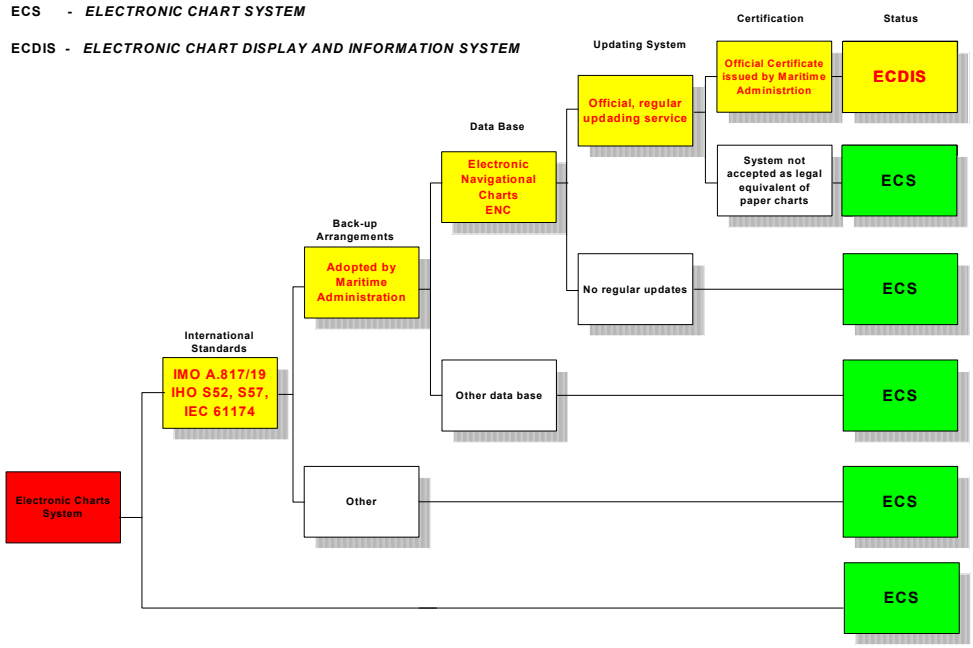

Fig. 6. Classification scheme for electronic charts systems pretending to internationally standardised name of Electronic Chart Display and Information Systems (ECDIS)

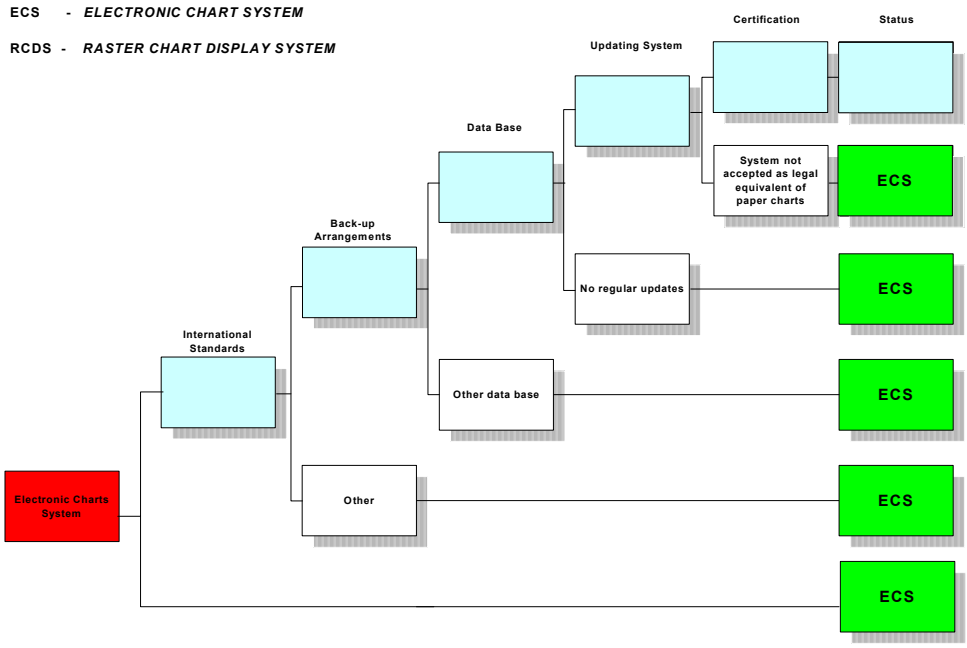

Fig.7. Classification scheme for electronic charts systems pretending to internationally standardised name of Raster Chart Display Systems (RCDS)

Electronic Chart System (ECS) can not 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 provided by hydrographic office, commercial manufacturer or user.

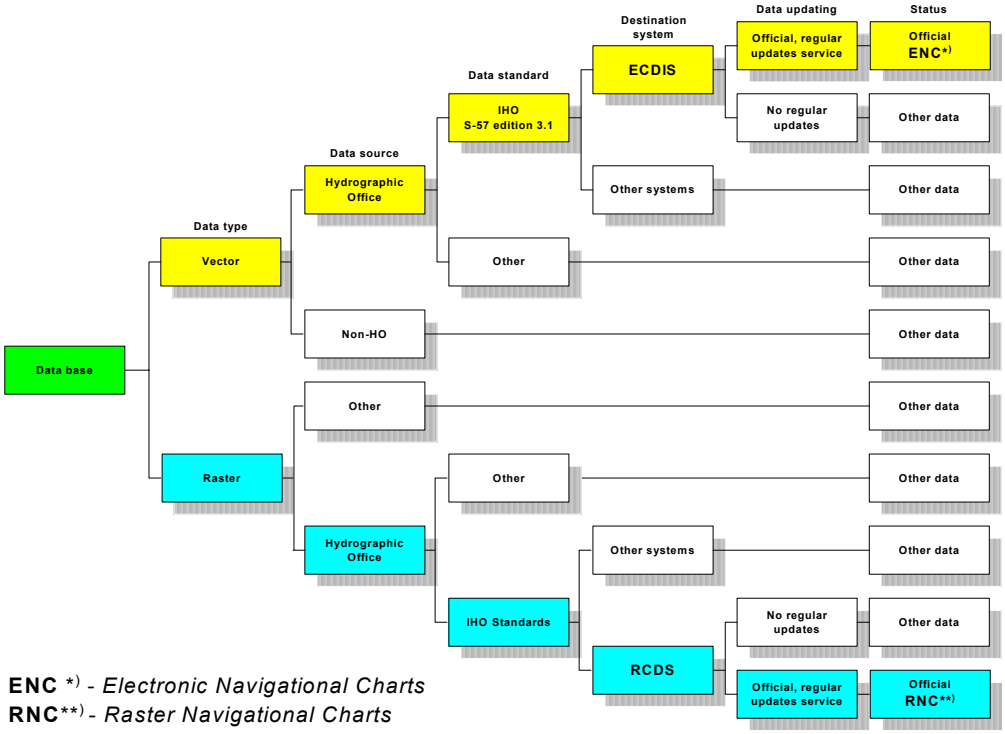

Fig.8. Classification scheme for data bases pretending to standardised name of electronic navigational chart (ENC) and raster navigational charts (RNC)

INTEGRATED BRIDGE SYSTEM (IBS) AND INTEGRATED NAVIGATIONAL SYSTEM (INS)

It must be said that now ECDIS is not the most integrated system on the navigational bridge, it is only element of the *Integrated Navigational System* (INS), sometimes called also *Electronic Charting and Integrated Navigation System* (ECINS), which is part of fully integrated, more sophisticated *Integrated Bridge System* (IBS), which combine ECDIS with GPS/GNSS, Radar/ARPA, GMDSS/COMSAT, AIS and with other ship's inner systems (such as: engine, administration, deck, cargo, etc.). IBS consists *of Integrated Navigational System* (INS), the *Integrated Control System* (ICC) and individual controls (e.g. steering and propulsion).

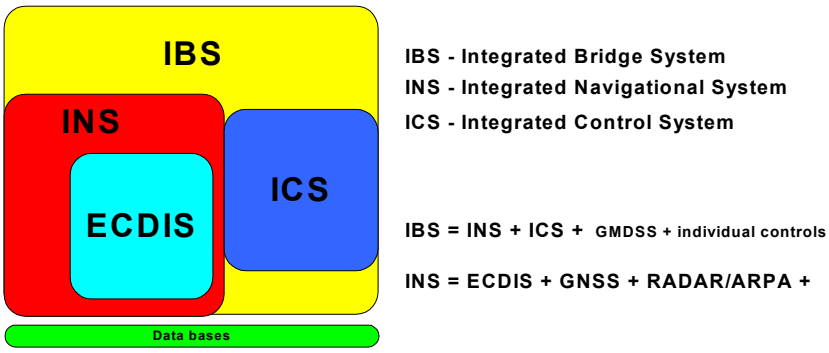

Fig.9. Classification scheme showing relations between IBS, INS and ECDIS.

WORLDWIDE SERVICE OF ELECTRONIC CHARTS

One of the most difficult impediments to greater use of GIS in marine applications has been the comparative lack of data. The ideal of providing a world-wide coverage and service of ENCs remains much in the mind of most national hydrographic offices but its realisation has been much harder to achieve than originally imagined. Meanwhile, government authorised raster charts and vector charts not authorised by HOs, are available for much of the world's oceans [Kerr, 2001]. Present situation is very unsatisfactory for navigators. While the government hydrographic community tries to get its world-wide ENC service together, ships continue to cross the seas. With ENC service absent for many parts of the shipping routes they look for the authorised but less versatile raster charts or the commercially produced, non-authorised vector charts, which may or may not be in the standardised IHO format.

Although quite a large number of HOs are now capable of producing ENCs and providing electronic updates, progress in providing complete coverage of all shipping routes, remains disappointingly slow. The organisation proposed by *the International Hydrographic Organisation* (IHO) to distribute the ENCs and to provide a global service, called *the World-wide Electronic Navigational Chart Data Base* (WEND), has failed to materialise in the manner expected. Up to now only one Regional ENC Co-ordinating Centre, has been formed, although, it must be said that this RENC, called PRIMAR and based in Stavanger, Norway, covered European waters, is finally entering into a productive mode, by providing an integrated database and updating service of high quality ENCs [Kerr, 2001].

DATA VISUALISATION

Humans take in most of the information about the world using their eyes, so the most natural method of presenting seabed information is to make it visible. The process of taking measured information and making it visible is called *'imaging'* or *'visualisation'*. Nowadays, imaging is almost entirely carried out using computers. The information to be visualised is held within the computer, and the visual output is presented on the computer screen, or printed onto paper [Green et al., 1998].

In the past, cartographers, hydrographers and others developed sophisticated methods of generalisation and abstraction to deal with precisely this problem, at a time when technology was unable to handle the volume of two-dimensional detail available about static, terrestrial features. Perhaps recent developments in technology are opening up a new research arena that will focus on generalisation methods for four-dimensional (dynamic, three-dimensional) data.

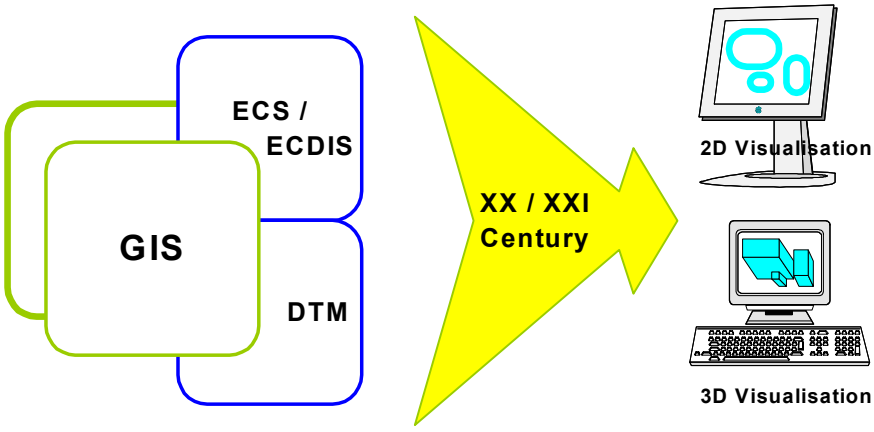

Fig.10. 2D and 3D visualisation of GIS / ECDIS / DTM data

3D displays, or oblique views, give the impression that the viewer is suspended above the seabed and looking down on it.

With the development of multibeam sonars and other high-resolution swatch mapping systems in concert with advances in positioning systems and computer processing power, our ability to map the seafloor has fundamentally changed. We now have the ability to obtain near complete coverage of relatively large areas of the seabed with unprecedented detail, providing a new perspective that has the potential to revolutionise our understanding of seafloor processes. The massive amounts of data collected by these new systems present tremendous challenges; firstly establishing the quality of the data acquired and then in terms of interaction, integration and interpretation [Gee et al., 2000].

THREE DIMENSIONAL DIGITAL NAVIGATIONAL CHARTS (3DNC)

The multibeam seafloor mapping technology makes it possible for the first time to map and to reveal all hazards to navigation with high confidence. If taken into use for shallow water areas with significant traffic density such as port entrances, ports, rivers and other inland waterways, it can mean a significant increase in the safety for shipping. For ports, the multibeam technology can be helpful for minimising the coast of dredging. It can also be used for efficient inspection of breakwaters, bridge foundations and other manmade constructions and for locating debris on the bottom. For surveying of canals and rivers, the increase in efficiency is very substantial, since the survey lines are now parallel to the shoreline.

3DNC is probably the next step in ENCs development.

CONCLUSIONS

The paper illustrates the broad usage of GIS in deep ocean, coastal and port environment, especially for navigational purposes. This paper can inspire others to identify further potentials and challenges in marine and navigational GIS, thereby stimulating continued research in this important application domain of geographic information science.

The human visual system has an enormous capacity for receiving and interpreting data quickly and efficiently and therefore must be an integral part of any effort to understand complex data. The key is to be able to present the data in as intuitive a fashion as possible. The more intuitive the presentation, the more rapidly data is interpreted, and the more new information can be extracted from that data. These elements have been incorporated in the some interactive ECDIS software application. The software was specifically designed to facilitate the interpretation and analysis of very large, complex, multicomponent spatial (vector) data sets.

ECDIS is one of the forms of marine applications of GIS, but this composed system is also part of MIS - *Management Information System* and NIS - *Navigational Information System* (INS and/or IBS) as well. Classification scheme showing relations between GIS, MIS, NIS and ECDIS is shown in Figure 11.

The past few years have seen dramatic advances in our ability to map the seafloor, but the new techniques produce massive data sets that can challenge our ability to process and manage the data. The great density of these data, however, offers the opportunity to take advantage of interactive 3D visualisation techniques that can improve the efficiency and accuracy of processing, and provide an unprecedented perspective of seafloor morphology and processes. For all this reasons the Author expect that seabed mapping and inspection using multibeam systems will become a natural part of the operation of ports as well as inland waterways in the future. The future for world-wide data base looks encouraging.

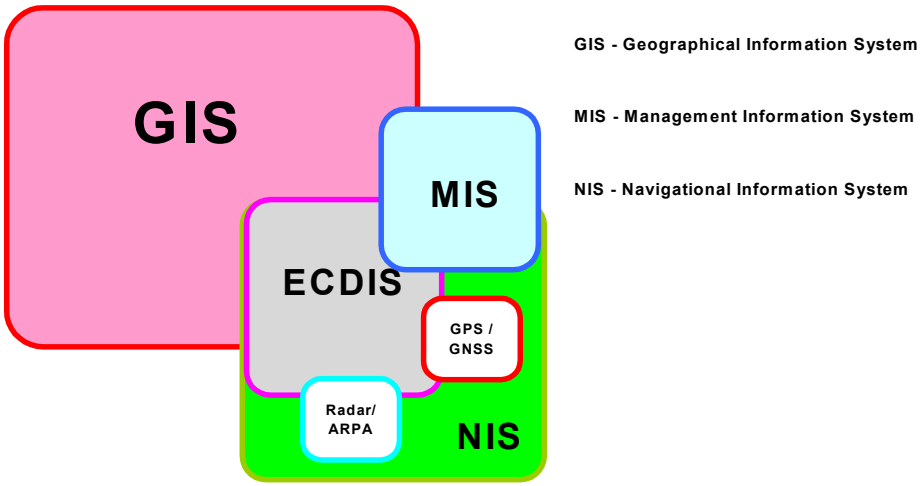

Fig.11. Classification scheme showing relations between GIS, MIS, NIS and ECDIS

Contrary to some pessimistic views, ECDIS and its accompanying ENCs are moving forward towards reality. The sea areas covered by vector S-57 ENCs persistently extend. Standardisation process for 2D ENCs is almost completed and some of the navigators took to thinking about *international standards for 3D ENCs.*

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