Towards new technology: an overview of the development and potential use of the electronic chart

King Kurwijira Ngabho Chiragi

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TOWARDS NEW TECHNOLOGY: AN OVERVIEW OF THE DEVELOPMENT AND POTENTIAL USE OF THE ELECTRONIC CHART

By

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The United Republic of Tanzania

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

in

MARITIME EDUCATION AND TRAINING
(Nautical)

1997

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

This dissertation establishes the evolutionary aspect of the electronic chart. The term electronic chart is used to describe the data component of a digital charting system.

The aim of this dissertation is to improve navigation safety and the efficiency of shipping in addition to highlighting legal, technical and administrative areas of electronic charting that are still unresolved.

The study explores different electronic charting systems with particular emphasis on Electronic Chart Display and Information System (ECDIS) and Electronic Chart System (ECS). It also compares the two charting systems and examines the different views prevailing on the use of Raster Chart Display Systems (RCDS) for navigation purposes on SOLAS class ships.

The study underscores the pros, cons and limitations of both electronic charting systems. The author addresses the issues of: development and legal aspects of electronic charts; standards used for ECDIS data; functions and applications for ECDIS; future ECDIS evolution; need for training and certification of ECDIS operators; and equipment type approval and carriage requirements.

The dissertation concludes that presently, ECDIS is the most suitable electronic charting system, which suggests that ECDIS standards be the minimum requirement for allowing an electronic chart replacement for paper charts on the bridges of SOLAS class ships.

Keywords:
1. Electronic Chart  
2. Vector  
3. Raster  
4. Performance Standards  
5. IMO-complaint  
6. ECDIS  
7. ECS  
8. Safe navigation  
9. Efficient shipping  
10. Limitations  
11. Applications  
12. Type approval  
13. Navigation sensor  
14. Training  
15. VTS  
16. Superimposition
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declaration</td>
<td>ii</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>iii</td>
</tr>
<tr>
<td>Abstract</td>
<td>iv</td>
</tr>
<tr>
<td>Table of contents</td>
<td>v</td>
</tr>
<tr>
<td>List of figures</td>
<td>vi</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>vii</td>
</tr>
</tbody>
</table>

## 1 Introduction

1.1 The Problem 2

1.2 Definition of Terms 2

1.3 Objectives 3

1.4 Scope and limitations 4

1.5 Methodology 4

## 2 The Electronic Chart

2.1 Background 5

2.2 Legal aspects 7

2.3 Basic approaches to electronic chart formats 8

2.3.1 Raster charts 8

2.3.2 Vector charts 10

2.4 Standardisation and development of the electronic chart 11

2.4.1 The role of IMO, IHB, IEC and other international bodies 12

2.4.2 The role of national hydrographic offices and safety administrations 15

2.5 Present status 18

2.5.1 Efforts in the United States of America (US) 18
2.5.2  Efforts in Canada  
2.5.3  Canada and US joint efforts  
2.5.4  European efforts  
2.5.5  Development at IHO  
2.6  Ways of managing an electronic chart database  
2.6.1  Chart-by-chart system  
2.6.2  Seamless technology  
2.7  Demand and benefits of electronic charts  
2.7.1  Basis for the development of electronic charts  
2.7.2  Benefits provided to shipowners by official electronic charts

3  
Electronic Chart Display and Information System (ECDIS) performance requirements and functions  
3.1  General  
3.2  Display of System Electronic Navigational Chart (SENC) information  
3.3  Information display characteristics  
3.4  Provision of chart information  
3.5  Updating of chart information  
3.6  Scale, units and legend  
3.7  Display of other navigational information  
3.8  Display mode and generation of the neighbouring area  
3.9  Colours and symbols  
3.10  Display requirements  
3.11  Priority Layers  
3.12  Route planning, monitoring and voyage recording  
3.13  Accuracy  
3.14  Connection with other equipment  
3.15  Performance test, malfunction alarms and indications  
3.16  Power supply
Electronic Chart System (ECS)

4.1 Background 52
4.2 The categorisation of Electronic Chart System 53
4.3 Standardisation of Electronic Chart System 55
4.4 Performance standards for RCDS 57
4.4.1 Arguments in support of setting standards 57
4.4.2 The counter argument 59
4.4.3 The United Kingdom and the Netherlands view regarding RCDS 61
4.4.4 Present status 62
4.5 Future developments 62

Potential use of ECDIS with traffic control systems and for other maritime applications

5.1 Use of ECDIS within Vessel Traffic Services (VTS) coverage 64
5.1.1 VTS and some of its functions 64
5.1.2 Some basic requirement for an efficient VTS 66
5.1.3 Effect of ECDIS-related technology on VTS 68
5.2 Impact of ECDIS on manoeuvring in channels, anchorage areas and on port navigation 68
5.2.1 Provision of information to the mariner 68
5.2.2 Identification of navigation marks and objects 70
5.2.3 Navigation techniques 70
5.2.4 Approaching anchorage areas and berthing 71
5.3 Other maritime applications 72
5.3.1 Small craft safety 72
5.3.2 Identification of fishing areas 74
5.3.3 Policing or surveillance 75
5.3.4 Training tool 75
6  Conclusions and Recommendations

6.1  Conclusions 76

6.1.1  ECDIS is the choice 76

6.1.2  Impact of ECDIS standards 78

6.1.3  ECDIS potential: accident prevention 79

6.1.4  ECDIS potential: implementation of bridge technologies 79

6.1.5  The obstacle: completing a world-wide ECDIS database 80

6.1.6  Chart surveys 80

6.1.7  Training in the use of ECDIS 81

6.2  Recommendations 82

Bibliography 83

Appendices 88
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>International organisations involved in ECDIS standards</td>
<td>17</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Relationship between terms used in the IMO standards for ECDIS</td>
<td>27</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Key Elements of an ECDIS</td>
<td>28</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Overview of Update Information Flow</td>
<td>36</td>
</tr>
</tbody>
</table>
LIST OF ABBREVIATIONS:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCS</td>
<td>Admiralty Raster Chart Service</td>
</tr>
<tr>
<td>ARPA</td>
<td>Automatic Radar Plotting Aid</td>
</tr>
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<td>BAFEGIS</td>
<td>Baltic Ferry Guidance and Information System</td>
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<tr>
<td>DGPS</td>
<td>Differential Global Positioning System</td>
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<td>ECDIS</td>
<td>Electronic Chart Display and Information System</td>
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<td>ENC</td>
<td>Electronic Navigational Chart</td>
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<td>EPA</td>
<td>Electronic Plotting Aid</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IHB</td>
<td>International Hydrographic Bureau</td>
</tr>
<tr>
<td>IHO</td>
<td>International Hydrographic organisation</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organisation</td>
</tr>
<tr>
<td>LORAN</td>
<td>Long Range Navigation</td>
</tr>
<tr>
<td>NAV</td>
<td>IMO Sub-Committee on Safety of Navigation</td>
</tr>
<tr>
<td>RENC</td>
<td>Regional Navigational Chart Co-ordinating Centre</td>
</tr>
<tr>
<td>RTCM</td>
<td>Radio Technical Commission for Maritime Services (USA)</td>
</tr>
<tr>
<td>SENC</td>
<td>System Electronic Navigational Chart</td>
</tr>
<tr>
<td>S-52</td>
<td>IHO special publication 52 (Provisional Specifications for chart content and Display Aspects of ECDIS)</td>
</tr>
<tr>
<td>S-57</td>
<td>IHO Special publication 57 (IHO Transfer Standards for Digital Hydrographic Data)</td>
</tr>
<tr>
<td>SOLAS</td>
<td>International Convention for the Safety of Life at Sea</td>
</tr>
<tr>
<td>VTS</td>
<td>Vessel Traffic Services</td>
</tr>
<tr>
<td>WEND</td>
<td>World-wide Electronic Navigation Chart Database</td>
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<tr>
<td>WGS</td>
<td>World Geodetic System</td>
</tr>
<tr>
<td>WMU</td>
<td>World Maritime University</td>
</tr>
</tbody>
</table>
CHAPTER ONE

1 INTRODUCTION

The last decades have seen dramatic development in the growth of electronic navigation systems. Technological advancements have given rise to more reliable and accurate positioning systems and sensors such as Differential Global Positioning Systems (DGPS) and collision avoidance systems including Automatic Radar Plotting Aids (ARPA). This technological advancement, especially the development of computers at an ever increasing pace, has also given rise to new bridge technologies, including expert systems such as Integrated Navigation Systems (INS) which promise to enhance maritime safety. Utilisation of such systems to their full potential becomes less realistic when the navigation chart is a paper chart. The private sector identified this limitation much earlier and saw the need and market for electronic charts. Electronic charts of different quality and reliability have been manufactured and marketed for use on ships. Use of these charts has been increasing in recent years particularly in the light marine industry. As Essenhigh (1995) rightly described it:

Shipowners, operators and insurers as well as navies are rapidly grasping the significance of this impending revolution in navigational practice. The increasing emphasis on safety and environmental protection may lead to ECDIS becoming virtually mandatory on many vessels before long.

Meanwhile many maritime states have realised that there is immediate need and demand for electronic charts for use on SOLAS class ships and for other applications. A few years back, several governments started working on the possibility of providing reliable charts to the shipping industry. The International Maritime Organisation (IMO) in collaboration with the International Hydrographic Office (IHO) and other organisations are working to ensure that the electronic charts so produced and used on ships will at least have the same availability and reliability of presentation as up to-date official paper charts before being accepted as being equivalent to the paper charts. The international maritime community is working co-
operatively at different levels, aiming at achieving improved navigation safety and protection of the environment by providing a reliable electronic chart.

This paper concerns the development of the electronic chart with particular reference to the Electronic Chart Display and Information System (ECDIS) and Electronic Chart System (ECS). The IMO has set international standards for Electronic Chart Display and Information System (ECDIS) which, if adhered to, will enable manufacturers provide a comprehensive digital form of the paper chart, with more functionality and flexibility. Such electronic chart with adequate back-up arrangements, will be regarded as IMO-compliant and could be allowed to replace paper charts on the bridge of a SOLAS class ship.

1.1 The problem

Technological development together with the legal requirements of charts have created a large segment of nautical chart users requiring an IMO acceptable electronic chart to replace paper charts. There are many electronic charts classified as Electronic Chart System (ECS) in use today which are not IMO-compliant. On the other hand, there are very few IMO-compliant charts ready for use on SOLAS class ships due to the lack of a world-wide ECDIS database. The challenge facing the international maritime community, which is addressed in this dissertation, is how to determine and provide a universally acceptable electronic charting system, in light of the many types of electronic charting systems available today and in the interest of safety of navigation.

1.2 Definition of Terms

For the purpose of this dissertation:

Electronic Chart: A very broad term to describe the data, the software, and the electronic system capable of displaying chart information. An electronic chart may or may not be equivalent to the paper chart required by SOLAS.
Electronic Chart Display and Information System (ECDIS): A navigation information system which can be accepted as complying with 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 monitoring, and if required display additional navigation-related information. The performance requirements for ECDIS are defined in the Draft Performance Standard for ECDIS developed by IMO/IHO HGE.

Electronic Chart System (ECS): Generic term for equipment which displays chart data but which is not intended to comply with the IMO performance standard for ECDIS. ECS is intended for use in conjunction with a paper chart.

Electronic Navigational Chart (ENC): The data base, standardised as to content, structure and format, issued for use with ECDIS on the authority of government authored hydrographic offices. The ENC contains all the chart information necessary for the 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.

Further definitions may be found in Appendix 6.

1.3 Objectives

This study intends to achieve the following objectives:

• examine technical and international initiatives for the development of electronic charts.

• examine the present status of electronic charting and identify benefits and limitations of ECDIS and ECS with particular emphasis on ARCS.

• consider the status and potential of ECDIS in the light of international performance standards and operational needs.

• examine the relationships between ECDIS and other navigation and control systems.

• examine the impact of ECDIS upon VTS operations and control.

• make conclusions on the need and use of ECDIS.
1.4 Scope and limitations

The main thrust of this dissertation concerns the evolution of the Electronic Chart and the evaluation of two charting systems: ECDIS and ECS. This study intends to consider the performance standards and functions of ECDIS in view of what it can do, especially as an aid for safe ship navigation and control. Different views on the use of ECDIS and/or ECS on SOLAS class ships are explored, touching on the ongoing debate of whether to use Admiralty Raster Chart Service (ARCS) as the sole navigation chart on SOLAS class ships during the period when ECDIS world-wide coverage is still not available. A limited discussion on the technical aspects of electronic charts is offered. However, it is beyond the scope of this study to cover the technical aspects in greater detail. This dissertation does not cover the commercial aspects of nautical charts. While ECDIS human factor aspects are cited, details of research findings regarding the subject are not included. Analysis of available data and information is made to try to establish the best suitable electronic charting system for improved safety of navigation and efficient shipping.

The author discusses in Chapter Two the development and legal aspects of the electronic chart. Chapter Three describes the performance standard, functions and limitations of ECDIS. Chapter Four describes the nature of ECS and examines the question of IMO setting performance standards for Raster Chart Display Systems (RCDS). Chapter Five presents potential use of ECDIS with Traffic Control Systems; applications for small craft safety, fishing and surveillance. Chapter Six contains the author’s conclusions and recommendations.

1.5 Methodology

This thesis addresses the development, potential use and application of the nautical electronic chart. The text is a synthesis of information and data obtained by the author from internet sources; WMU library search, specifically in technical publications; IHO publications and IMO meeting papers. Valuable information was also gathered from different experts on the subject during the author’s study period at WMU.
CHAPTER TWO

2 THE ELECTRONIC CHART

2.1 Background

According to the Encyclopaedia Britannica, hydrographic charting is the art of science of compiling and producing charts of water areas of the earth’s surface. The word chart is derived from the Latin carta ('paper') and has been used in English in the sense of a map since the 16th century. The present form is an abbreviation of the sea chart.

Four countries: France, U.K., U.S., and Russia, each attempted to provide their mariners with world chart coverage. However, there are cases when a country compiled its chart from an original survey carried out by another country. This has then been redrawn and reproduced according to national standards. Hydrographic charting has always been affected by technology and advancements in surveying techniques. The increase in size of ships in recent years, has for example made it necessary to repeat much of the existing charting due to increased ship drafts. To reduce the work involved in producing these new charts, the International Hydrographic Bureau (IHB) in 1967, took action to design a truly international series of charts, initially at 1:1,000,000 or smaller, which could be reproduced in facsimile by all IHB members through the interchange of reproduction materials.

Paper charts are seen as both cumbersome and limited in the information they are able to present (MacLeod, 1997). It was the leisure market which popularised the use of electronic charts in the late 1980s. The pull of consumer demand did not drive developments, it was the push of new technology. The availability of Decca, and the spread of accurate and cheap global positioning systems (GPS), from the military sector to the civilian sector, were the main influences. Mariners were quick to see the advantages of automatic position plotting onto digital charts. This period also saw the mass market availability of compact, powerful and affordable computers. This new
generation of computer technology really did speed the progress of digital charting, providing the necessary hardware platform (Dawson, 1997).

An Electronic Chart is a broad term used to describe the data component of a digital charting system. It falls into two categories:

(i) Official - an official electronic chart is one which is kept fully up-to-date and issued by, or on the authority of a national hydrographic office.

(ii) Non-Official - this term describes electronic charts which have been derived by commercial companies from data owned by national hydrographic authorities, but which are not endorsed by a national hydrographic authority.

The Electronic Navigation Chart (ENC) is an electronic representation of a nautical chart. It is a navigational derivative of a Geographic Information System (GIS). Development started in the 1970s, with the basic objective of equipping the navigator with geometric and bathymetric information during his collision avoidance and navigation decision processes, for improved navigation safety. Then came modern advances in computers and in Geographic Information System image generation technology which, since the late 1980s, has led to a great international interest in providing the navigator, and now, also the aviator, with electronic charts for their bridges and cockpits. These modern Electronic Navigation Charts (ENC) are now the key component of an Electronic Chart Display Information System (ECDIS).

Unlike most navigation aids, data obtained from the chart can hardly be checked and cross checked with other data in order to properly assess a developing critical situation. It has to be accepted as the basic authority on the bridge. For that matter, if the electronic chart is to be the substitute for the paper chart, it should have at least the same reliability and availability of presentation as the paper nautical chart published by government-authorised hydrographic offices.
2.2 Legal Aspects

Individual national maritime regulations require the carriage of enough and up-to-date charts (paper) for the intended voyage. If that is not adhered to then the ship becomes unsafe. And, consequently courts hold that a ship not provided with up-to-date navigational information is not seaworthy. Again, according to Regulation 20 of Chapter V of the 1974 International Convention for the Safety of Life at Sea (SOLAS V/20), all ships (SOLAS Class) have to carry adequate and up-to-date charts, and all other nautical publications necessary for the intended voyage. An equivalent to a paper chart, is allowed under the terms and conditions of regulation 5 of Chapter I of the same convention (SOLAS I/5). In order to accommodate electronic charts, chapter V on the safety of navigation is under revision and the working group at NAV 40 meeting produced a Draft Regulation 31 to replace the earlier Regulation 20 on nautical publications. However, the revised chapter is not expected to enter into force until the year 2002.

It is imperative that electronic charts should be competent enough for courts to be able to accept evidence derived from them as being equal to that normally available from paper charts. No court has yet ruled on the admissibility of such evidence, but attempts being made now make their acceptance a likely probability.

Having said that, a court in Australia has concluded that all charts, whether electronic or paper, contain errors. The case, which seems set to prove highly significant in the evolution of electronic chart technology, centred around the Australian Hydrographic Service (AHS) seeking to stop Italian raster chart supplier Navionics from selling its Electronic Chart Plotters, on the grounds that the electronic charts these use contain errors.

The AHS maintained that only official Hydrographic Service charts are safe. But the Federal Court of Australia concluded that all charts, including the official Hydrographic Service charts, have errors and determined that the Navionics charts, on
balance, contribute to the safety of navigation and that therefore they should continue to be sold (MacLeod, 1997).

The lack of official data with worldwide coverage has resulted in a slow uptake of electronic navigational systems among the SOLAS markets. Commercial vessels are still required to carry adequate and up-to-date paper charts for their intended voyage, and thus the user has little financial incentive for using electronic data. Nevertheless, the improved safety and additional functionality offered by electronic navigational systems has attracted early users. Many users have also installed systems so that they will be fully up and running when digital charts become legally equivalent to the paper chart.

2.3 Basic Approaches to Electronic Chart Formats

An Electronic Chart is constructed using one of two types of data. Several manufacturers are now developing electronic charts using the two basic approaches, raster and vector.

2.3.1 Raster charts

Raster data is produced by the scanning of the paper chart or its printing masters. The resultant image is made up of a number of lines, which in turn are made up of a large number of coloured dots or pixels. Being constructed in this way means that an individual object, such as a sounding, is not recognised by the computer as such. Thus the raster data is deemed unintelligent.

The fastest, easiest and least expensive way to create an electronic chart is to make a photographic image (scan) of the official paper chart so that it can be displayed on a computer screen. This technique is called scanning, and the resultant images are known as raster images. A raster chart looks exactly like the original, since it is an electronic duplicate. Raster Navigational Chart (RNC) means a facsimile of a paper
chart. Both the paper chart and the RNC are originated by, or distributed on the authority of, a government authorised hydrographic office.

Electronic raster charts are commercially available from some hydrographic agencies, such as the United States National Oceanographic and Atmospheric Agency (NOAA) and the British Admiralty.

**Advantages of raster charts:**

(i) The primary advantage of a raster chart, from the user's point of view, is its faithfulness of reproduction. The electronic chart looks just like the familiar paper chart. Old is gold?

(ii) Again as said above, raster charts are faster, easier and less expensive to create. This format offers a quicker, lower cost way to deliver existing paper charts to the mariner in a more modern, electronic package.

**Disadvantages of raster charts:**

(i) A raster chart is relatively inflexible. Data cannot be manipulated or updated easily.

(ii) The detail on a raster chart is difficult to view. The busy, cluttered raster screen cannot be simplified because raster charts are not digitised in layers. What you see is what you get, nothing more nothing less.

(iii) Can become cluttered when overlaid with other information.

(iv) Zoom and pan are limited. When you try to zoom in for greater detail, the photographic image is only magnified; more detail does not appear.

(v) At the edge of the raster chart, the computer must load the next adjacent chart which can be time consuming.

(vi) Raster chart systems are very memory intensive and may take many megabytes to store the image of a single nautical chart.

(vii) International Hydrographic Office's (IHO's) S-57 currently does not support raster data structures for ECDIS. The currently available raster products are simple reflections of a paper chart making process. These simple images are not capable of
supporting the advanced, 'GIS-like' operations that will be the core of the operational and IMO compliant ECDIS.

(viii) Currently formed raster products do not support point in polygon operation necessary to facilitate the antigrounding and other alarms required by the IMO Performance Standard.

(ix) Cannot be rotated to head-up or other orientation

2.3.2 Vector charts

Vector data is obtained by the digital capture of individual charted objects and their attributes, based on geographical positions. These objects are then stored in a database. For example, the database might contain reference to a buoy at a certain coordinate, along with its colour, shape, characteristics of its navigational light and so on. The nature of this data allows the display to be customised, (e.g. buoy names can be turned on or off), and thus it is deemed intelligent data.

To create a vector chart, paper charts are scanned to create raster files. Then the charts are vectorised, and information is stored in different layers. A vector chart is actually a graphic representation of a paper chart, produced by identifying, classifying and storing the objects relevant to navigation in a digital structure (structured encoding). A database has hundreds of layers available for storing different information types. Vector data can be compressed for efficient storage. A vector chart can for example, use less than 1/100th of the memory capacity needed by a raster chart to store the same amount of information (http://www.navionics.com, 1997). To produce detailed charts, manufacturers use the largest scale charts available to provide accuracy and best detail of the area. All navigational aids are included with precise positioning. The chart data is then supplemented and enhanced by more factual information from other sources, including information on marinas/harbours not shown on official charts, as well as information from local sources including hydrographic offices, search and rescue missions, local marine dealers, commercial and sport fishermen, diving and fishing clubs, local cruising clubs, and expert local navigators, etc.
The major hydrographic offices of the world, including the largest map maker in the world, the U.S. Defence Mapping Agency (DMA), have already announced that their electronic charts will be in vector format. The advantages and benefits of using vector format for charts are almost limitless and we can expect to see map makers of all types moving to the vector electronic chart in the years ahead.

Advantages of vector charts:

(i) The smaller data files mean that a vector chart is loaded and displayed much faster than a raster chart;

(ii) Vector charts are endlessly flexible and able to display different layers of information at different times. As you zoom in, increasing levels of detail are available without any sacrifice in image resolution;

(iii) As manufacturers use more and more powerful processors and more sophisticated software, vector charts will give the navigator ever more ability to select from the many types of information available;

(iv) User is able to manipulate chart data to customise his display;

(v) Can set own ship’s safety depth and warning alarms;

(vi) Charts can be rotated;

(vii) Chart data can be more easily used with other equipment, such as radar;

(viii) IHO’s S-57 currently support vector data structures for ECDIS.

Disadvantages of vector charts (Dawson, 1997):

(i) Charts are more complex, production is longer and more costly;

(ii) Large sea areas not likely to be officially available for several years;

(iii) Users will need additional training to use safely;

(iv) More difficult to ensure quality.

2.4 Standardisation and development of the electronic chart

In the development and production of any item including the electronic chart, standards are desirable. They guarantee quality, order and reason into what might
otherwise be a snarled job. On the other hand standards will help assure the maritime society that using an electronic chart is just as safe as using a paper chart.

2.4.1 The role of IMO, IHB, IEC and other international bodies

These organisations by the essence of their objectives, must be involved in the development of this very important tool for navigation.

Consider the aims and activities of the International Maritime Organisation (IMO) which are:
(i) to provide machinery for co-operation and the exchange of information among governments on technical matters affecting shipping engaged in international trade;
(ii) to encourage the adoption of the highest practicable standards in matters concerning maritime safety navigational efficiency, and the prevention and control of marine pollution from ships;
(iii) to provide a forum for member Governments and interested organisations to exchange information; and
(iv) to endeavour to solve problems connected with technical, legal and other questions concerning shipping and the prevention of marine pollution by ships,

and the purposes of the International Hydrographic Bureau, which are:
(i) to establish close association between hydrographic offices;
(ii) to encourage adoption of the best hydrographic survey methods;
(iii) to co-ordinate hydrographic work;
(iv) to make navigation easier and safer; and
(v) to obtain maximum uniformity in nautical charts and documents so mariners can use publications issued by other nations.

It is clearly noticed that these international bodies are expected and mandated by the international community to issue and publish international electronic chart standards. To that effect, there has been a continuing proliferation of standards that apply to ECDIS and Electronic Charting System (ECS).
IHO joined forces with IMO in a Harmonisation Group of ECDIS (HGE), that was given the assignment to create the IMO Performance Standard. The first ECDIS standards appeared in 1989, when IMO approved the provisional Performance Standard, advising member nations to make sea trials that would test the new standard, and proposing that it become final in 1993. IMO adhered to that schedule, and its Safety of Navigation subcommittee did recommend in September of 1993 that a Performance Standard for ECDIS be approved by the Maritime Safety Committee (MSC) and the Assembly of IMO. MSC approved the new standard in May of 1994 and the final approval by the assembly was done in November of 1995 under Resolution A. 817(19). Today, international ‘Standards for Electronic Chart Display and Information Systems (ECDIS)’ are available, and in that respect, an IMO-compliant ECDIS, can be considered equivalent to the up-to-date charts required by Regulation V/20 of the SOLAS Convention and provide a record for legal purposes, subject to individual national statutory regulations.

In the meantime through its circular to member governments (MSC/circ. 637), IMO has disseminated the ECDIS Performance Standard requesting member governments to have their national hydrographic offices (HOs):
(i) expedite the production of electronic navigation charts;
(ii) establish the associated updating service; and,
(iii) ensure that manufacturers conform to the performance standards when designing and producing ECDIS.

During the same period, the International Hydrographic Organisation (IHO) was at work establishing standards for display and chart database portions of ECDIS. IHO has produced a series of standards documents that are referenced within the IMO standard, and thus are part of the complete ECDIS standard documentation (see Appendix 1). In conjunction with the development of IMO Performance Standard for ECDIS, the International Hydrographic Organisation (IHO) has developed technical standards and specifications related to the digital data format, and specifications for the ECDIS content and display. Version 3.0 of IHO Special Publication No. 57 of November 1996 is the IHO Transfer Standard for Digital Hydrographic Data and it
describes the standard to be used for the exchange of digital hydrographic data between national hydrographic offices and for its distribution to manufacturers, mariners and other data users. It includes a general introduction to the Standard, a theoretical model and a description of the data structure (i.e. the S-57 format, formally called DX90 format). The two appendices contain the object catalogue of S-57 and Product Specifications for different applications. Edition 3.0, has been developed by the Data Base Working Group (DBWG) of the IHO Committee on Hydrographic Requirements for Information Systems (CHRIS), and will remain unaltered for four years from November 1996 onwards in order to facilitate ENC data production by Hydrographic Offices and the development of ECDIS equipment by manufacturers. Changes to this Standard are co-ordinated by the “Transfer Standard Maintenance Working Group” (TSMWG) of the IHO. National hydrographic offices which wish changes to be made to the standard, either to correct errors which they have identified or to enhance its applicability, must address their comments to the IHB. Other users of the standard, for example equipment manufacturers, must address their comments to their national hydrographic office (IHO, 1996d).

Also within IHO, an ENC Product Specification Working Group worked diligently to finalise an ENC Product Specification by early 1996. An ENC Product Specification is a detailed guide on how to use the IHO S-57 standard to create an ENC for ECDIS. It includes those specifications needed by all Hydrographic Offices to produce a consistent ENC, and for manufacturers to be able to economically use that data such that it satisfies the IMO Performance Standard. A standardised, consistent ENC is crucial in terms of providing the necessary information to generate the Base and Standard Display, Colours and Symbols, and for updating. IHO Special Publication No. 52 (IHO S-52) (and its three appendices related to the means/process for updating, colour and symbol specifications, plus glossary of ECDIS-related terms) is therefore, the IHO Specification for Chart Content and Display aspect of ECDIS.

At the request of IMO, the International Electrotechnical Commission (IEC) Technical Committee No. 80/Working Group 7 (IEC TC80/WG7), in close cooperation with the IHO/IMO Harmonisation Group, worked to identify and describe
the necessary performance tests and checks for ECDIS equipment, associated with the specifications and standards for ECDIS established by IMO and IHO. The IEC draft standard 1174 : Electronic chart display and information system (ECDIS) - Operational and performance requirements, methods of testing and required test results, is expected to be formally adopted by IEC in mid 1997. After adoption, it will become the basis for the development of type approval specifications related to operational methods of testing and required test results for an IMO-compliant ECDIS (Alexander, 1997a).

The development of ECDIS has spawned the Electronic Chart System (ECS). ECS is the variation which is agreed not to be the legal equivalent of the paper chart, but simply acts as an aid to navigation, that must always be used in conjunction with an up-to-date chart from a government sponsored hydrographic office. ECS has created its own coterie of standards. The Radio Technical Commission for Marine Services (RTCM) completed an ECS Performance Standard which was formally published in 1994. They have also been produced within IMO as guidelines (a variation on the concept of standard) for ECS.

2.4.2 The Role of National Hydrographic Offices and Safety Administrations

National Hydrographic Offices are governmental organisations established by most maritime nations to furnish their mariners with nautical charts and other publications necessary for navigation of their territorial waters and the oceans of the world. Activities of hydrographic offices _inter alia_ comprise:

- surveys at sea and along the coasts; and,
- publication and distribution of nautical documents.

The work of the hydrographic office does not end with printing a chart. The chart must be placed in the hands of the customer, who in turn must be provided with up-to-date information as to its correctness. Hydrographic offices therefore maintain branch offices or sales agents in the principal sea ports where mariners can purchase charts. Corrections to the charts are listed in weekly Notices to Mariners. Hydrographic
offices themselves put the corrections on their undistributed catalogue charts, and it is the purchaser's responsibility to refer to the Notices issued afterwards and to keep his charts current.

One of the main objectives of Safety Administrations is, to oversee all matters concerning maritime safety, including navigation. Activities include checking the carriage of up-to-date charts and all other navigational documents, in form of flag and/or port state control surveys.

In the Electronic chart era, the activities of these offices will basically remain the same, but possibly with some necessary changes to accommodate this new technology, e.g. acting in much closer co-ordination with private chart manufacturers.
Figure 1. International organisations involved in ECDIS standardisation

IMO : International Maritime Organisation
MSC : Marine Safety Committee
NAV : Safety Navigation Sub-Committee
HGE : Harmonisation Group on ECDIS
IHO : International Hydrographic Organisation
WEND : World Wide Electronic Navigational Chart Database
CHRIS : Committee on Hydrographic Requirements for Information Systems
IEC : International Electrotechnical Commission
TC80 : IEC committee on Maritime Navigation and Radiocommunications Equipment and Systems
WG7 : IEC working group on ECDIS
DGIWG : Digital Geographic Information Working Group
ISO : International Organisation for Standards
CIRM : Comite International Radio-Maritime

2.5 Present Status

There have been concerted efforts towards the development of electronic charts, both at national and international levels.

2.5.1 Efforts in the United States of America (US)

The US ECDIS Testbed Project administered by the Marine Policy Centre of Woods Hole Oceanographic Institution is currently focused on three main tasks (Alexander, 1997):

- evaluation of the Defence Mapping Agency digital data standard to meet IHO S-52 standards and IMO standards;
- development of additional system functionality for towboat and surveying operations on the lower Mississippi River for the US Army Corps of Engineers; and
- investigation of a number of input formats, user interface procedures and outputs to perform routine updating.

On the other hand, the U.S. National Oceanographic and Atmospheric Administration (NOAA) has begun production of digital raster versions of its nautical charts. They will be produced by scanning unscreened film positives of colour separates used in paper chart printing process. The primary use of NOAA raster charts will be for ECS systems (Alexander and Ganjon, 1995).

The US Radio Technical Commission for Maritime Services is working to develop a voluntary, industry-wide standard for an electronic chart system that would supplement the paper chart. The ECS would have to be used with an up-to-date chart from a government authorised HO. The USCG's evaluation of ECS includes determining the trade-offs between using government HO provided raster data and vector data that is provided by private companies (Alexander, 1997).
2.5.2 Efforts in Canada

Through its Electronic Chart Pilot Project the Canadian Hydrographic Service (CHS) is providing for the infrastructure required to produce, maintain, disseminate and update electronic charts. In partnership with a manufacturer and a major client, CHS has adopted a pragmatic approach -providing minimum level Electronic Navigation charts that will be upgraded to IMO-compliant level. The CHS is also conducting trials related to colours and symbols as well as general issues such as commonality, effectiveness and flexibility in operator control and operation of ECDIS. Canada has developed an ENC product specification and has established a partnership with Nautical Data International Inc. to market data for raster and vector electronic charts and other GIS applications (Alexander, 1997).

2.5.3 Canada and US joint efforts

A Canada-US co-operative research program was established in February 1992 to conduct research, development, test and evaluation of electronic chart-related technologies. Program participants include the Canadian Coast Guard, CHS; the Coast and Geodetic Survey (C&GS) and, the United States Coast Guard (USCG) (Alexander, 1997).

The program, based largely on the CHS Pilot Project, has now expanded into a comprehensive series of at-sea operational trials being conducted onboard commercial and government vessels with the objective of developing the infrastructure and standards necessary for the safe use of ECDIS as an aid to navigation in North American waters. Vessels in the Great Lakes, Pacific Northwest, St. Lawrence and Maritime coastal waters equipped with ECDIS are demonstrating that it is an aid in grounding and collision avoidance (Alexander, 1997). The project has provided an opportunity to acquire practical experience with ECDIS under a variety of working conditions. There is a possibility of the Japan Maritime Safety Agency also participating in these joint US-Canada ECDIS trials (Foxwell, 1995).
Other testing includes the use of marine training centres in British Columbia, Quebec and the Maritimes; as well as the ship-simulator facility at the Centre for Marine Simulation, St. Johns, Newfoundland and the Marine Safety International/computer Assisted Operational Research Facility at the US Merchant Marine Academy, in Kings Point, New York; to evaluate the human factor aspects of ECDIS design and operation (Alexander, 1997).

The Electronic Chart Project is also providing the United States, National Oceanographic & Atmospheric Administration (NOAA), US Coast Guard and Canadian Coast Guard with an important insight into the necessary government infrastructure that will be required to produce, maintain, disseminate, and update electronic charts. The project has demonstrated the usefulness of ECDIS as an aid to grounding and collision avoidance. It has also provided much useful background knowledge which will help in the process of recommending changes in laws and statutes in the US and Canada that will promote or mandate the use of electronic charts (Foxwell, 1995).

2.5.4 European efforts

In Germany, the Baltic and North Sea ECDIS testbed project (BANET) was conducted from April 1993 to March 1995 in order to create a regional database from which ENCs will be produced. It was a German Ministry of Research and Technology Project with International Participation. The main aim of the project was to continue development and application of a digital, object-oriented interactive navigation system suitable for operation on standard commercial work-stations, and to accelerate the rate at which ECDIS can be introduced through a series of realistic sea trials and simulations at SUSAN (Foxwell, 1995).

BANET’s objective was to attempt to integrate ECDIS to form a complete, self-contained system containing all major components, ranging from the acquisition of data (digitisation of charts) through their distribution and quality control right up to implementation of ECDIS and its trial on board.
One of the main aims of BANET was the co-ordination of data production at international level. Thus, the hydrographic services of Finland, Great Britain and Germany, as well as the company SevenCs GmbH, supplied digital ECDIS data for the on-board trials on the ferries "MV Hamburg" (Hamburg - Harwich) and "GTS Finnjet" (Travemünde - Helsinki). The hydrographic services of Denmark, Estonia, the Netherlands, Norway and Sweden likewise supported the BANET project.

Plans are being made to expand the US-Canada updating trials to include participation in Germany’s BANET Project. In this manner, both Europe and North American ECDIS manufacturers and vessels will provide a standardised ENC product. This would facilitate voyages between northern Europe and North America.

An updating procedure for ECDIS data was developed and was tested during practical operation on board. The procedure make it possible to update the ECDIS database fully automatically at the push of a button by means of a normal radio telephone link with the land-based computer. The process has meanwhile been submitted to the IMO (the International Maritime Organisation) as a proposal for adoption as an international standard (BAFEGIS Workshop, February 1996).

Meanwhile, following initial Dutch trials of a raster chart system with substantially reduced paper back-up aboard three Broere Shipping chemical tankers in 1996, two further trials using Admiralty Raster Chart Service (ARCS), the United Kingdom Hydrographic Office (UKHO) system, have been announced for 1997.

Alphatron Marine, of Rotterdam, is participating in a joint venture with Tresco Navigation Systems, shipowner Master Leemer and the UKHO, in which ARCS will be used aboard the 1,050 TEU newbuilding Sea Baltica, which entered service in December 1996, and sistership Sea Nordica, scheduled to enter service in April 1997.

In the mean time Ireland Marine department has followed the Dutch Government in approving trials of this kind. Irish containership operator Arklow Shipping has
adopted ARCS as the primary navigational charting system aboard its container ship *Arklow Castle*, completed in October 1996 (MacLeod, 1997).

2.5.5 Development at IHO

The IHO has two instruments directed at providing data for ECDIS. One of these has been the development of a digital data exchange standard known as S-57-DX-90 and the other is a committee called the World-wide Electronic Navigation Chart Database (WEND) Committee that is working to establish a global organisation of its IHO Member States’ Hydrographic Offices that will provide a world-wide database of ECDIS data.

The IHO WEND Committee has now developed in conceptual form a network of regional centres, known as Regional Electronic Navigational Chart Co-ordinating Centres (RENC). The first of these has been established at Stavanger, Norway and is managed by Norway and the United Kingdom in order to provide ECDIS data services for Northern Europe. This RENC is particularly important in terms of providing a pilot project to judge the rate of data delivery. It is reported that the United Kingdom is already making a substantial investment in this programme and that a trial service of ENC will be available in 1997, and from April 1998, a full ENC service covering major international shipping routes and ports will be provided. Another centre being planned is in Tokyo, Japan.

Several Hydrographic Offices have been actively producing digital data for electronic charts. Notable amongst these HOs have been those of Australia, Canada, Japan, Norway, Singapore, the United Kingdom and the United States. However, although some of this data was version 2 of S-57, very little as yet has been provided as S-57 Edition 3, which is essential format for ECDIS. Given the rapid development of data in the earlier version of the Standard, it is expected that translation of Edition 3 of the existing data and the development of new data will lead to an
expeditious delivery of ECDIS data meeting both IHO and IMO standards (IHO, 1996).

2.6 Ways of Managing an Electronic Chart Database

There are two basic ways to manage and display an electronic chart database. The chart-by-chart system or by seamless technology.

2.6.1 Chart-by-chart system

One way to store the electronic chart data is on a chart-by-chart basis. One paper chart goes into one file, the second chart goes in a separate file, and so on. The charts are displayed in the datum and scale of the paper chart. With a chart-by-chart system, when you get to the edge of a chart, your plotter will load the next available adjacent chart. This chart may or may not be the same scale as the one you were on previously.

2.6.2 Seamless technology

Seamless charts, on the other hand, use a layered vector database to capture information from all charts and many other sources, and stored on one map of the world in the computer. Individual charts are not stored in the chart-by-chart system. Rather, the cartographic data from all available charts and other sources is stored in layers in a single database, regardless of scale, and the scale of the chart is technically adjusted to be correct.

Layering information means chart data is stored in like types and fields and can be recalled selectively. For example, all the two-meter lines can be stored in one layer, all the ten-meter lines in another layer; all the names in another layer; all the navaids in another layer; all the cables in another layer and so forth. A database can have hundreds of layers available for information storage. This way, the information can be selected by the user or the navigational computer, according to the user's needs.
As chart plotter manufacturers use more and more powerful processors and more sophisticated software, this layering feature will give the navigator even more ability to select from the many types of information available. In the years ahead, many more types of information will be available to the navigator on their chart.

With a truly seamless vector layered database it is easy to zoom in on progressively smaller areas of the chart. At each zoom level, more detailed cartographic information is available. With a seamless database, the navigator moves easily from one chart to another, regardless of scale (http://www.navionics.com, 1997).

A limitation to this technology, could be where a chart manufacturer takes the data from several paper charts of many different scales and merges them together to create a chart. With a non-horizontally seamless technique, the source of the chart data could be lost when the database is created. Although convenient to the user, this process can generate a false sense of confidence because charts with different resolutions are displayed without any indication of a change (http://www.c-map.com/mframe.htm, 1997).

The overall quality of any database is equal to that of the lowest quality of data used in its creation. Critical navigational chart data is being sacrificed if a manufacturer creates a chart, using charts of a smaller scale with less detail, manipulating the data so that the user can zoom in to a given harbour and think that he is accessing more detailed information, when in fact, the same charts are merely being magnified.

Conversely in a horizontally seamless technique which respects the scales of government agency charts by clearly representing the source data; when a user zooms into a chart, he is actually viewing more detail (larger scale charts), not the same information in a magnified form.

Electronic charts are only as accurate as the paper government agency charts from which they are digitised. It is imperative that, during the digitising production process, the integrity of the paper chart is maintained in its electronic equivalent. Coastlines
should not be manipulated, buoys should not be arbitrarily moved or eliminated at will simply for the sake of making a pretty picture. Every electronic chart should provide the mariner with all of the information from his paper chart, plus additional navigational aids.

### 2.7 Demand and benefits of electronic charts

Compared to paper charts, electronic charts provide many functional advantages to the mariner. This section highlights grounds for development and the benefits this navigation aid offers to marine navigation and pilotage.

#### 2.7.1 Basis for the development of electronic charts

- Greater need for navigational safety and efficiency of shipping in light of:
  - (i) reduced manning standards and the 'one-man bridge';
  - (ii) fast ferry operations in restricted waters;
  - (iii) more rigid adherence to liner and ferry timetables.
- Availability of navaids such as Global Positioning System (GPS) and LORAN-C which are able to display dynamic ship position on an electronic chart.
- Development of 'Integrated Bridge' equipped with all electronic equipment built into consoles around a single control position.

#### 2.7.2 Benefits provided to shipowners by official electronic charts

- Reduced manning cost through valid reduction of ship crews.
- Increased navigational safety - especially in restricted waters.
- Improved track control - giving improved time-keeping and reduced fuel costs
- Reduced scope of navigational error.
- Event recording - allowing subsequent inquiry and audit of the navigation of the ship.
- New charts and corrections can be transmitted to a ship at sea. Chart corrections can be applied automatically, saving time and eliminating chances of error.
CHAPTER THREE

3 ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM (ECDIS) PERFORMANCE REQUIREMENTS AND FUNCTIONS

3.1 General

The purpose of IMO-compliant ECDIS is to be used by the mariner in the same way as the traditional paper chart: To navigate his vessel from one place to the other. ECDIS supports chart work in the same way as the paper chart but in a digital and much more flexible way. The primary function of the ECDIS is to contribute to safe navigation.

The ECDIS integrates electronic positioning and other information with Electronic Navigation Chart (ENC) data. 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 and list of lights) which may be considered necessary for safe navigation. The content, structure and format of the ENC are specified in IHO S-57 edition 3 and the associated ENC product specification.

The ECDIS marries a Management Information System (MIS) and a Geographic Information System (GIS) into an integrated tactical display for the navigator. For that matter ECDIS is a navigation information system which, with adequate back-up arrangements, may be accepted as complying with the up-to-date charts 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 if required. System electronic navigational chart (SENC) in this context 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.

**Figure 2. Relationship between terms used in the IMO Performance Standards for ECDIS**

![Diagram showing the relationship between terms used in the IMO Performance Standards for ECDIS.]

*Source: IHO Special publication No. 52 Appendix 3, 1993*

Current IMO/IHO standards require that as a minimum ECDIS be capable of doing the following:

- display all chart information necessary for safe and efficient navigation originated by, and distributed on the authority of, government-authorised hydrographic offices;
- facilitate simple and reliable updating of the electronic navigational chart;
- reduce the navigational workload as compared to use of the paper chart;
- enable the mariner to execute in a convenient and timely manner all route planning, route monitoring and positioning currently performed on paper charts;
• continuously plot the ship's position;
• have at least the same reliability and availability of presentation as the paper chart published by government-authorised hydrographic offices;
• provide appropriate alarms or indications with respect to the information displayed or malfunction of the equipment (see Appendix 5).

The back-up arrangements or system referred to above, and hereafter called back-up in this document, must display in graphical (chart) form the relevant information of the hydrographic and geographic environment which is necessary for safe navigation. The purpose of an ECDIS back-up system is to ensure that safe navigation is not compromised in the event of ECDIS failure. Conditions for the back-up system include: a timely transfer to the back-up system during critical navigation situations; allowing the vessel to be navigated safely until the termination of the voyage; and providing a reliable operation under prevailing environmental and normal operating conditions.

For the ECDIS as an equivalent to the paper chart, data content, data entry format and data media must be standardised for all equipment and for all ships. It is therefore imperative that ECDIS must at least meet international performance standards in fulfilling its functions, some of which are briefly explained in the following sections.

Figure 3. Key Elements of an ECDIS
3.2 Display of System Electronic Navigational Chart (SENC) information

ECDIS should be capable of displaying all System Electronic Navigational Chart (SENC) information. The SENC information available for display during route planning and route monitoring should be subdivided into three categories: Display base, Standard display, and all other information (see Appendix 2).

Should an "unknown object" occur in the SENC which is not adequately defined or for which no symbol exists, its presence shall be indicated on the display by a magenta "?" with the Standard display. In case the back-up is an electronic device, it should be capable of displaying at least the information equivalent to the Standard display.

ECDIS should present the standard display at any time by a single operator action. A single operation shall be achieved by activating a hardkey or softkey, including any necessary cursor movement. When a chart is first displayed on ECDIS, it should provide the standard display at the largest scale available in the SENC for the displayed area. This is only applicable when the first chart is displayed subsequent to power up. It should be easy to add or remove information from the ECDIS display but it should not be possible to remove information contained in the display base. The addition or deletion of information shall be limited to categories of information, e.g. prohibited and restricted areas, spot soundings and not individual items, e.g. an individual area or an individual sounding. The number of operator actions shall be no more than three.

It should be possible for the mariner to select a safety contour from the depth contours provided by the SENC and the ECDIS should give the safety contour more emphasis than other contours on the display. If the mariner does not specify a safety contour, this shall default to 30 m. If the safety contour specified by the mariner is not in the SENC, the safety contour shown shall default to the next deeper contour. If the safety contour in use becomes unavailable due to a change in source data, the safety contour shall default to the next deeper contour. In each of the above cases, the mariner shall
be informed. At all times, the safety contour shall be the one specified by the mariner or the next deeper contour if the specified one is not available.

It shall also be possible for the mariner to select a safety depth. ECDIS should emphasise soundings equal to or less than the safety depth whenever spot soundings are selected for display. It is important to note that depth information shall only be displayed as it has been provided in the ENC and not adjusted by tidal height.

The ENC and all updates to it should be displayed without any degradation of their information content. Degradation in this context means degradation in information quantity as well as quality with respect to a standard test chart provided by government authorised hydrographic offices. Additionally, ECDIS should provide means of ensuring that the ENC and all updates to it have been correctly loaded into the SENC. If not, it could set the scene for a "technology assisted incident" in case a crucial navaid is not displayed. The ENC data and updates to it should be carefully distinguishable from other displayed information, such as, for example, that listed in Appendix 3 of IMO Performance Standards (see appendix 3). Adherence to the IHO colours and symbols requirements ensures these features.

### 3.3 Information display characteristics

Information shall be displayed in the ECDIS on one or more physical screens, which may be divided into more than one display. Information may be displayed automatically, on demand or as a result of hand-entry. In addition the following rules apply:

a) The units for depth shall always be on the same screen as the chart display.

b) The following information shall be visual on demand on the same screen as the chart display is visual or on an additional graphic or text display:

1. positional data and time;
2. legend;
3. object description and associated attributes (result of "cursor query");
4. textual information from SENC;
3.4 Provision of chart information

The chart information to be used in ECDIS should be the latest edition of information originated by a government-authorised hydrographic office, and conform to IHO standards. The same applies to the back-up system. In order to identify the date and origin of the ENC in use, the ECDIS shall include a chart library, which lists the ENC in the ECDIS by edition and date. The chart library shall be presented at the mariner’s request. A new edition of an ENC will supersede a previous ENC and its integrated updates issued by a government authorised hydrographic office. For the back-up, the chart or chart data edition and issuing date should be indicated.

The contents of the SENC should be adequate and up-to-date for the intended voyage, as required by regulation V/20 of the 1974 SOLAS Convention. In the same way, information displayed by the ECDIS back-up should be up-to-date for the entire voyage. It should not be possible to alter the contents of both the ENC and the back-up. By this, the Hydrographic Office data is protected against accidental loss.

If the area covered by the ECDIS display includes waters for which no Hydrographic Office ENC at a scale appropriate for navigation exists, the areas representing those waters shall carry an indication to the mariner to refer to the paper chart. In case of an area with no data of any kind it shall be marked with the “no data” symbology. When an area with no ENC data is covered by non-ENC data, the area shall be marked by the “non-ENC area” symbology.
3.5 Updating of chart information

A main productivity and navigation safety benefit of ECDIS is its potential to offer quick and easy chart updates. This will provide the mariner with the most current information for the intended transit area. The timeliness of navigational information and warnings is one of the major benefits of an ECDIS device to the navigator. Updates should be stored separately from the ENC. However separate storage of updates may utilise the same data storage area.

ECDIS should be capable of accepting official updates to the ENC data provided in conformity with IHO standards. These updates should be automatically applied to the SENC. By whatever means updates are received, the implementation procedure should not interfere with the display in use and updates shall be clearly distinguishable on the display. Once accepted, integrated updates should be indistinguishable from ENC data. Non-integrated updates (e.g. those entered manually) shall be distinguishable as described in S-52 appendix 2/2.3.4. It shall be possible on demand to review a previously installed update. Official Hydrographic Office updates shall be distinguished from local ones. It shall be possible to display selectively any previously accepted integrated Update Set which has been applied to the current ENC Edition of data in the SENC.

ECDIS shall keep a record of updates, including time of application and identification parameters described in paragraph 3.2 (i) and Table 3.1 of appendix 1 of S-52, through a log file. The log file shall contain, for each update applied to or rejected by the SENC, the following information:

1. date and time of application/rejection;
2. complete identification number of update which includes: identification of Issuing Authority, sequence number of Update Set, Cell Identifier, Edition Number of ENC involved, Update Sequence number within the cell;
3. any anomalies (e.g. error messages or load warnings) encountered during application;
4. type of application: manual/automatic
The ECDIS shall warn the user when an update is out of sequence. Provision shall be made to allow updates to be applied even if out of sequence. It is worthy noting that S-57 Edn. 3 does not currently support application of updates out of sequence.

The ECDIS shall enable manual entry of updates for non-integrated presentation on the display. A capacity shall exist to enable the mariner to:

1. enter a symbol describing the updates;
2. ensure all update text information relevant to the new condition and to the source of the update is entered by the mariner and recorded by the system, for display on demand.

The system shall be capable of implementing manual updates to point objects and simple line and area objects such as traffic routeing schemes, restricted areas and shoreline constructions, but excluding complicated lines and areas such as contours and coastlines. The ECDIS shall be capable of sensing indications and alarms related to non-integrated (manual) updates, just as it does for integrated updates.

Manual updates shall be displayed as follows:

**Add** a new feature  
add the standard symbol.

**Delete** an existing feature  
The deleted object is distinguishable by a single slash through the feature (symbol CHCORDEL).

**Move** a feature  
"Delete" the feature, and "Add" the modified version at the new position.

**Modify** a feature  
"Delete" the feature, and "Add" the modified version at the same position with a higher display priority.

The manual updates shall be distinguishable as described in S-52 appendix 2/2.3.4;2.3.5. It shall be possible to remove from the display any manual update. However the removed updates shall be retained for future reviews. Manual updates shall be retained until a new edition of the ENC is issued or an official update to the ENC is received, whichever is earlier.
The ECDIS shall be capable of receiving updates in standard IHO format by 3.5” high density diskette and through a telephone network. The minimum requirement is that the ECDIS shall be capable of receiving updates via 3.5” diskettes. This is consistent with S-52 appendix 1/3.3.3. The identification of the issuing authority of the update shall be checked for conformance with the corresponding identifier of the ENC. If any errors are detected from the receiving device, the reception procedure shall be terminated and the update flagged invalid in the record of updates. The user shall be informed of the corruption, and allowed to restart reception of the update set beyond the point of corrupted data. The ECDIS shall reject corrupted files and provide a warning of this action. The mariner shall be warned of any previous official updates which have not been successfully applied. Updates not relating to a cell within the ENC may be discarded.

A summary report for the issuing authority’s official updates set shall be given after completion of receipt containing at least:

1. identification of issuing authority;
2. sequence number of update set;
3. cell identifiers of cell affected;
4. edition number of ENC cell involved;
5. number of updates in each affected cell.

After completion of application of the update set to the SENC a report shall be displayed giving the total number of updates applied, number of updates pending (i.e. to come into effect in the future) and any anomalies encountered.

It shall be possible for the mariner: to review the updates to be applied prior to adoption by displaying the SENC contents and highlighting those updates, and to reject an individual update prior to its acceptance if, for example, he sees the updated condition to be impossible (e.g., a buoy plotting on land). Rejected updates shall be so indicated in the record of updates. If a subsequent update depends logically on a rejected update, control shall be returned to the mariner. A rejected update shall be applied to the SENC, displayed, and then manually annotated as rejected by the
mariner, i.e. it shall not be possible for the mariner to reject an officially issued update by omitting its application entirely.

The contents of a sequential update assume that all earlier updates have been applied to the SENC and a new edition of an ENC shall supersede a previous ENC and its updates. It shall be possible to carry out updating operations in all ECDIS modes, e.g. route planning, route monitoring, etc. ECDIS should also be capable of accepting updates to the ENC data entered manually with simple means for verification prior to the final acceptance of the data. They should be distinguishable on the display from ENC information and its official updates, and not affect display legibility. ECDIS should keep a record of updates, including time of application to the SENC, and should allow the mariner to display updates so that the mariner may review their contents and ascertain that they have been included in the SENC.
Figure 4. Overview of Update Information Flow

Legend:
- ECDB: Electronic Chart Data Base
- ENC: Electronic Navigational Chart
- ENCD: Electronic Navigational Chart Data
- ENCDB: Electronic Navigational Chart Data Base
- SENC: System Electronic Navigational Chart

Source: IHO Special Publication No. 52 Appendix 1, 1996
3.6 Scale, units and legend

Regarding scale, ECDIS should provide an indication of whether:

1. the information is displayed at a larger scale than that contained in the ENC; or
2. own ship’s position is covered by an ENC at a larger scale than that provided by the display.

If an electronic device is used for the ECDIS back-up arrangements, it should provide an indication:

1. if information is displayed at a larger scale than that contained in the database; and
2. if own ship’s position is covered by a chart at a larger scale than that provided by the system.

If data from different compilation scales appears on the display, the boundary between different scales shall be clearly indicated. The manufacturer shall give the navigator the ability to use intermediate display scales, or zoom in between scales.

Following are units to be used on ECDIS displays:

1. Position latitude and longitude in degrees, minutes and decimal minutes
2. Depth metres and decimetres
3. Height metres
4. Distance nautical miles and decimal miles, or metres
5. Speed knots and decimal knots

The system shall also support:

7. Time hours, minutes and seconds
8. Direction degrees and tenths of degrees

Units used shall be indicated in the display legend, and there shall be no ambiguity about the units in use at a particular time.
A standard legend of general information relating to the area displayed, applicable to the ship’s position, shall be shown on a graphic or text display. This legend shall contain at minimum:

1. unit for depth
2. units for height
3. scale of display
4. data quality indicator
5. sounding/vertical datum
6. horizontal datum
7. the value of the safety depth if used
8. the value of the safety contour if used
9. magnetic variation
10. date and number of last update affecting the chart cells currently in use
11. edition number and date of issue of the ENC
12. chart projection

3.7 Display of other navigational information

Radar information or other navigational information may be added to the ECDIS display. However, it should not degrade the SENC information, and should be clearly distinguishable from the SENC information. Degraded means reduce the information content of ECDIS and added navigational information should use a common reference system. If this is not the case, an indication should be provided.

Radar

The main cause of groundings and collisions is poor monitoring and reliability of the ship’s position as well as inadequate lookout. ECDIS makes possible an automatic and continuous monitoring of the ship’s position in relation to the planned track and the hydrographic situation. Radar/Automated Radar Plotting Aid (ARPA) is an indispensable tool both for navigation and for collision avoidance as the movements of other ships can be tracked and displayed. The operational integration of ECDIS and radar/ARPA combines the main tasks of the watch on the bridge. The situation
involving encounters with vessels can at all times be assessed within the overall context by the overlaid display of radar picture and ECDIS. Such integrated systems are being developed at present and have already been implemented in voluntary systems. When ECDIS and radar/ARPA are superimposed, they form a single system to be used both as a primary navigation system and as a primary collision avoidance system serving to enhance the safety and efficiency of shipping. This applies especially:

1) directly because the information required for the ship’s navigation is combined, and
2) indirectly because the Officer Of the Watch is relieved of part of his workload (Berking et al, 1993).

Transferred radar information may contain both the radar image and ARPA or Automatic Tracking Aid (ATA) or Electronic Plotting Aid (EPA) information. The mariner must maintain caution that ARPA vectors are true motion and speed through the water vectors while ECDIS is operating on a speed over the ground parameter. Close-quarters situations with ARPA could result in collision situations due to these different frames of reference.

It is obligatory that the primary stabilisation mode for the superimposed ECDIS and radar/ARPA display is bottom stabilisation, since a uniform display is required. For ECDIS and radar picture bottom stabilisation is required when applied for navigation. The absolute movements of own ship and other ships displayed by ARPA, e.g. by absolute vectors, should normally also be bottom stabilised. But alternately, if required for determining an avoidance manoeuvre, for assistance in aspect recognition or for trial manoeuvres, it should be water stabilised. (Berking et al, 1993)

If the radar image or plotting information is added to the ECDIS display, the chart and the radar image or plotting information should match in scale and in orientation. Additionally the ECDIS and radar image or plotting information shall match in projection. The underlay of radar picture on an ECDIS is an important cross-check for the mariner on the ECDIS display accuracy. The underlay presentation is reportedly
the preferred display of radar data (versus overlay) (http://tamug.tamu.edu/~mart/e-chart/index.htm, 1997). The quality of radar accuracy (e.g. beam width and pulse limitations) will limit the ECDIS accuracy in navigation decisions. Other limitations to be considered during superimposition are possible excess of information from the integrated system to the navigator as well as masking of ECDIS information by radar clutter.

The radar image and the position from the position sensor should both be adjusted automatically for antenna offset from the conning position. It should be possible to adjust the displayed position of the ship manually so that the radar image matches the SENC display. The position adjust function shall be by quick and simple operator action and the adjusted offset should be clearly indicated, e.g. in range and bearing. The same indication required above, for a situation when ECDIS and added navigational information are not using a common reference system shall also be provided in this case. Furthermore it should be possible to remove the radar information by single operator action for fast 'uncluttering' of the chart presentation.

All information in this section also applies to the ECDIS back-up system.

3.8 Display mode and generation of the neighbouring area

First it should always be possible to display the SENC in a “north-up” orientation but other orientations are permitted. Human factors specialists point out that course-up orientation offers some safety advantages, and operational reports support this (IHO, 1996). ECDIS should again provide for true motion mode. Other modes are permitted. When true motion mode is in use, reset and generation of the neighbouring area should take place automatically at a distance from the border of the display determined by the mariner. It should also be possible manually to change the chart area and the position of own ship relative to the edge of the display. All the information in this section is applicable to the ECDIS back-up arrangement if an electronic device is used.
3.9 Colours and symbols

IHO recommended colours and symbols should be used to represent SENC information. Five colour tables are provided in the Presentation Library, all of which shall be available.

SENC information, when displayed at the scale specified in the ENC, should use specified size of symbols, figures and letters. ECDIS should allow the mariner to select whether own ship is displayed in true scale or as a symbol. It shall be possible to display the library version number on ECDIS. The Presentation Library includes an ECDIS chart 1 showing both simplified and full chart symbols and their explanations. The ECDIS shall provide linking by cursor interrogation between the symbols and the explanations. This is valid for both the IHO presentation library and one provided by a manufacturer. The presentation library contains colour differentiation test diagrams to enable the mariner to detect the stage at which the display can no longer be used to discriminate important features by colour.

3.10 Display requirements

ECDIS should be capable of displaying information for:

1. route planning and supplementary navigation tasks;
2. route monitoring.

The effective size of the chart presentation for route monitoring should be at least 270 mm by 270 mm. The display should be capable of complying with the colour and resolution recommendations of IHO. Five colour tables are provided in the Presentation Library, all of which shall be available. The method of presentation should ensure that the displayed information is clearly visible to more than one observer in the conditions of light normally experienced on the bridge of the ship by day and by night. The brightness and contrast controls shall have a provision to permit returning to the calibrated setting. The ECDIS manual shall carry a warning that use
of the brightness control may inhibit visibility of information at night. The text on the ECDIS shall be readable from 1 metre.

It shall be possible to call up all the information associated with an object by cursor enquiry on its symbol. This shall extend to areas (restricted area, depth area, etc.) and to “no symbol” areas (territorial seas, etc.) and meta areas (information about the area such as compilation scale, etc). By identifying any object (point, line or area) with a cursor on the chart display, the object description and all available attributes shall be displayed in text in common language terms. Text shall not appear automatically whenever the object it is associated with appears on the display and it shall always be possible to remove text independently off the object.

3.11 Priority Layers

ECDIS requires data layers to establish a priority of data displayed. The minimum of information categories required and their relative priority from the highest to lowest priority, are listed below (Bowditch, 1995):

- ECDIS Warnings and Messages.
- Hydrographic Office Data.
- Notice to Mariners Information.
- Hydrographic Office Cautions.
- Hydrographic Office Colour-Fill Area Data.
- Hydrographic Office On Demand Data.
- Radar Information.
- User’s Data.
- Manufacturer’s Data.
- User’s Colour-Fill Area data.
- Manufacturer’s Colour-Fill Area Data.
3.12 Route planning, monitoring and voyage recording

The basic premise is that it should be possible to carry out route planning and route monitoring in a simple reliable manner.

ECDIS should be designed following ergonomic principles for user-friendly operation. Experience with radar and ARPA shows that interface design differs between various manufacturers to such an extent that a mariner facing an unfamiliar model may be unable to operate it. Ideally, this should be avoided with ECDIS.

The ECDIS shall provide the mariner with the option of using either the traditional paper chart symbols or the new simplified symbols as best fits his purpose. The north arrow shall always be shown at the top left corner of the chart display, just clear of the scale bar or the latitude scale. Any windows containing text, diagrams, etc. superimposed on the route monitoring display shall be temporary (the window can be moved or removed from the display). It shall be possible to re-locate such a window on less important part of the display, such as on land, or behind the own ship symbol.

The largest scale data available in the SENC for the area given should always be used by the ECDIS for all alarms or indications of crossing the ship's safety contour and of entering a prohibited area, and for alarms and indications according to Appendix 5 of the IMO Performance Standard.

**Route planning**

It should be possible to carry out route planning including both straight and curved segments. Additionally it should be possible to adjust a planned route by, for example:

1. adding waypoints to a route;
2. deleting waypoints from a route;
3. changing the position of a waypoint;
4. changing the order of the waypoints in the route (including reversing the route).
It should be possible to plan an alternative route in addition to the selected route. The selected route should be clearly distinguishable from the other routes where available, otherwise alternate routes of the route net may disturb the mariner.

After a route is planned it is necessary to prove that the route fulfils given safety criteria. A route check is required because: the mariner responsible for navigation and route planning has to follow external criteria given by the charterer or the owner of the ship; and ECDIS thins the display of the chart at smaller scales and even loads scale depending chart data, the mariner may not see all dangers if he uses the wrong scale for route planning. It is hard to define criteria for route optimising but there is a set of minimum requirements that a route must fulfil for every vessel in every trade: a planned route should not cause the grounding of a vessel; a planned route should not cause the collision of the vessel with floating or fixed objects or obstructions; a planned route should take into account that depending on circumstances and navigational aids the vessel may deviate more or less from the route. Therefore, (i) an indication is required if the mariner plans a route across an own ship’s safety contour.

(ii) an indication is required if the mariner plans a route across the boundary of a prohibited area or of a geographical area for which special conditions exist (see Appendix 4).

(iii) it should be possible for the mariner to specify a limit of deviation from the planned route at which activation of an automatic off track alarm should occur.

The back-up should also be capable of performing the route planning functions, including:

.1 taking over of the route plan originally performed on the ECDIS;
.2 adjusting a planned route manually or by transfer from a route planning device.
**Route monitoring**

For route monitoring the selected route and own ship’s position should appear whenever the display covers that area.

For the ECDIS the redraw during route monitoring to follow the ship’s progress including scale changes due to change in the scale of the chart information, shall take less than 5 seconds. However, demands by the mariner that cannot be predicted by the ECDIS, such as draw at a different scale or in a different area may take more than 5 seconds. In the latter case:

- the mariner shall be informed;
- the display shall continue route monitoring until the new information is ready to draw within 5 seconds.

If there is delay in preparing (re-generating) data for display (e.g. due to a request for scale change or a look ahead to another area) the ECDIS shall inform the mariner. The previous display shall be maintained and updated, until the new display is ready for re-draw.

It should be possible to display a sea area that does not have the ship on the display (e.g. for look ahead, route planning), while route monitoring. If this is done on the display used for route monitoring, the automatic route monitoring functions (e.g. updating ship’s position, and providing alarms and indications) should be continuous and it should be possible to return to the route monitoring display covering own ship’s position immediately by single operator action.

ECDIS should give an alarm if the ship, within a specified time set by the mariner, is going to cross the safety contour. ECDIS should also give an alarm or indication, as selected by the mariner, if the ship, within a specified time set by the mariner, is going to cross the boundary of a prohibited area or of a geographical area for which special conditions exist (see Appendix 4). Another alarm should be given when the specified limit for deviation from the planned route is exceeded. It is significant to note that
most ship groundings occur after deviating from planned routes. A check against it
and its importance to the safety of the ship can not be over emphasised.

In order to safeguard against the risk of grounding, a position-monitoring
system shall enable detection of cross-track error in relation to the pre-
planned route and release an alarm at a time to danger of grounding which
allows for proper and effective action to be taken by the back-up officer


The ship’s position should be derived from a continuous positioning system of an
accuracy consistent with the requirements of safe navigation. Whenever possible, a
second independent positioning method of a different type should be provided;
ECDIS should be capable of identifying discrepancies between the two systems.
When multiple positioning systems are provided, the ECDIS shall have a means to
display the output from all available systems, identify which system is being used,
and provide a means to select the system that the operator wants to use.

In terms of accuracy, integrity, reliability and cost, there could be considerable merit
in using both the Differential Global Positioning System (DGPS) and Differential
Global Navigation Satellite System (DGLONASS) on one hand and Loran-C/Chayka
on the other. Loran-C/Chayka with real-time Additional Secondary Phase Factor
(ASF) corrections could be used as backup to GPS/GLONASS-DGPS/DGLONASS
when satellite signals are unavailable or blocked (e.g. land masses, man-made
structures, etc.). As a land-based radio navigation system, Loran-C/Chayka can also
serve as an integrity monitor for satellite-based GPS/GLONASS in terms of providing
a continuous quality factor evaluation of position accuracy. It is true that the world-
wide availability of Global Positioning System (GPS) and GLONASS makes them be
considered by many to be an important “enabling technology” necessary for the safe
operation of ECDIS. Both GPS and GLONASS have been accepted separately as
candidates for the Word-Wide Radionavigation System capable of providing 24
hours-a-day, world-wide coverage, available without interruption 365 days-a-year.
Without augmentation both systems’ accuracy is not suitable for navigation in harbour
entrances and approaches. However both Differential GPS and Differential
GLONASS will be able to satisfy the less than 20 meter (95% probability) accuracy requirement for the Harbour and Harbour Approach Navigation.

Based on results of a survey of mariners participating in the Canada-US Electronic Chart Pilot Project, Ship’s position is the most important function and display priority for ECDIS. The study also confirmed the importance of having DGPS when using ECDIS in confined waterways or during periods of limited visibility. Mariners with considerable ECDIS experience stated that when DGPS was not available, they were reluctant to rely on ECDIS.

ECDIS should provide an indication when the input from the position-fixing system is lost. ECDIS should also repeat, but only as an indication, any alarm or indication passed to it from a position-fixing system. This is to safeguard against a technology assisted incident caused by the mariner’s wrong sense of safety, thinking he had position information from the system when it was not so.

An alarm should be given by ECDIS if the ship, within a specified time or distance set by the mariner, is going to reach a critical point on the planned route. ECDIS shall permit the mariner to define critical points and the time or distance at which an alarm shall be given. The words “to reach a critical point” shall be considered passing abeam of the critical point on the planned route.

The positioning system and the SENC should be on the same geodetic datum. ECDIS should give an alarm if this is not the case. Both the ECDIS and GPS reference geodetic datum is WGS-84. It is possible with GPS/GLONASS receivers to select a geodetic datum.

It should be possible to display:

1. time-labels along ship’s track, manually on demand and automatically at intervals selected between 1 and 120 m; and
2. an adequate number of: points, free movable electronic bearing lines, variable and fixed-range markers and other symbols required for
navigation purposes and specified in Appendix 3

It should be possible to enter the geographical co-ordinates of any position and then display that position on demand. It should also be possible to select any point (features, symbol or position) on the display and to read its geographical co-ordinates on demand. Likewise, it should be possible to adjust the ship’s geographical position manually. This manual adjustment should be noted alpha-numerically on the screen, maintained until altered by the mariner, and automatically recorded.

The back-up should enable a take-over of the route monitoring originally performed by the ECDIS, and provide at least the following functions:

1. plotting own ship’s position automatically, or manually on a chart;
2. taking courses, distances and bearings from the chart;
3. displaying the planned route;
4. displaying time labels along ship’s track;
5. plotting an adequate number of points, bearing lines, range markers, etc., on the chart.

**Voyage recording**

ECDIS should store and be able to reproduce certain minimum elements required to reconstruct the navigation and verify the official database used during the previous 12 hours. The following data should be recorded at one-minute intervals:

1. to ensure a record of own ship’s past track: time, position, heading, and speed; and
2. to ensure a record of official data used: ENC source, edition, date, cell and update history.

In addition, ECDIS should record the complete track for entire voyage, with time marks at intervals not exceeding 4 hours.

It should not be possible to manipulate or change the recorded information and ECDIS should have the capability to preserve the record of the previous 12 hours and
of the voyage track. The back-up system should be able to keep a record of the ship’s actual track, including positions and corresponding times.

3.13 Accuracy

The accuracy of all calculations performed by ECDIS should be independent of the characteristics of the output device and should be consistent with the SENC accuracy. This is also true for back-up arrangements. The output device includes ECDIS display, stored memory, and/or printout.

Bearings and distance drawn on the display, or those measured between features already drawn on the display, should have an accuracy no less than that afforded by the resolution of the display. This equally applies to the ECDIS back-up system.

It is not enough to mention aspects of accuracy without considering the reasons for possible errors appearing in ECDIS equipment. Following are some of the potential causes of error on the ECDIS system, according to Ocean Voice (1997):

(i) The satellite navigational system plot on an electronic chart may be in error: in the case of the grounding of the Royal Majesty in 1995 there was an error of 17 miles in the GPS fix at the time of the accident. This sort of error can occur because of the failure of the GPS unit to identify satellites that are not giving good fixes.

(ii) The position fix may be calculated or transmitted in a different geographic datum to that of the displayed chart. This type of error has already caused a number of groundings to vessels using paper charts.

(iii) The navigator may attempt to navigate to a greater precision than the navigational satellite allows. The stated accuracy of non-differential GPS is better than 100m for 95% of the time.

(iv) The navigator may attempt to navigate to a greater precision than the survey accuracy of the chart. Many areas are surveyed far less accurately than modern navaids can operate.

(v) The displayed chart may not be to the required magnitude of scale for the intended navigational use.
Navigational calculations

The system shall be capable of performing at least the following calculations:

1. geographical co-ordinates to display co-ordinates and vice versa
2. transformation between local datum and WGS-84
3. true distance and azimuth between two geographical positions
4. geographic position from known position and distance/azimuth
5. projection calculations such as true distance, rhumb line, convergence and great circle

The accuracy of these calculations shall be such that there shall be no visible distortion on the display between the following:

1. rhumb line and chart data
2. great circle and chart data

3.14 Connections with other equipment

ECDIS should not degrade the performance of any equipment providing sensor inputs. Nor should the connection of optional equipment degrade the performance of ECDIS below IMO ECDIS Performance Standard.

ECDIS should be connected to systems providing continuous position-fixing, heading and speed information. If an electronic device is used as the ECDIS back-up, it should:

1. be connected to systems providing continuous position-fixing capability; and
2. not degrade the performance of any equipment providing sensor input.

With the advances in ECDIS-related technology, the traditional gyro-compass is becoming the weakest link in the ECDIS display. Its lagged and unrefined heading output is below the sophistication of the ECDIS device. Research is being conducted to elevate the accuracy of gyroscopic data to the level of the ECDIS system (http://www.tamug.tamu.edu/~mart/e-chart/index.htm, 1997).
3.15 Performance tests; malfunction alarms and indications

ECDIS should be provided with means for carrying out on-board tests of major functions either automatically or manually. In case of a failure, the test should display information to indicate which module is at fault. On board tests of major functions include the integrity of sensor input. If there is any detectable reason why the information presented to the operator is invalid, adequate and clear warnings shall be given to the operator. This clarification is consistent with IMO resolution XXX.

ECDIS being a ‘smart’ system which combines several different functions into one computerised system, it is possible to program it to sound alarms or display warnings when a certain parameter is exceeded or met. This assists the navigator to monitor navigation hazards. This also applies to back-up system if an electronic device is used. For alarms available on ECDIS see Appendix 5.

3.16 Power supply

The ECDIS must have the same reliability and availability as the paper chart as stated earlier. In that regard it should not be disturbed by the vessel’s power supply. It should be possible to operate ECDIS and all equipment necessary for its normal functioning when supplied by an emergency source of electrical power in accordance with the appropriate requirements of chapter II-1 of the 1974 SOLAS Convention.

Changing from one source of power supply to another, or any interruption of the supply for a period of up to 45 seconds, should not require the equipment to be re-initialised manually. However the equipment is not required to remain operational during this interruption of the power supply.

If an electronic device is used for the ECDIS back-up arrangements:

.1 the back-up power supply should be separate from the ECDIS; and
.2 conform to the requirements in this section
CHAPTER FOUR

4 ELECTRONIC CHART SYSTEM (ECS)

4.1 Background

Some years ago, at the beginning of the electronic chart evolution, a number of commercial organisations recognised that they could electronically copy official paper charts and market computer-based navigation systems and the data to feed them. These early projects were of limited applicability and thus of most interest to small craft users. However, the IHO and IMO recognised that some central direction of performance standards and equivalence issues was necessary to avoid uncontrolled proliferation. At that time, around 10 years ago, the technology for production and use of electronic charts (raster or vector) was relatively coarse, and the view formed then was that mariners' needs could only ever be achieved by adoption of vector-based electronic chart data as the standard. However, it was also recognised that there existed a large family of chart-like aids to navigation. These were termed Electronic Chart System (ECS).

Electronic Chart System (ECS) is a generic term for equipment which displays electronic charts but does not satisfy the SOLAS requirement to carry charts. ECS should therefore be used together with paper charts. The term ECS includes all systems using non-official data. These vary in complexity from the very simple to the extremely complex. It is because of this range of functionality that there is doubt over the practicability of producing ECS standards (Drinkwater and Wright, 1995). Electronic Chart System being manufactured and under development do not align with the IMO Performance Standards for ECDIS and are thus not legally equivalent to paper charts. However, they continue to be improperly compared to ECDIS.
4.2 The Categorisation of Electronic Chart System

Electronic Chart System have emerged in parallel with the development of ECDIS. As mentioned above, these vary from the simple to the extremely complex. Electronic Chart System currently available on the market can be divided into two main classes, being pseudo-ECDIS and Raster Chart Display Systems (RCDS).

Pseudo-ECDIS systems include those systems with the same functional capacity as ECDIS systems but do not meet the specifications of standard A.817(19) concerning chart information (use of vector data which do not comply with the recommendations of the International Hydrographic Organisation (IHO)).

Two cases can be envisaged under this category:

1. the chart information used is not certified by an official service;
2. the chart information used is certified by an official service but does not comply with IHO recommendations.

Use of uncertified data

In the absence of certification by an official body, it is unlikely that the data supplier can take responsibility for an accident due to an error in the data made available to the user, including among others such errors as:

1. error in the position or the height of a shoal correctly shown on official charts;
2. omission of a hazard shown on official charts; and
3. failure to take into account information disseminated to mariners subsequent to the latest edition of the paper chart which was the source of the numerical data.

The question here is one of responsibility for chart data. In other words who will be responsible in case of accident due to wrong or incomplete chart information. When uncertified data is used, we have a situation where no official authority (hydrographic office) is responsible, this makes systems based on such data unsafe to use for navigation. The use of such systems should be discouraged and equivalence to the paper chart refused by national maritime administrations.
Use of certified data which does not comply with IHO recommendations

Systems of this type are available or being developed. Examples are systems using NTX format data produced by the Canadian Hydrographic Office or the DNC (digital nautical chart) being produced by the Defence Mapping Agency of the United States Defence Department. It can be shown that these systems meet all the specifications of standard A.817(19), other than the format and structure of the chart information. However the non-mandatory nature of the IHO recommendations makes it no more permissible to oppose the approval of such systems by national administrations than to prohibit the use of official paper charts drawn up to standards which do not comply with IHO recommendations. In that case the use of such systems is likely to be confined to the territorial waters of the country in question, following that the production of the data necessary for navigation in the territorial waters of another State is subject, under the IHO, to the prior agreement of the competent authorities of the State. Only the use of standards which comply with IHO recommendations ensures the consistency in the production of nautical data by member States which is required to meet the needs of international navigation.

Raster systems (RCDS: raster chart display systems) and their hybrid version (superimposition of a raster image and a restricted band of vector information), by virtue of their construction cannot meet the specifications of standard A.817(19), notably the selection of visual data and navigational monitoring. The chart information necessary for such systems consist of raster data, in contrast to the vector data required for the functions described in standard A.817(19).

Use of uncertified data

When the data is not certified by an official body, the considerations concerning responsibility in the event of an accident, as briefly stated in section 4.2.1, tend to discourage the use of such systems and prevent them being substituted for official paper charts. It is therefore not desirable that such systems should be subject to an IMO guideline.
Use of certified data

Under consideration are RCDS systems using data certified by an official body, such as systems using the Admiralty Raster Chart Service (ARCS) of the British Hydrographic Office. Consideration of this issue is all the more pertinent since there is available now a large number of official raster display charts while little data is available in vector format. However, it should also be noted here that several manufacturers of systems for professional mariners are now offering virtually worldwide catalogues of (uncertified) vector format data.

4.3 Standardisation of electronic charting system

Japan generated the first opinion, at NAV 39 that it is necessary to develop the guidelines for the Electronic Chart System, because many ECS have been recently manufactured. The debate on this issue at NAV 39 and since has centred on arguments that any lesser standard than full ECDIS is undesirable, that ECS are subject to national, not international regulation, and that too much standardisation or guidance might inhibit technical innovation.

Following the request of the Sub-Committee in paragraph 6.36 of Nav 41/23, the Harmonisation Group on ECDIS (HGE) examined the need to develop ECS standards or guidelines, on consideration of various papers submitted to NAV 41. The HGE members voted unanimously against the need for performance standards for ECS but a majority supported the requirement for Guidelines for ECS. Representatives of USA and France did not support this view. Realising that the development of such guidelines would require a detailed study, the HGE as a start summarised the main parameters of the Guidelines as given below (HGE, 1996).

Warning on using non-equivalent electronic charts:

1. Shipowners and mariners are warned of the possible dangers of using “non equivalent electronic chart systems”, which use data not compatible with the WGS-84 data and do not comply with the performance standards for ECDIS.
2. Whilst the equipment concerned may be of assistance to navigation, if used without due care and full understanding of its limitations and possible errors or if poor chart data, not based on official or authorised chart databases supplied by hydrographic offices, are used in conjunction with an accurate position fixing system such as the GPS, the equipment could be a danger, rather than of assistance, to proper navigation.

Guidelines for ECS should describe a system with the following aims:

1. The primary functions of the Electronic Chart System (ECS) are to enhance the safety of navigation and to simplify some navigational routines connected with navigational graphics and calculations workload; and

2. ECS should be capable of displaying chart data and information related to the past, present and planned position of the ship and should present navigational data concerning ship’s routeing:

With the following considerations:

1. minimum guidelines to ensure safe navigation;
2. ensure use of reliable data for ECS;
3. encompass greatest possible range of applications; and
4. provide recommendations for minimum performance requirements.

Other related views

There exist three distinct views on the issue of ECS Standards/Guidelines:

Opposition to drawing up a guideline or a standard concerning electronic chart systems using non-official data or electronic chart systems which are not intended to have equivalence to paper charts, pursuant to rule 20 of chapter V of the SOLAS Convention. This view is held by France.

Countries like Australia do not wish to see a “second tier” ECDIS standard emerge, though they support the provision of suitable guidelines for non-ECDIS compliant systems. Their point is that although ECS are not intended to satisfy SOLAS V/20 and are not the legal equivalent of a paper chart, they are a useful aid to navigation, bringing together a real time presentation of ship’s position and electronic chart. In the
short term, ECS and Raster charts can bridge the gap between the availability of paper charts and a full, world-wide ECDIS capability which could be several years away. It will also enable users to become familiar with ECS concept and, in the light of experience gained from such systems, clarify their requirements for ECDIS as that higher capability develops.

An alternative view arises from the Radio Technical Commission for Maritime Services (RTCM) Special Committee NO. 109 whose recently issued draft standard for ECS in paper 8-94/SC 109-114, dated December 1993, recommends specific standards along the ECDIS line rather than general guidance for manufacturers and system developers (Australia, 1994).

4.4 Performance Standards for RCDS

A majority of the HGE members supported the proposal contained in NAV 42/7/18 (previously announced in NAV 41/INF.5) to recommend approval of performance standards for Raster Chart Display Systems (RCDS). Representatives from France, Germany, Norway and Russia expressed reservations. Canada supported in principle but expressed reservations (HGE, 1996).

4.4.1 Argument in support of setting standards

Regardless of economic factors relative to the availability of data, there are several arguments in favour of standardising RCDS systems using certified data:

- Although ECDIS was conceived initially as an equivalent to the paper chart, the performance standards describe equipment with much more functionality than the paper chart, including a facility for the navigator to display only those elements of chart data which he requires for his immediate needs.
- The contents of the up-to-date paper charts which satisfy SOLAS regulation V/20 can be provided and displayed electronically on board ships by Raster Chart Display Systems (RCDS).
The use of an RCDS system fed with certified data and linked to an electronic updating facility offers better assurance of maritime safety than the use of manually updated paper charts.

Thanks to the possibility of automatic interfacing with positioning systems and the superimposition of additional information from radar scanner, for example, the use of an RCDS system improves maritime safety, even though the maximum dimensions of the display on the screen are less than the normal dimensions of the paper chart.

The lack of standards or guidelines for RCDS systems encourage the proliferation of ECS systems of very variable quality. There is danger to life at sea and the marine environment which could arise from the use of incorrect and not-regularly-updated data.

Official raster charts (at least those produced by the United Kingdom Hydrographic Office (UKHO)) are generated from the digital files of material used in the printing process and are thus guaranteed to be as complete as the paper product since the quality control processes are fully integrated.

Lower cost and increasing computer power in electronic navigation systems allowed large-screen presentation of official raster data to a degree of fidelity not envisaged when first evaluating early ECS equipment.

Evolution of shipboard systems has enhanced the utility of raster-based ECS with vector overlays, permitting a wide range of navigation functions against the backdrop of the raster chart. Official raster charts which are at least as accurate and as fully complete as the paper versions from which they are derived, when used in RCDS-compliant bridge systems, many of which have been subject to extensive trials, can perform at least as well as the paper chart (Essenhigh, 1997).

The sum of these parallel developments has meant that, in the quality sector of ECS market, systems now exist which provide to all but the very specialised user levels of performance which match large elements of what will eventually become available when ECDIS has been developed. Such systems certainly give the mariner all of the functionality he currently obtains from his paper chart and, indeed, some go well beyond this basic level of utility (Essenhigh, 1997).
• It is in recognition of this fact that the UK and the Netherlands have proposed to the IMO that use of suitable equipment, now referred to as RCDS (Raster Chart Display Systems) and official raster chart data, such as that provided by ARCS, should be awarded paper chart equivalency. Such performance using official, fully correctable raster data like the UKHO’s ARCS is available now, ready for use and ready to be supported with automatic, error and effort-free updating services. Chart coverage already extends over many of the world’s major shipping routes and is growing (Essenhigh, 1997).

• The maintenance of a full worldwide vector Electronic Navigational Chart (ENC) database up-to-date for all dangers is so expensive that a world ENC will not happen soon, if ever. The UKHO is concentrating on digitising the major shipping routes first. They intend ARCS to fill this gap for the commercial market, both now and in the future (Dawson, 1997).

• The IMO has not designed ECDIS for the leisure market, and it may be prohibitively expensive for this sector. Users who have experience of ARCS may also choose to continue to use the service, especially if the IMO grant legal equivalence (Dawson, 1997).

4.4.2 The counter Argument

• The functions of an RCDS system, given the inherent nature of raster data, are inferior to those of an ECDIS system. In particular, it is impossible to provide automatic monitoring of maritime safety alarms and indicators (nearing the safe depth limit, for example).

• The ECDIS performance standards are minimum standards which were subject to a long period of study prior to their adoption by the IMO General Assembly, while the technology of RCDS raster systems was also available. The significantly improved performance in data storage and display screens does not of itself justify a premature review of the relevance of IMO resolution A.817(19). The adoption of performance standards allowing national administrations or users the choice of an RCDS (or hybrid) system or ECDIS system would be to reject those who participated in the long work of standardising ECDIS. Such a step would put a
brake on the efforts needed to ensure the earliest possible availability of the data needed by ECDIS systems, and services to distribute and update that data. Unless a clear priority is set out by international bodies, some hydrographic services may turn part of the resources needed for the more laborious development of ECDIS data to more immediately profitable raster products. There is risk that the possible short-term advantage, for maritime safety, of standardising RCDS (or hybrid) systems might delay access to a greater benefit expected from the introduction of ECDIS (France, 1996).

- Unlike the ECDIS standard, the work on RCDS standard is obviously being carried out in haste, without the thoroughness which was inherent in the development of ECDIS standard. It should be noted that there are no large scale international trials of raster charts and no study of their limitations, and this can adversely affect the level of safety at sea (The Russian Federation, 1997).

- The currently available experience of using vector charts (ECDIS) has proved them to hold a considerable promise and has shown their advantages in the solution of problems involved in the automation of navigation and ship handling, and for the elimination of human error. Admittedly, the adoption of RCDS as an equivalent of paper charts would be a step back in the navigation procedure as, should IMO agree that a raster chart display screen is equivalent to the displayed paper chart fragment, the use of raster charts would be analogous to using paper charts, i.e. to the old technology (The Russian Federation, 1997).

- Some raster chart technical limitations (no single geodetic datum, impossibility of promptly obtaining additional information on the navigation area ( WARNINGS ) and so on require a thorough study. As of today this would prevent the raster charts from being spoken of as paper chart equivalent. The raster charts are undoubtedly entitled to be used in ECS; however, it is only vector charts now produced in conformance with IHO’s S-57 standard which can be acknowledged as being equivalent to paper charts (The Russian Federation, 1997).
The United Kingdom and the Netherlands propose that the combination of authoritative raster charts and suitable equipment - referred to as a raster chart display system (RCDS) - should be accepted as being equivalent to the paper chart, and so satisfy the requirements of SOLAS V/20. The United Kingdom and the Netherlands believe that RCDS would occupy an important place between ECS, which is not equivalent to the paper chart, and ECDIS, which is much more. To ensure a consistent approach, the United Kingdom and the Netherlands have developed the draft RCDS performance standards. The standards include the following specifics:

(i) The effective size of the chart presentation for route monitoring should be at least 270 mm by 270 mm. This would exclude small portable - computer based systems.

(ii) The Raster Navigational Chart (RNC) in RCDS should be the latest edition of that originated by, or distributed on the authority of, a government authorised hydrographic office. This excludes the use of privately supplied data used in many such systems today.

(iii) Keep a record of the ship’s actual track, including position and time.

(iv) The equipment must provide at least the following monitor functions:

.1 Plot own ship’s position automatically or manually on a chart
.2 Take courses, distances and bearings from the chart
.3 Display a planned route
.4 Display time labels along ship’s track
.5 Plot adequate number of points, bearing lines, range markers, etc, on chart.

(v) Mandatory connection to a system providing continuous position-fixing capability.

Likewise, the use of raster data in RCDS will not conflict with the mandatory use of vector data of ECDIS. RCDS is modelled closely on the ECDIS performance standards in order to support further compatibility between RCDS equipment and ECDIS equipment.

There is need to prepare performance standards for RCDS in order to ensure the operational reliability of such equipment and that the information provided and
displayed electronically is equivalent to that of the up-to-date paper charts, and to avoid, as far as practicable, adverse interaction between RCDS and other shipborne navigational and communication equipment (United Kingdom and Netherlands, 1996).

4.4.4 Present Status

The IMO is currently debating the legal status of RCDS. In document NAV 42/7/18 the UK and the Netherlands proposed to adopt the recommendation on performance standards for raster chart display system (RCDS). Consideration of this proposal was continued by HGE 17 in February 1997. The main problem, which is under strong discussion, is RCDS equivalency to paper charts. RCDS were back on the agenda for consideration again in July 1997 at IMO and no decision was reached. It remains to be seen how long it will take for the draft standards to be able to command a sufficiently reasonable consensus at IMO for adoption, if ever.

France considers it inappropriate for the IMO to take steps to standardise raster chart display systems (RCDS) or hybrid systems using official data (France, 1996). Russia is equally opposed to any standardisation of RCDS.

4.5 Future Developments

In the future, the commercial mariner may gain much benefit from using a combination of official raster and official vector data. The use of combined official raster and commercial vector data is already possible, but not in place of paper chart. Some systems can display ARCS images, with commercial vector beneath, providing the automatic passage planning and alarm functions. Such systems have become known as ‘dual fuel’ systems. The drawback with these systems is the lack of adequate updates for the commercial data. An important notice to mariners correction, applied to the ARCS chart but not to the commercial vector chart, would not trigger the automatic alarm. This makes the system potentially unsafe to use. Dual fuel
systems, using a combination of official raster and vector data, are likely to provide the best navigational systems over the next ten years. ENC data is unlikely to be available for much of the world even at the end of this period.

In North America, the National Oceanographic Service (NOS) is developing a hybrid raster/vector digital chart product. The intention is to display a raster reproduction of a standard chart, but to link this to a vector database containing some vital navigational information. This idea has the advantage of saving time and money in vectorising the entire chart, and just concentrating on the most important features. It also means that the mariner can view the traditional chart image on the screen, therefore reducing training. An important drawback to the system is the lack of legal equivalence, because the system does not conform to the ECDIS performance standards (Dawson, 1997).
CHAPTER FIVE

5 POTENTIAL USE OF ECDIS WITH TRAFFIC CONTROL SYSTEMS AND FOR OTHER MARITIME APPLICATIONS.

The eventual employment of ECDIS will have a profound impact on all aspects of maritime navigation, piloting and safety. Environment and safety concerns in many parts of the world are leading to the development of vessel traffic management schemes, particularly in traffic choke points, and ECDIS is likely to become a key component of such systems (Essenhigh, 1995). ECDIS has a very wide range of applications and current developments in shipbuilding are making ECDIS an increasingly important and indispensable aid. The faster ships become, and the trend is clearly towards increased ship speed, the more important effective and reliable navigation aids are. In short the more important ECDIS is becoming (http://www.sevencs.com/7cs/aboutECDIS/ecdis-en.html, 1997). Like any other new technology there are both challenges and opportunities related to the use of ECDIS. Following is a short discussion of some of the applications of ECDIS and related technology.

5.1 Use of ECDIS within Vessel Traffic Services (VTS) coverage

5.1.1 VTS and some of its functions.

By definition VTS is any service implemented by a competent authority functioning to improve safety and efficiency of traffic and the protection of the environment. A VTS may range from the provision of simple information messages to an extensive management of traffic within a port or waterway. The service should have the capability to interact with the traffic and respond to traffic situations developing in the VTS area. It is required to ensure that the effects of vessel traffic services, routeing, aids to navigation, pilotage, etc. are fully integrated. In line with that, a VTS organisation is required to be equipped with communications facilities and, where appropriate to the tasks performed by the VTS, have surveillance radar and other
equipment. This obviously includes chart facilities and as such, ECDIS is for the better. SOLAS class ships participating in a VTS will be fitted with navigational and communications equipment in accordance with chapter IV and V of that convention as amended. Carriage of ECDIS could more effectively fulfil navigation chart requirements.

The core of a typical VTS system is the software for vessel traffic management in congested harbours, straits and their approaches. Systems provide digital target acquisition, tracking and prediction. Where appropriate display backgrounds are digitised representations of hydrographic charts. Navigation chart information and vessel data are simultaneously displayed on a computer screen using information from an electronic chart display and information database. The benefits of implementing a VTS are that it can enable the identification and monitoring of vessels, strategic planning of vessel movements and the provision of navigational information and assistance. It can also assist in the prevention of pollution and co-ordination of pollution response. As such more and more port authorities and search and rescue organisations are now implementing VTS to cater for environmental, efficiency and safety issues.

The functions of VTS include *inter alia*; data collection, data evaluation, information service, etc. Data collection may include: gathering data in the fairway and traffic situation by appropriate equipment, e.g. hydrological (tides, tidal range, currents) and meteorological (weather and ice conditions) sensors, radar, VHF direction finder, etc. ECDIS could be a powerful tool for data collection especially in terms of position and navigation safety information.

Data evaluation may include: monitoring the manoeuvres of ship for compliance with international, national and local requirements and regulations, monitoring the fairway situation (Hydrological and meteorological data, aids to navigation). Referring to the ECDIS functions, especially voyage monitoring and recording capabilities, it is clear that it can be a very profitable tool in this regard.
Information service may include: exchanging information with vessels on all relevant safety matters (notices to mariners, status of aids to navigation, meteorological and hydrological information, etc.); warning vessels about hindrances to navigation such as hampered vessels, concentration of fishing vessels, small craft, other vessels engaged in special operations and giving information on alternative routeing. The comprehensiveness of ECDIS chart information and updating plus voyage planning capabilities make it a very useful technical aid for the information service of VTS.

5.1.2 Some basic requirements for an efficient VTS

For efficient VTS performance, at least three events need to be accomplished: object identification, tracking or monitoring and promulgation of information.

a) Identification

Initial contact- identification of ship by a VTS centre is vital. This identification may be assisted by technical means such as shore-based radar or VHF direction finder. When a vessel requests navigational assistance or when such assistance is deemed necessary by a VTS centre, the VTS operator has to ensure positive identification and location of the vessel by reliable means and obtain other relevant information. Sending the correct instructions to the wrong ship does not enhance safety. When there is no automatic tracking after reception of the sailing plan and identification of the ship, position reports are necessary to update the movement data of a ship. Ships may be required to send position reports at prescribed positions. The functions of ECDIS as discussed in chapter three, make it indispensable for this application. Integrating VHF direction finder and an ECDIS and radar (ARPA) superimposition provides VTS with a better tool for identification of ships and other objects.

b) Monitoring

In any coverage area the efficiency of a VTS could be limited by inter alia, ability to define a vessel’s course and detect a course change in time to warn of imminent grounding. One of the main advantages of ECDIS is to be able to enable the mariner to know the ship real-time position and also to monitor the ship’s movement in relation to the surrounding surface and subsurface environment. When ECDIS with its
related technology and radar information are integrated the mariner acquires a monitoring tool for his ship covering the entire operation environment. All this information is vital for navigation decision making which increases safety and reduces the navigator's data evaluation time for faster and safe action. On the other hand, a VTS operator with access to the same amount of information will be better equipped, by understanding the shipping environment within the covered area for better control and efficiency. For example in approaches to a port, the use of transponders would be an added advantage for VTS authorities, who would be able to more easily identity vessels and track them on their equipment to and from the berth.

c) Promulgation of information
A VTS authority should ensure that the local traffic movement rules and regulations in force, the services offered and the area concerned are promulgated appropriately. The publications should include, where possible chartlets showing the area and sector boundaries, general investigational information about the area together with procedures, radio frequencies or channels, reporting lines and reporting points. Where the VTS is beyond the territorial sea, the limit of the territorial sea should be clearly indicated on the chartlets. In essence today, the guide for a particular VTS centre consists of a series of diagrams, based on charts but showing no soundings or other detailed navigational information. These diagrams show only the pictorial details which will be of interest to a ship which wishes or needs to communicate with the shore, or receive communication from the shore. For example, the diagrams show such details as radar coverage, required VHF frequencies, limit of pilotage, pilot station, VTS centre, and main routeing systems. Facing each diagram is a page of written information added to workstations. At present at the control centre of a modern VTS, radar pictures are presented on VTS high-resolution colour traffic display monitors. These monitors incorporate facilities for superimposition of converted data upon specially digitised high-accuracy electronic charts. There is no doubt that all of this information could be provided more comprehensively by convenient use of ECDIS, through what could be a VTS guide display covering the whole VTS world. Let us remember technology today allows workstation (in main
control centres) displays to be combined with electronic chart display and information system (ECDIS) data.

5.1.3 Effect of ECDIS-related technology on VTS

Rapid technological advances in satellite navigation and digital communications will lead to dramatic changes in the types of Vessel Traffic Service (VTS) that will be operated to benefit the efficiency and safety of marine commerce. An important component of the VTS of the future will be increased employment of ECDIS-related technology. Instead of relying primarily on land-based radar and voice communications, vessels will most likely have GPS/DGPS transponders that will communicate with one another and to a VTS centre. With a standard format and protocol (e.g., vessel ID, location, course, speed, and time), it will be possible for each vessel to display on the ECDIS the location and movement of other vessels. At the VTS centre, a digital Navigation Safety Broadcast Service ("silence VTS") will provide information back to ships regarding the location and movement of vessels within the VTS area of operations. This will be broadcast from the VTS centre and overlain on an ECDIS display using a standard format and protocol. Likewise, it is also expected that other navigation-related information such as ECDIS updating, automated notice to mariners, currents, water levels, and ice coverage could be provided in digital form via a Navigation Safety Broadcast (Alexander, 1997a).

5.2 Impact of ECDIS on manoeuvring in channels, anchorage areas and on port navigation

5.2.1 Provision of information to the mariner

Navigating in ports and manoeuvring in channels and anchorage areas is a special task and process which needs good knowledge, experience and alertness on the part of the mariner and as such it requires the ready availability of essential information. During this process many factors could affect the ship and its operation environment. To maintain safety, the mariner in those circumstances could be required to make
continuous (quick and correct) manoeuvring actions. This process as stated above, obviously requires a constant input of necessary data. Whenever navigating or manoeuvring in these circumstances a mariner has to put into consideration *inter alia* the following parameters which affect navigation and collision avoidance decision making:

- increased traffic
- limited sea room and/or water depth in relation to ship’s draft
- presence of dangers to navigation
- hydrological (tides, tidal ranges, currents, etc.) factors
- meteorological (wind, visibility, etc.) factors
- Coastal state or port requirements (e.g. anchorage berths, political/military activities, passing distances, prohibited areas, etc.)
- availability of Vessel Traffic Services (VTS)
- traffic rules and regulations (e.g. Traffic separation schemes, speed limits, etc.)
- ship handling aspects (e.g. manoeuvring characteristics, etc.)

As stated above the mariner requires the necessary information to enable him take the correct collision avoidance, navigation and ship control decisions. It should be noted that cases could arise where there is need to make a decision in a multiple danger situation within a limited time. A typical example being when a desired give way action could lead into a grounding situation.

ECDIS and its related technology could undoubtedly provide much of the information, needed for decision making, to the mariner. While the traffic information component could be obtained from the radar/ARPA input, the other relevant data besides chart information could be supplied by ECDIS from different sensors, such as depth sounder, positioning sensors, gyrocompass, rate of turn, autopilot etc. The greatest impact of ECDIS, in the case of manoeuvring in channels and anchorage areas, will thus come from its ability to provide instantaneous chart, position, course, speed, etc. information to the mariner which allows the mariner to monitor own ship’s position relative to its operating environment. This is enhanced by ECDIS’ capability of allowing the mariner to pre-plan voyage routeing and test the overall route for validity and hazards.
With the imminent advent of transponders, it will be possible for each vessel to display on ECDIS the location and movement of other vessels. In ECDIS obstacles (especially shallows) and own ship's free manoeuvring space are displayed. Through the superimposition of ECDIS and radar, the manoeuvring space available for the other ship is also indicated. This yields a better situation of the overall situation and gives the mariner a good chance to make better seamanlike manoeuvres or decisions for collision avoidance. All of this will in no doubt increase safety of shipping in port channels and anchorage areas by reducing incidents arising from lack of enough navigation and traffic information.

5.2.2 Identification of Navigation marks and objects

Proper identification of targets is a vital task performed by the mariner during a coastal passage. Wrong identification of targets could lead to a wrong fix with disastrous results (grounding etc.). The use of ECDIS primarily eliminates possibilities of such error. Collisions that occur through insufficient navigational information, e.g. by sailing in the wrong traffic lane, may be avoided. More to that it is easier to differentiate or even identify a radar target by means of the superimposed ECDIS chart, e.g.

- buoys can possibly be identified in clutter
- buoys and ships at anchor can be recognised and identified.

5.2.3 Navigation techniques

Without ECDIS, the navigator is continually plotting the ship position on relevant paper charts with data from other equipment and at intervals confirming them with visual bearings. It is evident that this stream of data is subject to the inescapably human process of acquiring, interpreting and plotting it to give timely helm instructions. For instance, if a navigator takes one minute to fix a position on the paper chart, a ship moving 15 knots has travelled 460 metres during that time; that is by the time the navigator looks up from the chart table, the fixed position is one
quarter-mile astern. That in no way guarantees safety, especially in channels and port approaches.

Keeping the right course is vital when sailing in channels and port areas due to marine safety considerations-arising from increased traffic and dangers to navigation plus other possible concerns. Early detection of cross track error is necessary in channels and port approaches. Mariners usually utilise pilotage techniques when navigating in channels, anchorage areas and port approaches, to ensure effective and safe navigation. The major reason for use of these techniques is to ensure that the ship keeps her track and does not go into danger areas. As discussed in this document, ECDIS enables the mariner to plan and monitor his voyage very conveniently. With ECDIS in use the ship is watched on the display following the planned and verified route, easily detecting any cross track error. This allows for timely heading adjustment to keep the required course and maintain safety. When ECDIS is in use the application of such tedious techniques as: limiting danger lines, transits, leading lines, clearing bearings and clearing ranges, parallel indexing etc. can be applied as appropriate to supplement use of ECDIS rather than as the primary means of track monitoring.

In channels course alteration points are normally chosen in consideration of easiness to establish their position and the turn monitoring. With ECDIS in operation on board, a navigator has more flexibility in the choice of alter course points, as these functions are more easily and conveniently carried out without much dependence on where the course alteration point is located.

5.2.4 Approaching anchorage areas and berthing

Approaches into, as well as departure from, anchorage areas must be planned, taking account of manoeuvring data, as well as possible current or tidal effect. A speed plan should also be drawn up. Alternative anchoring positions must be planned on the chart. The safe depth in the anchorage area must be verified and the anchorage position selected in relation to the other ships already anchored. These tasks can be
performed better with a radar/ECDIS superimposition. All necessary information will be provided, e.g. ships at anchor, soundings, nav-aids, land marks etc, by the system. Equipped with this data, the mariner will more effectively determine how to approach the anchorage and where to anchor.

Today tools like radar/ARPA, autopilot, Rate of Turn Indicator (ROT), doppler log and other berthing devices greatly help pilots when berthing ships. The pilot’s prime goal is to achieve correct positioning of the ship and safety. An integrated berthing system incorporating ECDIS will be a formidable tool for realising that goal. With ECDIS, he can predict and monitor the future dangers in relation to the ship’s position at anytime. ECDIS can allow a pilot to select or display (use) only the information he needs and thus concentrate on that vital data.

5.3 Other Maritime Applications

The convenience and efficiency gained by using integrated electronic charting systems are of benefit to owners of both small and large vessels. Even though ECDIS is a sophisticated navigation system developed for use by SOLAS class ships, it could give the same or more advantages and opportunities to the fishing and light marine industry.

5.3.1 Small craft safety

It was the leisure market which popularised the use of electronic charts in the late 1980s. Mariners were quick to see the advantages of automatic position plotting onto digital charts (Dawson, 1997). ECDIS does more than display charts on a screen. It also provides a unique opportunity to make trips safer and more efficient by allowing chart customisation with a variety of symbols such as targets, marks, events and waypoints. A mark can be a numbered symbol which identifies a specific spot on the ECDIS chart. Several marks may therefore be used in combination to delineate an entire zone such as a hazardous area that should be avoided. Events could identify a specific location of something unique like a wreck or for marking dangerous currents,
etc. Waypoints are specific locations, each with a stored set of co-ordinates, that are used to build a route. A planned route is obtained by connecting the waypoints. With ECDIS you can watch your craft in real time on the screen from way point to way point, easily detecting cross track error thus providing a chance to adjust the heading to stay on the intended course. All of these functions make for safer and more efficient navigating.

All waypoints, marks, and events can be stored for future use. As a result, trips can be repeated and wreck locations can be saved for future reference and identification. This function is definitely of much use for small craft especially in bad weather conditions (caught in a storm) and poor visibility. It can be said that ECDIS increases safety in the following but not conclusive ways:

a) *Staying on course.*
A craft which inadvertently goes off-course could face the risk of running into dangers to navigation. By charting the course ahead of time on ECDIS it is easy to stay on course. ECDIS can show where the craft is, where it has been and where it is going, in real-time, on the display.

b) *Exploring unfamiliar waters.*
If a craft is sailing through unfamiliar waters, the mariner needs sound navigational aids to ensure safety in reference to marked reefs, shallow areas and other dangers to navigation. In this regard ECDIS gives an exact graphic representation of the area and makes vital information available by simple operation. ECDIS also can allow the marking or identification of the dangers, e.g. shifting shoals and store them in the system. This way, the same safe route can be used again and again with ease and confidence.
c) Keeping up with changes in an area.

Sometimes nav-aids move (e.g. buoys) and shoals could shift. These changes and others are normally detailed in Notice To Mariners Updates. Updates to ECDIS are automatic, easy and timely. In this way ECDIS also ensures navigational correctness to the small craft mariner, especially those not keen on manual chart updating.

d) Reducing error.

When using traditional paper charts, there is plenty of room for human error. Coordinates obtained from GPS or position information from radar may be read incorrectly or plotted incorrectly on a paper chart. ECDIS drastically eliminates the chance of such error when navigating, through its automatic and continuous positioning.

5.3.2 Identification of fishing areas

A state of the art fishing captain makes use of a wide variety of electronic devices in navigating his vessel and operating his gear. He could have at his command an array of controls and displays, products of a growing technology which has transformed modern fishing into a complex technical operation.

Fish detection equipment could comprise echo sounders (ship's vertical fish-finder and net sounders) and multi-beam sonar. By using ECDIS with a depth sounder comes the benefit of seeing an accurate visual representation of the depth sounder signals, thus allowing noting of targets (fish sign) on the chart for easy reference. ECDIS could enable fishermen where needed, to get to certain bottom features or structures and recognise them and more to that stay on them.

A mark can be used to identify a fishing hole and several marks may be used in combination to delineate an entire zone such as restricted fishing area or fish-shoal. Events can be used to identify the specific location of fishing gear etc. Events symbols can be used for marking dangerous currents or marking drifts when trolling, etc. These marks and events could be stored for future use. Thus favourite fishing holes
and grounds can be efficiently revisited. In short ECDIS could enable fishermen more efficiently to locate new fishing grounds thus saving time and fuel for better productivity.

5.3.3 Policing or surveillance

There is need for coastal states to police their waters because of environmental, security, economic and other considerations. A maritime surveillance system utilises the same concepts and techniques extended into monitoring of coastal fishing areas, separation schemes, territorial waters and for use in counter smuggling operations. Today there are technical aids enabling frontier guard or coast guard units to monitor vast stretches of territorial waters and economic zones which can now be achieved through radar observations both from stationary coastal posts and from special ships. The principal purpose of this surveillance is to detect and track seaborne objects crossing state frontiers and to transmit the data to the command post. Increasingly there is also the need to monitor vessel traffic in the vicinity of places such as areas to be avoided and marine environmentally high risk areas.

The functions of ECDIS make it a useful tool in this regard. When ECDIS and its related technology is integrated into the surveillance system, a very efficient technical aid is obtained for that purpose. Craft will be detected and where possible identified, exact positions and movements known at any time. This knowledge will lead to better tracking, monitoring thus making surveillance more efficient.

5.3.4 Training tool

Simulation systems used for the basic and advanced training of navigators, pilots etc. are fitted with ECDIS (http://www.sevencs.com/7cs/aboutECDIS/ecdis-en.html, 1997)
6 CONCLUSIONS AND RECOMMENDATIONS.

6.1 Conclusions

In this dissertation the evolution of the electronic chart has been discussed, highlighting the development, benefits and limitations of the digital chart. Two chart categories, vector and raster were covered, identifying and comparing the advantages and disadvantages of these chart formats. The discussion in this document particularly focused on two chart systems: Electronic Chart Display and Information Systems (ECDIS) and Electronic Charting System (ECS) covering developments of each system. Different views on the use of these charting systems for navigation on SOLAS class ships have been investigated.

6.1.1 ECDIS is the choice

This study has established that the International Maritime Organisation (IMO), and all major maritime nations and organisations have recognised that ECDIS with adequate back-up system is equivalent to the paper chart and guarantees maritime safety. It has become known that efforts are underway in different places in the world for provision of a world-wide Electronic Navigational Chart (ENC) data.

However, it has also been understood that a few governments, especially those of the UK and the Netherlands are striving to obtain international recognition for the use of Admiralty Raster Chart Service (ARCS) for navigation on SOLAS class ships as an interim measure pending a world-wide ECDIS coverage. This is meeting with stiff resistance from other countries within IMO. It is the opinion of the author that this on-going intensive debate within IMO is not a healthy phenomenon in view of the urgent need for the development of a world-wide ECDIS database. While recognising the positive contribution ARCS could have on electronic chart navigation, the author is still sceptical about the recommendation to accept ARCS as being able to replace the
paper chart, even as an interim measure. There is a big risk and likelihood that this measure will in one way or another lead to the delaying or even inhibition of the advent of ECDIS’ world-wide coverage. If this measure is internationally accepted, some Maritime Safety Administrations and the shipping industry in general might deem to have acquired electronic charts, providing for enough of their electronic chart requirements even though not to the level of ECDIS. This could lead to the maritime industry negating on ECDIS. It should be remembered that ECDIS has been more researched upon and evaluated and it has been proved beyond doubt that its use will enhance safety of navigation more than any other charting system available today. Governments and organisations supporting the recognition of ARCS are assuring IMO of their commitment to ECDIS development. However, the author fears that this is not enough to completely eliminate the possibility of hindrance, or delay of a world-wide ECDIS coverage arising from the implementation of such a measure.

It is evident from information gathered during this study that ECDIS effectively presents accurate surface and subsurface chart data combined with real time position information, (e.g. DGPS, LORAN-C, etc.) on an electronic chart display. Additionally it incorporates information from other sensors (i.e. depth sounder, radar, gyrocompass, etc.) to provide a navigation information system. The position of the author as based on this study, is that ECDIS has great capabilities which makes it a powerful tool for use in any type of terrestrial navigation, Vessel Traffic Services (VTS) and control, surveillance and other similar applications.

Through this study it has become evident that the benefits to mariners of using electronic chart technology have became more widely known through a number of test-bed trials and demonstrations. This includes an initial series of North Sea trials, the Netherlands’ ECDIS Project, Norway’s SEATRANS Project, and the US Coast Guard’s US Test Bed ECDIS trials. The knowledge acquired notwithstanding, the author strongly cautions that practical navigators need to know and respect ECDIS limitations, if they wish to avoid a technology assisted incident.
6.1.2 Impact of ECDIS standards

It is critical to navigation safety and to the success of ECDIS, that ECDIS be done right from the start. There is no doubt that ECDIS standards will provide the users and regulators in the maritime community with the assurance they need: that they are actually improving safety. By the same token the existence of the standard(s) serve to legitimise ECDIS. The IMO endorsement will increase demand for ECDIS data and systems by SOLAS class shipowners and possibly induce government and private sector to work co-operatively to achieve a common goal.

In this study it has been illustrated that ECDIS is a technology that will benefit the entire international maritime community. In this regard the author stresses that there are many aspects of ECDIS implementation that require close international cooperation. Governments and organisations still need to more actively pursue co-operative ECDIS research, development, test and evaluation. As stated above all ECDIS standards discussed in this study will become the basis for ECDIS regulations in many countries. Following the completion of these standards and specifications each country requires a series of steps in order to implement ECDIS. Important among them are:

- The Type Approval involving Classification Societies which could be the basis for compliance.
- Type Approval by Maritime Safety Administrations leading to granting of equipment/system certificate.
- Maritime Safety Administrations giving ECDIS carriage requirements and mariner training/certification.
- Hydrographic offices ensuring availability of ENCs.
- Both hydrographic offices and Maritime Safety Administrations ensuring ENC Updating Service.
6.1.3 ECDIS potential: accident prevention

Considering its functions, it is apparent that ECDIS decreases the workload on the bridge including the portion of time spent on navigation tasks, allowing the mariner with more time for the higher risk task of collision avoidance. Mariners with a high workload will therefore find ECDIS to be the most effective method of navigation enhancing safety.

6.1.4 ECDIS potential: implementation of bridge technologies

Through this study it has been established that ECDIS has the potential of replacing paper charts and work around solutions with a far more precise and timely navigation tool. It is the view of the author that ECDIS provides the key to the implementation of many of the emerging bridge technologies: Integrated Bridge Systems, Dynamic Positioning Systems, Integrated Navigation Systems, etc. ECDIS provides the mariner with the necessary information to effectively make use of such technologies. ECDIS can also play a key role in the safe operation of high speed craft in a sea area with a growing volume of traffic, such as is the case in European waters.

The author agrees to conclude that:

In future, it will be possible to a much greater extent to actively support the ship's command personnel from the shore in the execution of their tasks, and to supplement the existing (and often inadequate), oral communication (radio) by introducing other information media. The future use of transponder information requires ECDIS as a visualising and integrating system on board, as on land (BAFEGIS, 1996)

The author expects that when ECDIS becomes a fully usable technology, the charting function of the information system could potentially advance to a more mature format through the transformation of electronic charts into something more than an electronic version of paper charts; a safety system which would clearly define operational space, navigational rules and procedural instructions, prompting the captain with an alarm if
there is a violation of rules. This form of ECDIS would change navigation forever by reducing it to a set of pre-defined procedures leaving little room for subjective judgement of the captain. By performing this function ECDIS would help increase the safety of the world's waterways and would as a result reduce the amount of pollution resulting from maritime disasters.

6.1.5 The obstacle: Completing a World-wide ECDIS Database

The author sees the main obstacle towards a world-wide ECDIS coverage as being the lack of a complete world-wide data in the form of a vectorized ECDIS database. Most government agencies are unable, for different reasons, to develop an ECDIS data base on their own to meet the anticipated demand. Despite the fact that there has been much testing with ECDIS over the past decade, the completion of a world database of ECDIS charts for SOLAS class ships has been delayed. The author is of the opinion that technology and resources used by commercial companies in development of ECS could complement the development drive of this database. Hydrographic offices, Maritime Safety Administrations and commercial companies could work in partnership to hasten the development of ECDIS and provision of a worldwide ENC data.

6.1.6 Chart surveys

Modern charts must be treated with great respect in consideration of the possibility of older survey techniques being utilised to acquire the charted data. It should be known that ECDIS provides the navigator with a tactical tool which incorporates a high accuracy positioning device. The navigator can zoom in on an ECDIS chart to a scale beyond the intended accuracy of the charted information. In doing so, the navigator is at risk for exceeding the operational parameters of the chart. As a result, the navigator can acquire a comfort index which could reduce his defences (the art of navigation) and cause a false sense of security and accuracy. This could be a significant risk for large commercial vessels that operate with an ECDIS which contains S-57 data derived from existing nautical chart surveys. ECDIS technology thus demands new
survey information if navigation safety is to be preserved for large commercial vessels. IMO standards for ECDIS do require an alarm or indicator condition when the navigator exceeds the scale of the source chart. However, this does not preclude operator error.

As stated above, it is desirable to obtain new hydrographic surveys to ensure the data is as up-to-date as the technology, however it is still not mandatory and it is not a requirement of the ECDIS Performance Standards to have the same reliability and availability of presentation as paper charts. If today a large ship can leave a certain port with the latest available paper chart, correctly updated, it can be assumed that it can still safely leave that port with the same information, properly encoded, in an ECDIS. The author hopes that the need for new chart surveys will not delay moves towards the development of a world-wide ENC data base.

6.1.7 Training in the use of ECDIS

Under SOLAS 1995, an owner and his ship’s master must ensure that seafarers are fully acquainted with equipment they will be using on a vessel. This applies to ECDIS as to any piece of equipment or system. Given the sophisticated level of an ECDIS, it is certain that a mariner must invest time and effort to master the device prior to his first navigational watch. It is important that ECDIS users are trained inter alia to be familiar with the following aspects of ECDIS:

- Ergonomic features and standardisation of control names, abbreviations, symbols, etc.
- Legality of systems: IMO compliant and officially type-approved by a relevant national authority.
- Performance standards and functions
- Accuracy and error: Trainees made aware of limitations and potential causes of error.
6.2 **Recommendations**

In view of the foregoing remarks and conclusions, the author of this paper strongly recommends that:

- IMO make carriage of ECDIS mandatory on all SOLAS class ships, once a worldwide ECDIS database is completed and endorsed by hydrographic offices. This will cause ECDIS to be used more successfully to increase the safety of the world's waterways.

- Government and private sectors work co-operatively to produce the ECDIS data to eliminate the main obstacle now impeding a swift use of the new IMO ECDIS standard on global basis.

- Governments (Maritime Safety Administrations) and/or Maritime Training Institutions ensure that fully and comprehensive instruction in the overall use of ECDIS is introduced into the training curriculum of navigators.

- IMO provide potential and interested ECDIS trainers with a Model Course to give a standard syllabus and guide in the instruction of ECDIS operators.

- IMO/Governments ensure that when IMO-compliant ECDIS is carried on a ship in lieu of paper charts, the installation shall be under the control of a person qualified in the operational use of the system.

- Classification societies/IMO/Governments formulate a standard ECDIS ergonomic criteria.

- IMO/Governments prepare and enforce ECDIS carriage requirements.
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'Vector or Raster?'. *Seamless Navigation* by NAVIONICS.

http://www.navionics.com/


‘What is ECDIS and what can it do?’.

APPENDIX 1

IMO CONVENTIONS AND RESOLUTION; IHO AND IEC PUBLICATIONS
CONCERNING ECDIS

1. Carriage Requirements
SOLAS I/5, V/20

2. Performance Standards
Res. A. 817(19) ‘Performance Standards for Electronic Chart Display and Information System (ECDIS)

3. Training
STCW A- II/1

S-52 Appendix 2 3rd Edition, August 1995
S-52 Appendix 3 2nd Edition, September 1993


6. IEC Publication 1174 “Electronic chart display and information system (ECDIS) - Operational and performance requirements, methods of testing and required test results”


APPENDIX 2

SENC INFORMATION AVAILABLE FOR DISPLAY DURING ROUTE PLANNING AND ROUTE MONITORING

1 Display base, permanently retained on the ECDIS display, consisting of:

.1 Coastline (high water);

.2 own ship’s safety contour, to be selected by the mariner;

.3 indication of isolated underwater dangers at depths of less than the safety contour which lie within the safe waters defined by the safety contour;

.4 indication of isolated dangers which lie within the safe water defined by the safety contour such as bridges, overhead wires, etc, including buoys and beacons, whether or not these are being used as aids to navigation;

.5 traffic routeing systems;

.6 scale, range, orientation and display mode;

.7 units of depth and height.

2 Standard display, to be displayed when the chart is first displayed by ECDIS, consisting of:

.1 display base

.2 drying line

.3 indication of fixed and floating aids to navigation

.4 boundaries of fairways, channels, etc.

.5 visual and radar conspicuous features

.6 prohibited and restricted areas

.7 chart scale boundaries

.8 indication of cautionary notes

3 All other information, displayed individually on demand, for example:

.1 spot soundings

.2 submarine cables and pipelines

.3 ferry routes

.4 details of all isolated dangers

.5 details of aids to navigation

.6 contents of cautionary notes

.7 ENC edition date

.8 geodetic datum

.9 magnetic variation

.10 graticule

.11 place names
APPENDIX 3

ECDIS NAVIGATIONAL ELEMENTS AND PARAMETERS

1 Own ship
   .1 Past track with time marks for primary track
   .2 Past track with time marks for secondary track

2 Vector for course and speed made good

3 Variable range marker and/or electronic bearing line

4 Cursor

5 Event
   .1 Dead reckoning position and time (DR)
   .2 Estimated position and time (EP)

6 Fix and time

7 Position line and time

8 Transferred position line and time
   .1 Predicted tidal stream or current vector with effective time and strength
      (in box)
   .2 Actual tidal stream or current vector with effective time and strength
      (in box)

9 Danger highlight

10 Clearing line

11 Planned course and speed to make good. Speed is shown in box

12 Waypoint

13 Distance to run

14 Planned position with date and time

15 Visual limits of lights arc to show rising/dipping range

16 Position and time of “wheelover”
APPENDIX 4

AREAS FOR WHICH SPECIAL CONDITIONS EXIST

The following are areas which ECDIS should detect and for which it should provide an alarm or indication under section 10.4.5 and 10.5.4 of the IMO Performance Standards:

- Traffic separation zone
- Traffic routeing scheme crossing of roundabout
- Traffic routeing scheme precautionary area
- Two-way traffic route
- Deepwater route
- Recommended traffic lane
- Inshore traffic zone
- Fairway
- Restricted area
- Caution area
- Offshore production area
- Areas to be avoided
- Military practice area
- Seaplane landing area
- Submarine transit lane
- Ice area
- Channel
- Fishing ground
- Fishing prohibited
- Pipeline area
- Cable area
- Anchorage area
- Anchorage prohibited
- Dumping ground
- Spoil ground
- Dredged area
- Cargo transhipment area
- Incineration area
- Specially protected areas
<table>
<thead>
<tr>
<th>Section</th>
<th>Requirements</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.3</td>
<td>Alarm or indication</td>
<td>Largest scale for alarm</td>
</tr>
<tr>
<td>10.4.6</td>
<td>Alarm</td>
<td>Exceeding off-track limits</td>
</tr>
<tr>
<td>10.5.3</td>
<td>Alarm</td>
<td>Crossing safety contour</td>
</tr>
<tr>
<td>10.5.4</td>
<td>Alarm or indication</td>
<td>Area with special conditions</td>
</tr>
<tr>
<td>10.5.5</td>
<td>Alarm</td>
<td>Deviation from route</td>
</tr>
<tr>
<td>10.5.8</td>
<td>Alarm</td>
<td>Approach to critical point</td>
</tr>
<tr>
<td>10.5.9</td>
<td>Alarm</td>
<td>Different geodetic datum</td>
</tr>
<tr>
<td>13.2</td>
<td>Alarm or indication</td>
<td>Malfunction of ECDIS</td>
</tr>
<tr>
<td>5.1</td>
<td>Indication</td>
<td>Information overscale</td>
</tr>
<tr>
<td>5.2</td>
<td>Indication</td>
<td>Larger scale ENC available</td>
</tr>
<tr>
<td>6.2</td>
<td>Indication</td>
<td>Different reference system</td>
</tr>
<tr>
<td>10.4.4</td>
<td>Indication</td>
<td>Route planning across safety contour</td>
</tr>
<tr>
<td>10.4.5</td>
<td>Indication</td>
<td>Route planning across specified area</td>
</tr>
<tr>
<td>10.5.7</td>
<td>Indication</td>
<td>Positioning system failure</td>
</tr>
<tr>
<td>13.1</td>
<td>Indication</td>
<td>System test failure</td>
</tr>
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</table>
GLOSSARY OF ELECTRONIC CHART-RELATED TERMS

*Aids to Navigation:* Visual, acoustical or radio device external to a craft designed to assist in the determination of safe course or of a vessel's position, or to warn of dangers and obstructions.

*Alarm:* An alarm or alarm system which announces by audible means, or audible and visual means, a condition requiring attention.

*All other information:* Term used in the Performance Standard for ECDIS to describe information not belonging to the Standard Display. Also sometimes called “on-demand information”.

*Attribute:* A defined characteristic of an entity (e.g. the category of a light, the sector limits, the light characteristics etc.).

*Automatic Chart Correction:* A correction applied to an ENC in a machine readable form so that no operator interaction is involved.

*Automatic Radar Plotting Aid (ARPA):* A system wherein radar targets are automatically acquired and tracked and collision situations computer assessed and warning given.

*Automatic Tracking Aid (ATA):* Simplified ARPA, limited to 10 target tracking, no auto acquisition, no trial manoeuvre, no past position.

*Chart (Nautical):* A chart specifically designed to meet the requirements of marine navigation, showing depths of water, nature of bottom, elevations, configuration and characteristics of coast, danger and aids to navigation. The carriage of up-to-date charts (plus certain other nautical publications) by vessels at sea is mandatory requirement of SOLAS regulation V20.

*Data:* A representation of facts, concepts or instructions in formalised manner suitable for communication, interpretation or processing.

*Data base:* An organised, integrated collection of data stored so as to be capable of using relevant application with the data being accessed by different logical paths. Theoretically it is application-independent but in reality it is rarely so.

*Display:* A visual presentation of data (e.g. a line of alphanumeric data, a window, or the entire screen).

*Display Base:* The level of SENC information which cannot be removed from the display, consisting of information which is required at all times in all geographic areas and all circumstances. It is not intended to be sufficient for safe navigation.
**Differential Global Positioning System (DGPS):** A form of GPS in which the reliability and accuracy are enhanced by broadcasting a time-varying correction message from a GPS monitoring receiver (Differential Mode) at a known position on shore. The corrections are fed automatically to the GPS receiver onboard and used to compute an improved position.

**Electronic Chart:** Very broad term to describe the data, the software, and the electronic system capable of displaying chart information. An electronic chart may or may not be equivalent to the paper chart required by SOLAS.

**Electronic Chart Display and Information System (ECDIS):** A navigation information system which can be accepted as complying with 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 monitoring, and if required display additional navigation-related information.

**Electronic Chart System (ECS):** Generic term for equipment which displays chart data but which is not intended to comply with the IMO performance standard for ECDIS. ECS is intended for use in conjunction with a paper chart.

**Electronic Navigational Chart (ENC):** The data base, standardised as to content, structure and format, issued for use with ECDIS on the authority of government authored hydrographic offices. The ENC contains all the chart information necessary for the 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.

**Electronic Plotting Aid:** A Third level electronic plotting aid intended for smallest ship particularly those not carrying a gyrocompass.

**Expert system:** A knowledge-based computer system which utilises artificial intelligence to do some of the inferential computation/decision making.

**Geographic Information System (GIS):** A system for storing, checking, integrating, manipulating, analysing and displaying data which is spatially referenced to the Earth. This is normally considered to involve a spatially referenced computer database and appropriate applications software.

**Global Positioning System (GPS):** A satellite navigation system intended to provide highly accurate position and velocity information in three dimensions and precise time and time interval on a global basis continuously (e.g. NAVSTAR GPS, GLONASS). By common usage, GPS has come to mean the U.S. NAVSTAR GPS System.

**Indicator:** Visual indication giving information about the condition of a system or equipment.
Integrated Navigation Systems (INS): These are Vessel control stations that integrate and (partially) automate navigation functions in a single location, allowing a small number of operators to perform all tasks necessary for safe navigation. INS generally include an electronic chart display.

International Electrotechnical Commission (IEC): An international organisation which produces world standards for electrical and electronic engineering with the objective of facilitating international trade.

International Hydrographic Organisation (IHO): Co-ordinates the activities of national hydrographic offices; promotes standards and provides advice to developing countries in the field of hydrographic surveying and production of nautical charts and publications.

International Maritime Organisation (IMO): Formerly called IMCO, the IMO is the specialised agency of the United Nations responsible for maritime safety and efficiency of navigation.

Layer: A group of related information displayed as a whole.

Loran: A Long Range Aid to Navigation. A master and slave stations transmit synchronised signals which can be received by a special receiver. Since radio signals travel at a known speed, the difference in time in which the signal arrive at the receiver can be converted into distance. Two pairs of stations can fix a position.

Marina: A yacht harbour which usually provides fuel, fresh water and other facilities besides moorings, for yachts.

Navigational aid: Any instrument, device, chart, method, etc., used onboard intended to assist in the navigation of a craft.

Notice to mariners: A periodical or casual notice issued by hydrographic offices, or other competent authorities, regarding changes in aids to navigation, dangers to navigation, important new soundings, and, in general, all such information as affects nautical charts, sailing directions, light lists and other nautical publications.

Object: A digital representation of all or part of an entity by its characteristics (attributes), its geometry, and (optionally) its relationships to other features (e.g. the digital description of light sector specifying, amongst others, sector limits, the colour of the light, the visibility range, etc., and a link to a light tower, if any).

Performance standard: Standards developed under the authority of IMO to describe the minimum performance requirements for navigational devices and other fittings required by the SOLAS convention.

Pixel: Contraction for "picture element". The smallest element resolvable by electronic raster devices such as scanner, display, and plotter.
**Raster Data Presentation**: Method of presenting all, or part, of a chart digitally by matrix-like scheme of pixels or gridpoints.

**Standard display**: The SENC information that should be shown when a chart is first displayed on the ECDIS and depending upon the needs of the mariner, the level of information it provides for route planning or route monitoring may be modified by the mariner.

**Sequence number of update set or Update set number**: Digital equivalent to the Notice to Mariners number.

**System Electronic Navigational Chart (SENC)**: A data base 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 data base that is actually accessed by ECDIS for the display generation and other navigational functions and is equivalent to an up-to-date paper chart. The SENC may also contain information from other sources.

**Update**: Same as Automatic Chart Correction.

**Update set**: A digital equivalent of Notice to Mariners.

**Vector**: Direct connection between two points, either given as two sets of co-ordinates (points), or by direction and distance from given set of co-ordinates, or a point in a vector space defined by one set of co-ordinates relative to the origin of co-ordinate system.

**Vector Chart**: A graphic representation of a paper chart, produced by identifying, classifying and storing the objects relevant to navigation in a digital structure (structured encoding).

**Vector Data Presentation**: Method of presenting individual chart features digitally by points, lines and polygons given through their co-ordinates and appropriate code(s).

**Vessel Traffic Services**: A service implemented by a competent authority functioning to improve safety and efficiency of traffic and protection of the environment

**World Geodetic System (WGS)**: A global geodetic reference system developed by the USA for satellite position fixing and recommended by the IHO for hydrographic and cartographic use.

**Zoom**: A method of enlarging graphics displayed on a graphical display, usually a function provided by the hardware of the screen. Either a selected window may be enlarged to cover the entire screen or repeatedly pressing a button will cause stepwise or continuous enlargement of the screen contents keeping the graphics centred at the screen’s centre.
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