EVALUATION OF THE CARIS HYDROGRAPHIC PRODUCTION DATABASE IN THE PRODUCTION OF PAPER CHARTS, ENC, AND AML

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PREFACE

This technical report is an unedited reproduction of a report submitted in partial fulfillment of the requirements for the degree of Master of Engineering in the Department of Geodesy and Geomatics Engineering, August 2004. The research was co-supervised by Dr. David Wells and Dr. John Hughes Clarke, and support was provided by the Instituto Hidrografico and the Direccao do Servico de Formacao, Portugal.

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To my wife Laura and son Guilherme.

ABSTRACT

CARIS Hydrographic Production Database (HPD) is a representative example of a new generation of software systems designed for the production of nautical cartographic products. Conceptually, it is based on a system of applications implemented over a Spatial Database and Management System (SDBMS), where each feature just needs to be stored once, and using the single data set is able to produce the range of cartographic products created in a typical Hydrographic Office (HO). The characteristics of CARIS HPD have created great interest in several HOs, including the Portuguese, related to the possibility of significantly increasing the efficiency of its cartographic production. However, as CARIS HPD is a new product, with several functionalities that are still in development, it needs to be evaluated as to whether it can really meet the general requirements of a HO. Those requirements include cartographic data management, data updating and the production of paper charts, Electronic Navigational Charts (ENCs) and Additional Military Layers (AML).

To execute such an evaluation, the general requirements have been identified. A sample database was created and populated with data from three Portuguese ENCs cells. With these data an ENC and a paper chart were produced. Additionally the production of AML products was attempted. All the processes implicated in the data loading, management, preparation and the production of ENCs, paper chart and AML products were analyzed.

During the evaluation sixty two requirements were identified, CARIS HPD being fully compliant with forty of them. In addition forty-six issues were identified and thirty seven recommendations were produced. In conclusion, CARIS HPD is a system capable of positively answering the HOs’ expectations, especially in data storage, management and preparation, and in the production of ENC products. Three issues do not allow the production of a paper chart completely compliant with the International Hydrographic Organization (IHO) specifications, but due to the simplicity of those issues, the system should be compliant in the very near future.

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I would also like to thank CARIS (Universal Systems Ltd.) for providing the software, the necessary training to develop this project, support in understanding the HPD issues and the important comments and suggestions provided.

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Most importantly, I thank my wife for convincing me to undertake this unforgettable Canadian experience, accompanying me and supporting me at all moments, and to my son for all his support, companionship, love and understanding.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF ABBREVIATIONS

AML	Additional Military Layers.
C^4I^2	Command, Control, Communications, Computers, Information and Interoperability.
CACS	Computer Assisted Cartographic Systems.
CHRIS	Committee on Hydrographic Requirements for Information Systems.
CHS	Canadian Hydrographic Service.
DBA	Database Administrator.
DDSNCP	Database Driven Systems for Nautical Cartographic Production.
DIGEST	Digital Geographic Information Exchange Standard.
DNC	Digital Nautical Charts.
ECDIS	Electronic Chart Display and Information System.
ECS	Electronic Chart Systems.
ENC	Electronic Navigational Chart.
HD	Hard Disk.
HO	Hydrographic Office.
HPD	Hydrographic Production Database.
IEC	International Electrotechnical Commission.
IHO	International Hydrographic Organization.
IHO INT 1	Symbols and Abbreviations Used on Portuguese Nautical Charts.
IHO INT 2	Chart Specifications of the IHO - Borders, Graduation, Grids and Linear Scales.
IHO INT 3	Chart Specifications of the IHO - Use of Symbols and Abbreviations.

IHO M-4	Regulations of the IHO for International (Int) Charts and Chart Specifications of the IHO.
IHO S-44	IHO Standards for Hydrographic Surveys.
IHO S-52	Specifications for Chart Content and Display Aspects of ECDIS.
IHO S-57	IHO Transfer Standard for Digital Hydrographic Data.
IHPT	Portuguese Hydrographic Institute.
IMO	International Maritime Organization.
ISO	International Organization for Standards.
MSC	Maritime Safety Committee of the IMO.
NATO	North Atlantic Treaty Organization.
RCDS	Raster Chart Display System.
RDBMS	Relational Database and Management Systems.
RNC	Raster Nautical Charts.
SDBMS	Spatial Database and Management System.
SENC	System Electronic Navigational Chart.
SOLAS	International Convention for the Safety of Life at Sea.
STANAG	NATO Standardization Agreement.
TSMAD WG	Transfer Standard S-57 Maintenance and Application Development Working Group.
UKHO	United Kingdom Hydrographic Office.
VPF	Vector Product Format.
WECDIS	Warship Electronic Chart Display and Information System.

CHAPTER 1
INTRODUCTION

In the last two decades, several important evolutions have occurred in nautical cartography. The most important have been the development of new products, of which ENCs should be emphasized; the implementation of several international standards; and the evolution in the cartographic production processes with the implementation of Computer Assisted Cartographic Systems (CACS) to support cartographic production.

The appearance of ENCs have increased the responsibilities of a typical HO in terms of cartographic product production, compelling the allocation of important resources to produce them, while maintaining paper chart production at the same time. For some HOs from countries belonging to the North Atlantic Treaty Organization (NATO), like the Portuguese Hydrographic Institute (IHPT), the development of Additional Military Layers products will probably create additional responsibilities, and consequently the need to allocate some more precious resources.

Recently, a new generation of software systems have appeared on the market, with the objective of answering the HOs' requests in terms of producing all these products with an economy of human and technological resources. Those systems, generalized and entitled in this report as Database Driven Systems for Nautical Cartographic Production (DDSNCP), consist of a system of specific applications which implement the system-explicit functionalities, connected to a SDBMS that manages all the data and provides some of the system functionalities.

CARIS HPD is a representative example of this new generation of products, where each representation of a real world object just needs to be stored once, and one system using only one data set can produce the range of general HO cartographic products, simplifying significantly the production and the updating processes. CARIS HPD, however, is a new product, with some functionalities that are still in development. Thus, it needs to be evaluated to see whether this system can really meet the general requirements of a common HO in cartographic data management, updating and in the mentioned products production.

1.1 The Problem

The Database Driven Systems for Nautical Cartographic Production, due to their concept and characteristics, promise to improve the efficiency of cartographic production processes, with the saving of important resources.

As one part of the CARIS Hydrographic Database Solution, a database system capable of managing the full range of an HO's hydrographic data, CARIS HPD is related to the production of cartographic products with the processed data, ready to be used in cartographic applications. The main objective of this report is the evaluation of CARIS HPD capabilities and limitations, to satisfy the cartographic production requirements of a typical NATO-allied HO, such as the Portuguese Hydrographic

Institute, in the cartographic data storage and management, and in the production of paper charts, ENC and AML products.

1.2 Report Outline

Chapter 2 provides a brief description of the DDSNCP concept, then it states the requirements that a typical NATO-allied HO should have from a DDSNCP.

Chapter 3 describes the methodology used to evaluate CARIS HPD. This Chapter starts by providing an overview of CARIS HPD. In the second section the contribution of this system in an HO cartographic organization such as the Portuguese one is briefly described. The third section describes the hardware and software system used to perform the evaluation, including the data used to populate the database. In Section 3.4 are mentioned the products produced during the evaluation of CARIS HPD.

Chapter 4 evaluates CARIS HPD compliance with the requirements compiled in Chapter 2.

Chapter 5 presents and discusses some issues found during the practical products production with CARIS HPD. Forty-five comments and issues have been considered important and generated thirty six recommendations that are stated in Sections 5.1 to 5.5. Section 5.6 contains a suggested efficient backup process.

Chapter 6, the final chapter, presents the conclusions, the contributions of this report and the most important recommendations.

After the main body, this report contains four appendices. The first three provide additional information about some of the products and systems mentioned in the main body.

Appendix I gives an introduction to electronic charts and the two basic formats vector and raster. The IHO S-57 exchange standard, due to its importance to ENC and AML products, is analyzed in detail. The requirements to be an ENC are stated and a System Electronic Navigational Chart (SENC) is defined. In this appendix also, the Electronic Chart Display and Information System (ECDIS) is analyzed, including related specifications, advantages and problems in its acceptance.

Appendix II is about Additional Military Layers. The AML concept is analyzed and explained, and the Warship Electronic Chart Display and Information System (WECDIS) is introduced and its capabilities described. The scope and the specific objective of each AML product is defined, and finally an overview of the AML product specifications and the implementation in the S-57 format is given.

Appendix III defines the advantages of using a DBMS to store and manage the data, and why the SDBMS are different from the Relational Database and Management Systems (RDBMS). Since Oracle Spatial is the SDBMS used by CARIS HPD, it is described in this appendix.

Appendix IV contains a summary of the elaborated recommendations with priority assigned by the author to each one, and feedback from the CARIS company in terms of the time estimated for their respective implementations.

CHAPTER 2

HO REQUIREMENTS FROM A DATABASE DRIVEN SYSTEM FOR NAUTICAL CARTOGRAPHIC PRODUCTION

This chapter begins with a brief description of the Database Driven Systems for Nautical Cartographic Production concept. Section 2.2 states the requirements that a typical NATO-allied HO would expect to be satisfied by a Database Driven Systems for Nautical Cartographic Production, in cartographic data storage and management, and in the production of paper charts, ENC and AML products.

CARIS HPD software, which will be described in the next chapter, is a representative example of this new generation of products characterized by a system of applications implemented over a SDBMS. Some other products that may be considered Database Driven Systems for Nautical Cartographic Production are:

- The CPS^{NG} Hydro from T-Kartor;
- The Production Line Tool Set for Nautical Charting from ESRI;
- And, dKart Office from dKart, which includes a database, but has a different data storage concept. It does not store all the source data in the same database[1].

[1] The concept used from dKart is more product-oriented, just the data common to more than one product is in the FODB (Feature Objects Database), the data belonging to just one product is stored within the product. Also they do not provide a multi-user environment, so just one user can work in one product at one time.

2.1 DDSNCP Concept

A DDSNCP consists of a system of specific applications connected to a Spatial Database and Management System (SDBMS). The specific applications connect to the database and implement the system-explicit functionalities. The SDBMS manages all the data, and some of its inherent functionalities are used by the specific applications, avoiding the costs associated with its development and implementation. Figure 2.1 illustrates the DDSNCP concept.

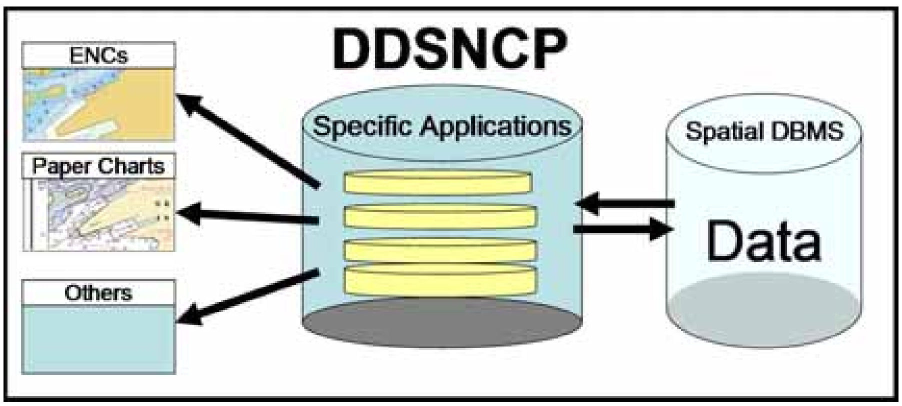

Figure 2.1 - General schema of the Database Driven Systems for Nautical Cartographic Production concept.

Some of the most important advantages of this concept that simplifies the data management significantly, the products production and the updating processes, are:

- Each real world object just needs to be stored once in the database;
- One system, using only one data set, can produce all the range of cartographic products in the incumbencies of a typical HO;

- A multi-user environment is provided allowing different users to browse, update the data within the database, and create products at the same time, with functionalities to avoid the generation of data inconsistencies;
- A seamless data coverage provides the flexibility to allow the easy creation of products with different areas.

In some of the DDSNCPs, the flexibility of the concept allows or is planned to allow, in addition to ENC and Paper Charts production, the production of other cartographic products such as Digital Nautical Charts (DNCs) and non-cartographic products such as the AML products.

2.2 HO Requirements from a DDSNCP

The DDSNCP characteristics have created high expectations in several HOs, including the Portuguese HO, related to the possibility of significantly increasing the efficiency of its cartographic production procedures.

In the case of the DDSNCP, as in the case of any other system, the requirements identification and compilation should be the first step, prior to the decision to acquire a system. Before an HO decides to buy and centralize its cartographic production with a DDSNCP, it should first define what the requirements from such a system are. Then all the comparable systems in the market should be analyzed, a major aspect being the capability to meet these requirements.

The following requirements are an attempt to define some of the general requirements that an HO, like the Portuguese one, should have from a system to store and manage the cartographic data and produce ENCs, paper charts and S-57 AML products, based on a system of applications implemented over a SDBMS.

Most of the requirements described in the next sub-sections were defined using more than one source of information for each, so unless otherwise indicated all information in this section came from: the author's experience and knowledge; the collaboration of the Portuguese Hydrographic Office; Logica [2002]; CARIS [2003c]; CARIS [2004a]; and, CARIS [2004b].

Some abbreviations of IHO specifications are mentioned often in this report. The complete descriptions are in the references corresponding to the following:

- IHO S-57 - "IHO Transfer Standard for Digital Hydrographic Data" [IHO, 2000];
- IHO S-52 - "Specifications for Chart Content and Display Aspects of ECDIS" [IHO, 1996];
- IHO M-4 - "Regulations of the IHO for International (Int) Charts and Chart Specifications of the IHO – M 4" [IHO, 2002];
- IHO INT 1 - "Symbols and Abbreviations Used on Portuguese Nautical Charts" [IH, 2003];
- IHO INT 2 - "Chart Specifications of the IHO - Borders, Graduation, Grids and Linear Scales" [IHO, 1990];

- IHO INT 3 - “Chart Specifications of the IHO - Use of Symbols and Abbreviations” [IHO, 1992];
- IHO S-44 - “IHO Standards for Hydrographic Surveys” [IHO, 1998].

2.2.1 General Requirements

The general requirements identified are the following:

A.1 - The system should be capable of loading data in IHO S-57 version 3.1 formats[2].

A.2 - The system should be capable of providing a multi-user environment, with multiple users accessing the database simultaneously, whilst avoiding data inconsistencies that may be caused by multiple users updating the same data at the same time.

A.3 - The system should have functionalities to record the source or sources of data from which an object comes, allowing the retrieval of all objects originated from a specific source.

A.4 - The system should have functionalities to allow one object to be stored just once in the database. This requirement implies that a feature object may be associated with more than one spatial objects, because the system should allow its representation in more than one usage (i.e. scale band), without the need of

[2] The data in the database follows the IHO S-57 standard. It could have more object classes and more attributes (e.g. user defined) but at least should have the S-57 ones, so just data complying with the S-57 format could be considered in a load requirement.

creating another feature object, just relating the feature object with one or more spatial objects. Each of the related spatial objects will be the spatial representation of the object and should be assigned to one or more usages, depending on the different levels of cartographic generalization required on different usages.

A.5 - The system should provide tools to allow the identification of duplicated objects in the database, which could be activated during the load procedure or on user demand. These tools shall be able to detect duplicates, not only within a usage but also between different usages, and be capable of removing them, and assigning the different spatial objects as different representations of the same object. This may require a decision from the user in doubtful cases (e.g. objects of same class in the same position but with different attribute values, objects of the same class almost in the same position, etc.).

A.6 - The system should be capable of storing and displaying: geographic positions in degrees and minutes, and degrees, minutes and seconds, and converting between the two forms; distances in nautical miles, kilometres or metres; and, depths in metres, feet or fathoms.

A.7 - The system should have capabilities to store comments associated with the objects, to allow the users to record and associate related observations to complement some aspects of the data. The capabilities should be also available during the data preparation and the product’s production. These comments will not be part of the products and may be deleted when they are not needed any more.

A.8 - The system should be capable of storing all S-57 Feature Objects (i.e. Meta, Cartographic, Geo, and Collection) and all their respective attributes and attribute values.

A.9 - The system should have tools to allow users to create new object classes and attributes, and associate user-defined or S-57 attributes to the user-defined and S-57 objects.

A.10 - The system should have tools to allow users to create, modify and delete the symbols in the symbol presentation libraries.

A.11 - The system should have tools to allow users to associate the new objects created by the user with the existing symbols (i.e. IHO S-52 and INT 1) or the ones created by the user.

2.2.2 Workflow Management Requirements

The identified requirements related with the data, production and system security[3] are the following:

B.1 - The system should have administration tools to create and delete system users with the respective passwords, allowing the assignment of privileges or limitations to at least: query the database; create, change and/or view the data in the database;

[3] As is mentioned in section 2.2.5, any requirement related with the backup of the data or the system was not included, because the author proposes the implementation of a backup process described in Section 5.6 which is independent of the system.

create the products; verify objects within the database and load data in the database.

B.2 - Access to the system should be limited to the administrator and authorized users, which should have access only to the respective assigned privileges. Control of the access should be done by a robust process based on defined passwords which stops unauthorized users accessing either the data within the database, or the system functionalities.

B.3 - The system should have capabilities to implement a verification system on data creation or modification by a designated supervisor. Only objects verified by a user with a supervisor role will be allowed in the production processes, and consequently included in products created by the system.

B.4 - After a verified object has been modified, the system should have the capability to automatically turn its verification status to unverified.

B.5 - The system should provide tools to allow the quick selection and identification of the objects waiting for verification.

B.6 - The system should provide tools to record and report the modifications generated by each user in the database with the identification of the respective user and the date and time.

B.7 - The system should be capable of storing different versions of the data (i.e. when either a feature or a spatial object is updated, instead of deleting the old version, maintain it stored in the database but with a version attribute), providing the capability to restore one of the old versions as the current one.

B.8 - The process to delete objects from the database (or remove them from the actual version associating a different version) should pass a verification step, before which it should be possible for users to undelete all or a specific object marked for deletion.

2.2.3 Data Editing Requirements

The identified requirements related with the editing capabilities, are:

C.1 - The system should provide tools to allow users to visualize the data stored in the database.

C.2 - The system should provide functionalities to query an object's attributes and stored information by its selection with the mouse.

C.3 - The system should provide tools to allow the authorized users to create, delete or modify the feature and spatial objects stored in the database, including the respective attribute values, shape and location.

C.4 - The system should provide capabilities to allow editing, creation, deletion and modification of the individual nodes constituting a spatial object.

C.5 - The system should provide functionalities to allow editing of different parts of a large spatial object by multiple users at the same time (e.g. the coastline which could have the entire extension of a country's coastline or a bathymetric contour which may be in the entire area of a dataset).

C.6 - The system should provide capabilities to store the spatial objects associated within a given usage (scale band), allowing the authorized users to modify the range of the scale band associated with each usage.

C.7 - The system should be able to report the present editor of an object in the database to the other users.

C.8 - The data that are locked when a user edits an object should remain visible to the other users.

C.9 - The system should be able to display the data in the database simultaneously with geo-referenced data from other common vector and raster formats. This is not only to allow the visual checking of the differences among them, but also to allow the creation of new objects or the modification of the objects into the database from the displayed data. The possibility of enabling the user to select different transparency levels to each layer would be a significant advantage.

C.10 - The system should provide functionalities to allow the establishment of the IHO S-57 relationships among different objects in the database, such as the master-slave and collection relationships (i.e. aggregation and association).

C.11 - The system should provide functionalities to allow the selection and editing of relationships (i.e. master-slave and collection) among different objects in the database.

C.12 - The system should provide capabilities to select the data in the database by the different phases of the verification process (e.g. tools to select just the unverified objects, or the verified objects, or the objects waiting for verification).

C.13 - The system should allow the user to select the presentation of the database data using either the IHO S-52 or paper chart symbolization (i.e. IHO INT 1).

C.14 - The system should provide capabilities to execute a zoom in and out on the display view.

C.15 - The system should provide functionalities to display the current coordinate system and projection, allowing the user to change these settings to other common coordinate systems and projections.

C.16 - The system should provide functionalities to select objects by groups using different criteria, such as by feature acronym or feature type.

C.17 - The system should have tools to allow the users to select the objects within a geographic area defined with a mouse.

C.18 - The system should indicate continuously the position of the cursor on the screen in accordance with the coordinate system used on the view.

C.19 – It should be possible to define the current view scale manually.

C.20 - The system should provide an automatic validation by data domain, just accepting data values within the defined domains, and establishing the permissible data types and data range values where applicable (e.g. do not accept characters in attribute values that should be numeric such as an object's height).

C.21 - The system should have tools to measure the distance and azimuth between two points in the selected projection.

2.2.4 Product Generation Requirements

The identified requirements related with general product construction are:

D.1 - The system shall be able to record the parameters associated with each created product allowing its reproduction at any time (e.g. the area and information about the objects used in the product).

D.2 - The system should allow a user to create product-specific objects (e.g. compass rose). These objects will be just part of a given product without needing to be in the database.

D.3 - The system should be able to identify the differences between the objects in a product and the corresponding objects in the database, to detect the changes made in the database since the creation of the product.

D.4 - The system should have the capability to produce a product update, that is, a product containing a difference between a previously produced product and the verified selected data within the database.

D.5- The system should allow the insertion of images in the most common formats (e.g. JPEG and TIFF) in the products.

D.6 - The system should be capable of maintaining a consistent look for the products in the production phase and the final products, in terms of image and text layout and format (i.e. the layout and format in the final product should be similar to the ones that are displayed on the monitor).

2.2.4.1 ENC Products Generation Requirements

The identified requirements related with the S-57 ENC cells, ENC updates and exchange data sets generation are:

E.1 - The system should have the capability to produce ENC data sets and update files, and exchange data sets, fully compliant with the IHO S-57 Standard and its Appendix B.1 “ENC Product Specification”. In particular:

a) The system should be able to include all the objects, their respective attributes, and relationships among those objects, included in the IHO S-57 and allowed by the “ENC product specification”.

b) The generated products should be able to have the defined types of spatial objects (point, line and area) in the chain node topological level.

E.2 - The system should support the catalogue and the ENC’s file names defined in the S-57 Appendix B.1 “ENC Product Specification”, including the respective producer code.

E.3 - The system should allow the creation of the products either with the required user defined parameters (e.g. the product’s geographic extent, the navigational purpose, etc.) or using the parameters from an existing product.

2.2.4.2 Paper Charts Generation Requirements

The identified requirements related with the construction of paper charts are:

F.1 - The system should be capable of producing paper charts meeting the IHO specifications published in the IHO M-4 document.

F.2 - The system should be capable of generating paper chart borders, graduation, grids and linear scales fully compliant with the IHO INT 2 Standard.

F.3 - The system should be capable of generating paper charts with the symbols and abbreviations fully compliant with the IHO INT 1 and INT 3 standards.

F.4 - The system should be capable of generating paper charts with insets, allowing the creation of non-rectangular borders.

F.5 - The system should be capable of generating compass roses to depict the magnetic variation in a paper chart product.

F.6 - The system should be capable of generating paper chart products, on the most common coordinate systems, using the most common projections, including Mercator and Transverse Mercator.

F.7 - The system should provide the capability to create, edit and delete chart notes to be included in a paper chart product.

F.8 - The system should provide the capability to export to a plotter the information that allows the plot of the product or part of the product, at user defined scales and projections.

F.9 - The system should provide the abilities to generate source and reliability diagrams based on: the position accuracy and percentage of seabed covered; types of IHO S-44 surveys; surveying systems used and data density; and, surveying systems and year of survey.

F.10 - The system should have the capability to automatically adjust graphics, images and text to fit them in a specific area of the product.

2.2.4.3 AML Products Generation Requirements (S-57)

The identified requirements related with the construction of S-57 AML products are:

G.1 - The system should be capable of producing AML products fully compliant with the respective NATO AML Product Specifications.

G.2 - The system should be capable of generating, editing and modifying all AML feature and spatial objects along with their respective attributes.

G.3 - The system should be capable of generating, editing and modifying all the relationships among features described in the AML Product Specifications, such as dependency (i.e. parent-child) and association relationships.

2.2.5 Data and System Backup

In these requirements, the indispensable backup tools were intentionally omitted. Although Oracle is well known for its robustness, a database for cartographic production is too valuable to not have an efficient backup system in place. This should be capable of resisting the possible sources of damage (e.g. physical damages due to natural or human causes, hardware problems with the hard disk, virus, bugs in the system, etc), and be back in operation in the shortest time delay.

Section 5.6 suggests a backup procedure composed of two different types of backup processes, both independent from the evaluated system.

CHAPTER 3

METHODOLOGY USED IN CARIS HPD EVALUATION

CARIS HPD is a representative example of the DDSNCP, with the concept described in the previous chapter. Due to its implemented characteristics, those products have attracted the attention of many HOs, including the Portuguese one, interested in the possibility of implementing a more efficient cartographic production. The main objective of this chapter is to describe CARIS HPD and the methodology used in its evaluation.

This chapter starts by providing an overview of CARIS HPD. Section 3.2 describes the general workflow modifications in an HO, such as the Portuguese HO, that the HPD implementation implies. Section 3.3 describes the system used to evaluate HPD. Finally Section 3.4 mentions the products produced during the evaluation. This chapter is related with CARIS HPD, so unless otherwise indicated all the information came from CARIS [2003a], CARIS [2003b], CARIS [2004a], CARIS [2004b], CARIS [2004c], and CARIS [2004d].

3.1 CARIS HPD Overview

CARIS HPD is an independent system integrated in the CARIS Hydrographic Database Solution, which is a set of systems that aspire to provide a complete solution from hydrographic data collection to the generation and distribution of hydrographic products. HPD is integrated into the product production and data storage and management. The objective is to provide a complete solution for managing the data, up to product production and producing all the range of cartographic and cartographic related products that could be the responsibility of most Hydrographic Offices, such as ENCs, nautical paper charts, AML products, and Digital Geographic Information Exchange Standard (DIGEST) DNCs.

3.1.1 HPD Databases

At the conceptual level, CARIS HPD is composed of two databases, illustrated in Figure 3.1, the **Source Database** which manages the source data composed of spatial and non-spatial data that will be used in the products production, and the **Product Database**, in which the data about the product definitions is stored and managed, including, for instance, its coverage and cartographic representations. Both databases are connected, so every change in the data in the Source Database, such as a feature object update will be reflected in the Product Database allowing the update of the products that include that feature object.

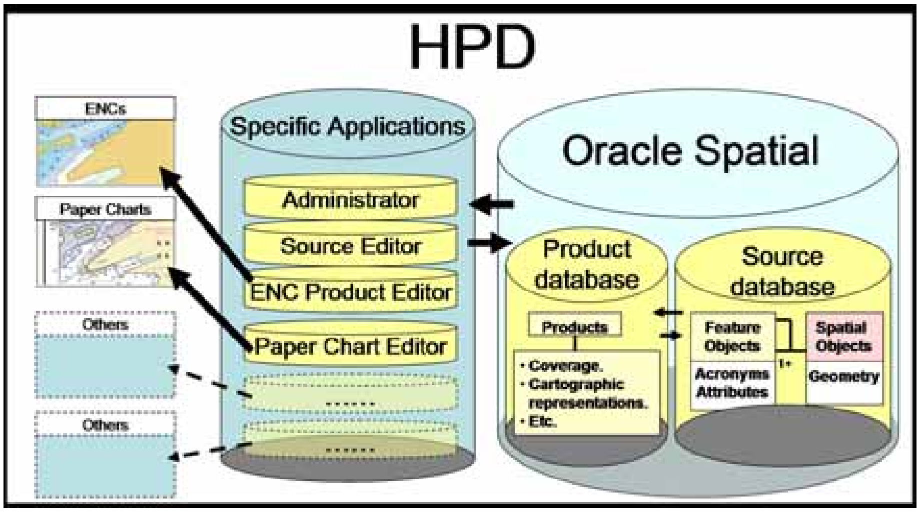

Figure 3.1 - HPD composed of the Specific Applications and Oracle Spatial with the two conceptual databases.

The system implementation is done using the Oracle Spatial Database and Management System, which allows CARIS HPD to take advantage of Oracle capabilities in data storage, management and other aspects with significant importance to the HPD functionalities, such as:

- A client-server environment;
- A multi-user data access, with the locking of the objects involved in update operations to avoid inconsistencies;
- The control of user access to tasks and data;
- Version management, allowing each object to never be deleted from the database, but be associated with a version which could be the current one or not;

- Data independence through the use of a logical view, not dependent on the system which implies that other programs can access the data on the Oracle SDBMS;
- And, backup, data recovery and consistency checking capabilities.

In addition, some of the operations executed by the specific applications use Oracle spatial operators and functions in all or in a part of the operation. The availability of those functions, further described in Appendix III, simplifies significantly the implementation in the system of the capabilities that requires those operations. With the change in the CARIS HPD client-server concept since version 2.0, described in Section 3.1.5, the utilization of Oracle Spatial operators and functions was significantly reduced. However, some operators are still often utilized by the system, such as SDO_RELATE and SDO_FILTER.

3.1.2 HPD Specific Applications

The HPD specific applications, at the moment of this evaluation (up to 2 July 2004), with the respective versions described in the Section 3.3 of this Chapter, are:

- The HPD Administrator - tools to allow an administrator to execute administration tasks, such as the creation of users with the respective privileges, the creation of new projects, the definition of the usages scale bands and the customization of the HPD Dictionary;

- Data loader programs which allow the loading of S-57 data into the database;
- The HPD Source Editor - an interactive graphic user interface program designed to allow the execution of all the operations related to the data within the database, except the product production (at this time does not allow to import the data in the database). In those operations are included the data addition, deletion, editing and verification;
- The HPD S-57 ENC Product Editor - an interactive graphic user interface program designed to execute all the operations necessary to produce ENC cells, ENC updates and ENC Exchange Sets;
- And, the HPD Paper Chart Editor - an interactive graphic user interface program designed to execute all the operations necessary to allow the production of paper charts.

3.1.3 HPD Data Model

The HPD data model, illustrated in Figure 3.2, is based on the IHO S-57 and the DIGEST data models, and with the AMLs when implemented using one of these standards. It is based on the concept of modeling each real world object as a combination of a feature object and a spatial object. A feature object may be related with none, one or more spatial objects to describe its location and shape, but each spatial object must be related with at least one feature object. In this model, more than one feature object can share the same spatial object. However, a feature object may be related with none, one or more other feature objects (e.g. to express any IHO S-57 relationship, such as a master-slave or a collection, a feature object is related with one or more other feature objects).

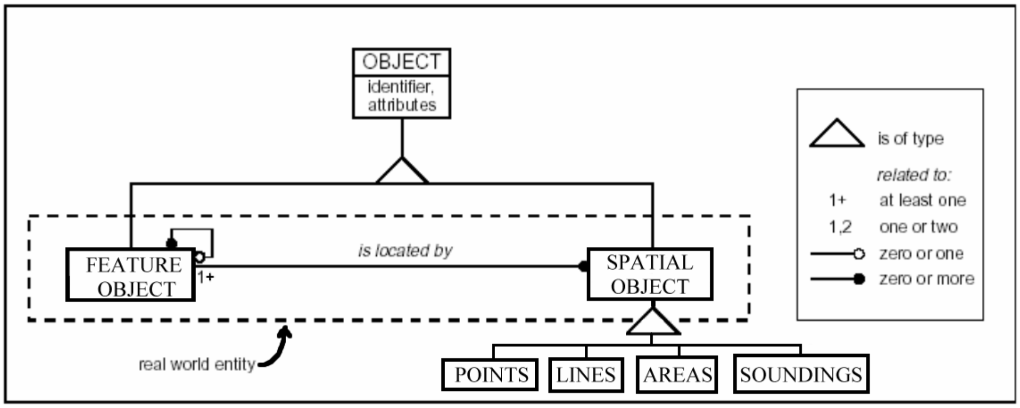

Figure 3.2 - HPD data model (after IHO [2000, p.2.1] and CARIS [2003a, p.7])

One of the most important characteristics of HPD is the data model capability to generate various kinds of products from the same data stored in the source database. CARIS HPD is now capable of producing ENC and paper charts, which mean all the range of cartographic products that are the responsibilities of most of the HOs. But the flexibility of CARIS HPD is expected to allow its extension, to be able to deal with products using additional objects such as the AML products and DNCs.

3.1.4 One Object, One Time

In the CARIS HPD concept, each object just needs to be stored once in the database even if this object is used in several different products. This implies that the updates to one object just need to be done once, which simplifies significantly the updating procedures. As will be mentioned and explained in Section 5.2.2, compliance with this concept might not be always possible or even preferable. To solve the problem related with the different levels of generalization that may be required at different scales, CARIS HPD has implemented the possibility of different cartographic representations being associated with the same object. CARIS HPD can store different representations to each object organized by usage levels, as is illustrated in Figure 3.3. The usage levels are scale bands covering a scale range that could be defined by the user. But, by default, HPD use the IHO S-57 scale bands.

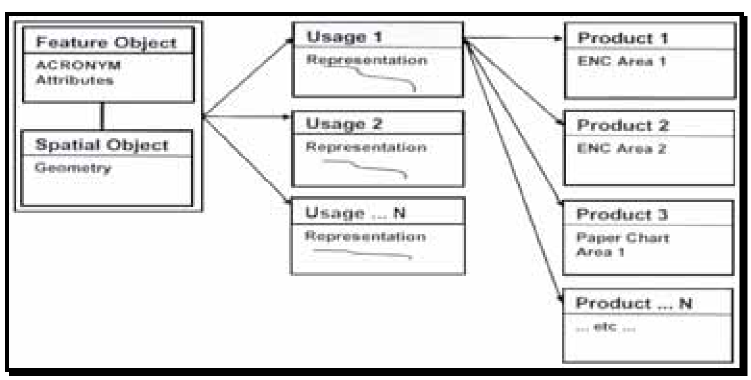

Figure 3.3 - HPD usages concept (from CARIS [2003, p.12])

3.1.5 Other Main Characteristics of CARIS HPD

In terms of data coverage, in the HPD Source Database, the data is continuous in the area of coverage without being divided by the areas of the products. This characteristic provides an important flexibility to the products production, allowing the easy generation of new products with different limits since they are within the area of coverage.

The presentation in the HPD is not dependent on the data. Following the concept of implementing the data in the IHO S-57 structure in the database, no information about the presentation is stored within the data. However, to allow data visualization, it makes sense that the data presentation is the same used by the products that the system might generate. So the presentation in the Source Editor and in the ENC Product Editor follows the IHO S-52 presentation library. The Paper Source Editor uses the IHO INT 1/M-4 presentation library.

The HPD software allows the user to view external vector and raster data in several formats (e.g. CARIS, SHP, GEOTIFF, TIF/TFW, and BSB), overlapping with the HPD database data, as is illustrated in Figure 3.4. This capability permits the comparison of the data from both sources and the creation of new objects in the database by snapping to those data formats.

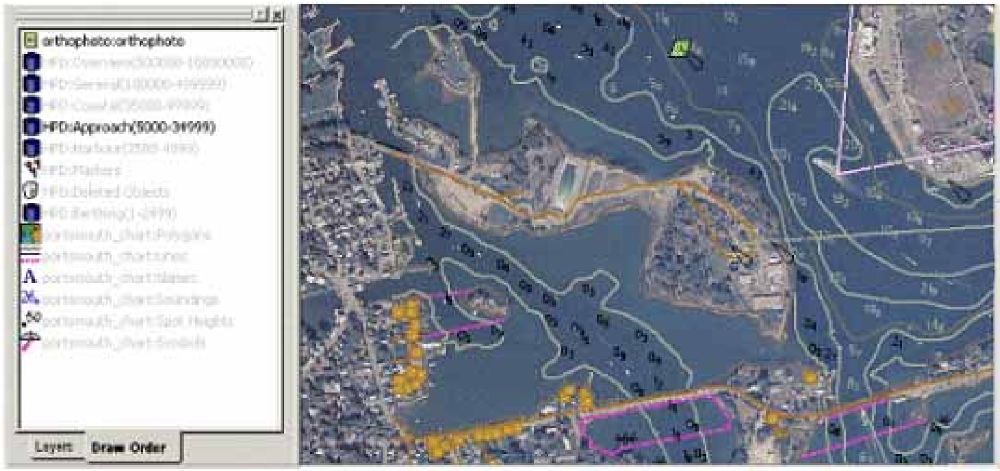

Figure 3.4 - Data of an HPD database displayed with an orthophoto of the same area (From CARIS [2004a])

HPD has implemented a verification process, through which all the data before they can be used in a product should pass. This process normally starts with all the data in an “under construction” status, then, when they are considered ready to be used by the user, they pass to a “not verified” status which means that they are submitted to be verified. At that point, a user with a verification role may turn the data into either “verified”, or “rejected” if the data considered is not ready to be used in the products creation.

The record of each object’s change history is another of the HPD functionalities, which allows not only the visualization of all the spatial and attribute changes made to the object, but also the identification of the users who made those changes, and the respective date.

The initial client-server implementation of CARIS HPD Version 1 was based on having all the data in the server, to which all the clients connected and performed the operations within the server. But, due to implications in the time necessary to execute each operation always being dependent on the connection to the server, the CARIS HPD Version 2.0 changed this client-server environment radically. Versions 2.0 and later are based on a client-server architecture characterized by clients loading the data within the respective workspaces, and performing the operations within the respective copies of the data. When the user saves the workspace, the changes are submitted to the server, but the communication and exchange of information is permanently maintained with the server, to control and lock to the other users the objects being edited by one user, for instance. With this architecture all the operations are significantly faster, except the client data loading and data saving.

3.2 Cartographic Production with CARIS HPD

The implementation of CARIS HPD in the cartographic production in an HO like the Portuguese HO is expected to bring a significant efficiency improvement. This efficiency will come from the economy in resources, the flexibility provided by the system in the construction of new products and also by the simplification in data storage, updating and management. In the Portuguese HO, it is expected that the production processes will be significantly reduced in length. The two existing almost independent workflows, one towards the ENCs and the other towards the paper charts, which have in common the support in the data preparation given by a Computer Assisted Cartographic

System (CACS), will be converted into one unique workflow centralized in CARIS HPD, as is illustrated in Figure 3.5. This will mean an economy of human resources that can be assigned to other functions, and also in equipment, materials and installations.

The flexibility of the concept allows the prediction that in the near future CARIS HPD will also be capable of producing other products, such as AML products and DIGEST DNCs, and will provide the necessary functionalities to start the production of those products with the same workflow which means with almost the same resources.

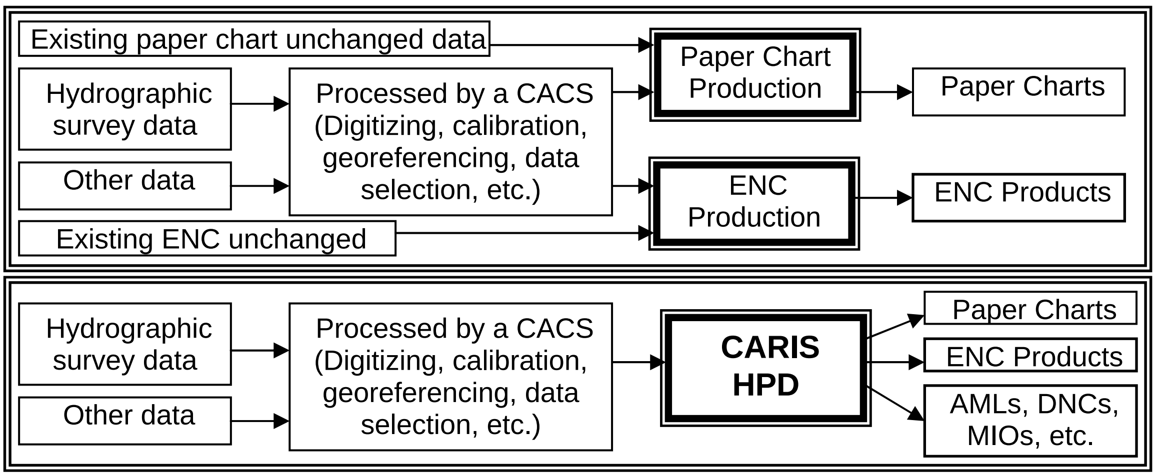

Figure 3.5 – Basic components of the IHPT ENCs and paper charts production process (above), and the idealized workflow with the HPD (below).

3.3 System Used to Evaluate CARIS HPD

The practical aspects of the evaluation of CARIS HPD mentioned in this report were performed in a private network physically located at CARIS headquarters.

The hardware configuration, illustrated in Figure 3.6, was composed of:

- One Dell OPTIPLEX GX260 desktop computer with a CPU Intel Pentium 4 at 2.4 Ghz, 1 GB of RAM, an Intel PRO/1000MT network card, and a Samsung SV2024D Hard Disk (HD) with 20 GB.
- One Fujitsu-Siemens Amilo M-6500 laptop with a CPU Intel Pentium III at 1.0 Ghz, a NETGEAR FA410TX network card, and a 20 GB HD.
- One 3COM Baseline 10/100 switch with 24 ports.
- The backup tests have been performed with a Maxtor 80GB HD.

The Dell desktop was configured as a server. As recommended by CARIS the HD was partitioned in three. In the first partition the following HPD software was installed:

- HPD Administrator 2.1 – initially Release 3, and later when the Paper Chart Editor was ready, this was updated to Release 4;
- HPD Source Editor 2.1- Service Pack 2;
- HPD S57 ENC Product Editor- Service Pack 2, with Hotfixes 3, 4 and 5; and
- HPD Paper Chart Editor 2.0.

Oracle Spatial 9i Enterprise Edition 9.2.0.4.4 Server was installed in the second hard disk partition and the Oracle databases were created in the third partition.

On the laptop the client version of Oracle Spatial 9i, and the following HPD software was installed:

- HPD Source Editor 2.1- Service Pack 2;

- HPD S-57 ENC Product Editor- Service Pack 2, with Hotfixes 3, 4 and 5; and
- HPD Paper Chart Editor 2.0.

Both computers' operating systems were the Windows XP Professional updated with the Service Pack 1.

Figure 3.6 - System used to make the HPD evaluation.

CARIS HPD database was populated with data from three Portuguese ENC cells (i.e. PT324205 [coastal], PT426408 [approach] and PT528514 [harbour]) that contain in common the area of Sines harbour in different scales, and are illustrated in the Figure 3.7. The choice of different charts containing the same area, and by consequence having some common features, was intentional to evaluate how CARIS HPD can deal with the loading of ENC files that may have some features in common.

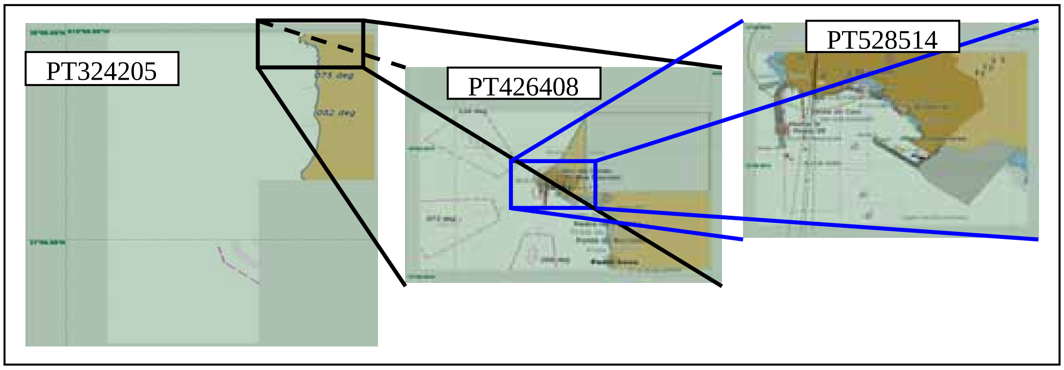

Figure 3.7 - The Portuguese ENC cells used to populate the HPD database.

3.4 Products Produced to Evaluate CARIS HPD

During the CARIS HPD evaluation the following products were produced:

- Several ENC cells, one sent to the Portuguese Hydrographic Institute to be analyzed by its quality control tools;
- An ENC update;
- The respective ENC exchange sets;
- One replica of the Portuguese nautical paper chart International 1883, National 26408 from Sines Harbour and Approach to Sines Harbour, this chart was plotted with the real dimensions (1107.7*757.9 mm). A reduction of the produced chart is represented in Figure 3.8.

Also, the HPD dictionary was extended to create four different AML objects, the “Q-route”, “Q-route legs”, “Turn Points” and “Mines”, and the respective attributes, which is described in Section 5.5.

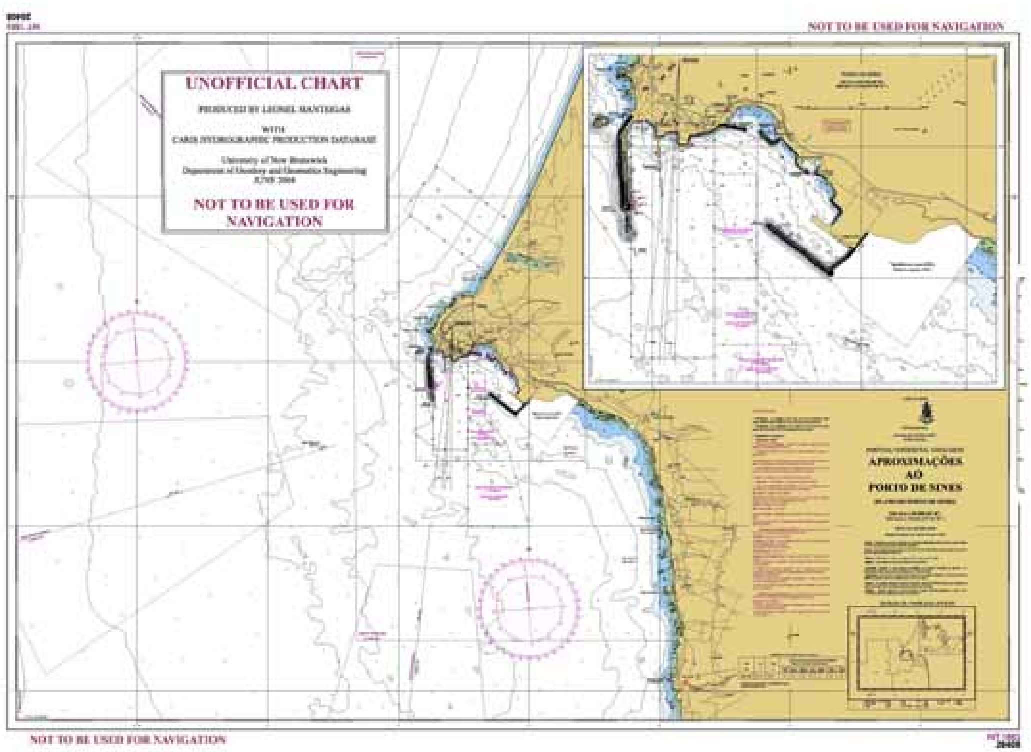

Figure 3.8 – Reduction of the paper chart produced with CARIS HPD.

CHAPTER 4
CARIS HPD COMPLIANCE WITH THE REQUIREMENTS

This Chapter analyzes the HPD compliance with the requirements that a general HO should have from a system to store and manage the cartographic data and produce ENCs, paper charts and S-57 AML products. Those requirements have been described in Chapter 2, Section 2.2 of this report. As a result of this CARIS HPD evaluation, several recommendations, described in Chapter 5, have been elaborated. The considered priorities and CARIS' predicted milestones for implementation are described in the Appendix IV.

4.1 HPD Compliance with the General Requirements

A.1 - Data loading capabilities - HPD is **fully compliant** with this requirement. It has two loader programs which allow the loading of IHO S-57 ENC cell (.000) files, CARIS chart and HOB files (.hob, .cel, .des and .dta).

A.2 - Multi-user environment - HPD **complies** with this requirement. It provides a stable multi-user access, robust in the prevention of data inconsistency errors due to the updating of the same objects by multiple users, using a locking procedure that locks any object edited by one user, making it available just for display by the other users. In the Section 5.2.9 more information is available about the locking procedure.

A.3 - Record Objects sources - HPD **complies** with this requirement. The sources of data are stored automatically in the objects SORIND (Source Indication) attribute only if that information is in the objects loaded in the database. Users can also update and/or store this information in any object (Section 5.2.13 has further information and a recommendation). The retrieval of all objects originating from a specific source is available with the “Complex Filter” tool, by doing a search of all objects having SORIND attribute value equal to a given string.

A.4 - Allow the non duplication of objects - HPD **complies** with this requirement, but the data preparation to meet this requirement in most of the cases may be so costly that the natural option will probably be just try to maintain some of the objects stored once in the database. Section 5.2.2 discusses the duplicated objects issue, and improvement of the “Find Duplicate Tool” is recommended. Section 5.2.3 describes why the creation of generalization relationships does not comply with this requirement.

A.5 - Identification of duplicated objects - HPD **partially complies** with this requirement. It has a function in the data loaders to not load duplicated data. As the loaded data is always from the same usage, this does not avoid the objects duplication between different usages (except if they have the same FOIDs[4]). On the other hand, it has a “Find Duplicates Tool” that can be activated by a user at anytime, but this is just available for points.

A.6 - Positions, distances and depths units and formats - HPD **supersedes** this requirement. It is capable of storing and displaying the geographic positions distances and depths in the required units and formats.

A.7 - Comments storage - HPD **partially complies** with this requirement. The HPD Source Editor has “markers” which may be associated with one or more objects and allows the insertion of comments by the users. But, the HPD S-57 ENC Product Editor and the HPD Paper Chart Editor do not currently have this marker (or an equivalent) functionality (see Section 5.2.8).

A.8 - Capability to store all S-57 Feature objects and attributes - HPD **fully complies** with this requirement. The cartographic objects and respective attributes are available in HPD Paper Chart Editor, as is expected.

A.9, A.10 and A.11 - Capabilities to create new object classes, attributes and symbols, and associate all objects (news or existent) with all symbols (news or existent) - HPD **partially complies** with these requirements. In reality it is possible to create new objects, attributes, symbols and the required associations, but the complexity of the process and the need to use other CARIS software external to the HPD system makes this unavailable for the normal user. However, a

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[4] Feature Object Identifier. In accordance with IHO [2000, Appendix B.1, p. 3], the FOID should be unique world-wide for each object. Multiple instances of the same object, for example in different usages may or may not have the same FOID.

customer may contract CARIS to do it or invest in an advanced training. More information about this topic is provided in the Section 5.2.12.

4.2 HPD Compliance with the Workflow Management Requirements

B.1 - Tools to create system users - The system **does not comply** with this requirement. Although HPD Administrator provides a tool to create users and attribute them the specific roles, as is described on Section 5.2.5 the roles at the moment are not fully implemented.

B.2 - Access limited to authorized users - HPD **partially complies** with this requirement. The access to the system requires the insertion of an authorized username and the respective password, but, as was mentioned previously, the control of the user roles is not currently implemented.

B.3 - Data verification system - HPD **partially complies** with this requirement. In Section 3.1.5 is described the verification process which is fully implemented, except on the Paper Chart Editor as is described in the Section 5.4.8.

B.4 - Turn unverified a verified updated object - HPD **fully complies** with this requirement.

B.5 - Tools to select objects waiting for verification - HPD **fully complies** with this requirement. The filter tools allow the quick selection of objects with any combination of certification status.

B.6 - Tools to record and report user modifications - HPD **partially complies** with this requirement. All the object changes are recorded with the respective user associated, but HPD does not currently have any functionality to report the objects modified by a given user. The implementation of this functionality is recommended.

B.7 - Capability to store different versions of data and restore an old version as the current one - HPD **partially complies** with this requirement. In the database the data is associated with a version, but HPD does not have a tool to display or recover data from other than current version. Section 5.2.4 provides further information about this topic.

B.8 - An object deletion should have a verification step - HPD **fully complies** with this requirement. Any deleted object until verified as deleted can be undeleted by a user.

4.3 HPD Compliance with the Data Editing Requirements

C.1 - Have tools to visualize the data in the database - HPD **fully complies** with this requirement.

C.2 - Functionalities to query one object by the selection with the mouse - HPD **fully complies** with this requirement. The selection of one data object with the mouse automatically activates a panel not only with the attributes of the object and the respective values, but also the representations, the components, the history and associated markers.

C.3 - Tools to create, delete and modify feature and spatial objects - HPD **fully complies** with this requirement. HPD Source Editor and ENC Product Editor have tools to do all the required functionalities. The Paper Chart Editor allows the change of the cartographic attribute values.

C.4 - Tools to edit, delete, modify and create the individual nodes of the spatial objects - HPD **fully complies** with this requirement within all editors.

C.5 - Capability to allow multiple users editing different parts of a large spatial object - HPD **does not comply** with this requirement. The concept of locking an object being edited does not allow the editing of a part of a locked object. To avoid this, an organization may adopt a division of the large objects into small ones.

C.6 - Capability to store spatial objects associated with usages which might be user customized - HPD **fully complies** with this requirement. The HPD Administrator has a "Usage Manager" which by default is based on the IHO S-57 ENC navigational purposes or usages, but allows the user to associate to each usage customized scale bands or to create additional usages.

C.7 - Ability to report the present editor of an object - HPD **does not comply** with this requirement as is further described on Section 5.2.10.

C.8 - Locked data should remain visible to the other users - HPD **fully complies** with this requirement. The edited objects are locked to editing by other users, but are still visible to all.

C.9 - Ability to display database data simultaneously with other geo-referenced data - HPD **fully complies** with this requirement. The formats that can be opened by the HPD Source Editor are: BSB (.kap); CARIS file (.des); CARIS SAF file (.saf); GeoTIFF file (.tif); S-57 ENC files (.000); HOB Files (.hob); TFW Images (.tfw); Shapefile (.SHP); and, DGN Files (.dgn).

C.10 - Functionalities to establish IHO S-57 relationships - HPD **fully complies** with this requirement. The user can create a master-slave relationship with one master and one or more slaves, and collection objects formed by a set of objects with a relationship of the types aggregation or association.

C.11 - Allow the selection and edition of relationships - HPD **fully complies** with this requirement. In the "Select" menu the user is able to select the master-slave relationships and view its members or the collection objects with the respective members.

C.12 - Capabilities to select the data in different phases of the verification process - HPD **fully complies** with this requirement. It has a filter tool that allows not only the selection of the data in any phase of the verification process, but also permits the selection of the objects in any combination of certification status.

C.13 - Allow the user to select either the IHO S-52 or paper chart presentation - HPD **partially complies** with this requirement. The data in the database, using the HPD Source Editor just as an IHO S-52 presentation and the user can select in Tools>Options>S-52 the points presentation as full chart and the areas as symbolized boundaries which is closer to the paper chart presentation, but is not a pure IHO INT 1/M-4 symbolization.

C.14 - Zooming capabilities - HPD **fully complies** with this requirement. In View > Zoom, the user is able to select different zoom and panning commands providing the necessary zooming functionalities.

C.15 - Allow the user to change the coordinate system and projection, showing them - HPD **fully complies** with this requirement. The HPD has defined several different common coordinate systems and projections, but it also allows the user to not only customize the displayed list of options but also create other geodetic datum definitions by providing the necessary parameters, as is described in the Section 5.4.5.

C.16 - Functionalities to select the objects by groups using different criteria - HPD **fully complies** with this requirement. The use of filters, that allows the selection of objects having specific characteristics in common, is vast. In addition the groups of objects can be selected by lasso, range, all in the workspace and all in the display.

C.17, C.18 and C.19 - Select objects within an area defined by the mouse, indicate continuously cursor’s position on the screen and define the current scale manually - HPD is **fully compliant** with those requirements.

C.20 - Provide an automatic validation by data domain - HPD **supplants** this requirement. It not only has a validation by data domain, but also allows the administrator to refine the domain of the attribute values associated with each attribute using the “HPD Dictionary Editor”.

C.21 - Tools to measure the distance and azimuth between two points - HPD is **fully compliant** with this requirement. The measuring tool indicates the geodetic and planimetric distance and the azimuth between any two selected points. The user is also allowed to change the distance units.

4.4 HPD Compliance with the Products Generation Requirements

D.1 - Capable of recording the parameters about each created product - HPD is **fully compliant** with this requirement. It is possible at any time to reproduce a product previously produced by the authorized users.

D.2 - Allow the creation of product specific objects - HPD is **fully complian**t with this requirement. The authorized users are allowed to produce IHO S-57 specific objects on the ENC products, without being in source database, and cartographic objects in the paper chart products, also without being in source database.

D.3 - Ability to identify the differences between a product and the correspondent objects in the database - HPD is **partially compliant** with this requirement. The ENC Product Editor is able to do this, using the “Compare product to Source” tool, creating four layers with the updated, the deleted, the replaced and the new objects. Paper Chart Editor does not currently have any tool to do this as is mentioned in Section 5.4.7.

D.4 - Capability to produce a product update - HPD is **compliant** with this requirement. The HPD ENC Product Editor is fully compliant. The updates to the paper charts are normally divulged in "Notices to Mariners" and are introduced into the chart either manually or by an automatic system, so there is not a significant advantage in implementing this functionality in the HPD Paper Chart Editor.

D.5 - Allow the insertion of images in the products - HPD is **partially compliant** with this requirement. The ENC Product Editor is able to incorporate images in the ENC Exchange Data Sets, but the Paper Chart Editor does not allow the inclusion of images in the produced charts as is mentioned in the Section 5.4.6.

D.6 - Maintain a consistent look for the products in the production phase and the final products - HPD is **compliant** with this requirement. ENC Product Editor and Paper Chart Editor in the products view are fully compliant. CARIS HPD Source Editor is not able to display a compliant IHO INT 1/M-4 presentation. But the requirement is related with the production process, so it is considered that HPD complies with this requirement.

4.4.1 HPD Compliance with the ENC Products Generation Requirements

E.1 - Capability to produce ENC data sets and update files, and exchange data sets, fully compliant with the IHO S-57 Standard - HPD is **compliant** with this requirement. Section 5.3.4 states the conclusions of the quality control analysis performed by the ENC Production Department of the Portuguese HO.

E.2 - Support the catalogue and the ENC's file names defined in the IHO S-57 Standard - HPD is **compliant** with this requirement. Not only does HPD already have a full list of producer codes, but it also allows the users to modify this list.

E.3 - Allow the creation of the products either with user defined parameters or using the parameters from an existing product - HPD is **compliant** with this requirement. The user can select between the creation of an ENC cell using an existent one as a template to import the extent and the metadata, or the creation of an ENC cell by the user definition of the extent and necessary metadata.

4.4.2 HPD Compliance with the Paper Charts Generation Requirements

F.1 - Produce paper charts meeting the IHO M-4 specifications - HPD is **not compliant** with this requirement. During the evaluation of the Paper Chart Editor by the production of a complex paper chart, it was concluded that, in one way or another, almost all the problems have more easy or complicated solutions to produce a Paper Chart in according with the IHO M-4 specifications, except three unsolvable aspects described in the Section 5.4.21:

- Incapability to represent soundings out of position;
- The soundings in depths deeper than 5m are represented in gray;
- Represent as black some lines that are in magenta in the specifications.

Section 5.4 and respective sub-sections describe these issues.

F.2 - Capable of generating paper chart borders, graduation, grids and linear scales fully compliant with the IHO INT 2 Standard – CARIS HPD is **compliant** with this requirement. It has all the borders defined by IHO INT 2. During the production of the paper chart to evaluate CARIS HPD only the INT 2 borders E and F [IHO, 1990] were used. Besides the issues described in the Section 5.4.4, the "Template Editor" allows the user to customize the parameters of each border.

F.3 - Capable of generating paper charts fully compliant with the IHO INT 1 and INT 3 standards - HPD is **not compliant** with this requirement. The issues related in the evaluation of the requirement F.1 are applicable here. In addition, most of the sub-sections of Section 5.4 describe issues related with the compliance with the IHO INT 1 and M-4 specifications, found during the execution of the paper chart.

F.4 - Capable of generating paper charts with insets, allowing the creation of non-rectangular borders - HPD is **partially compliant** with this requirement. The creation of insets is possible. An inset was created in the produced paper chart.

But at the moment, the creation of non-rectangular borders is unavailable to normal users.

F.5 - Capability to generate compass roses - HPD is **fully compliant** with this requirement. The generation of compass roses could be done as is described in Section 5.4.13.

F.6 - Generating paper chart products, on the most common coordinate systems, using the most common projections - HPD is **fully compliant** with this requirement. CARIS HPD has already defined the most common coordinate systems and projections. In addition it allows the user to customize the displayed list of options, and also create other geodetic datum definitions by providing the necessary parameters. This customization operation is described in the Section 5.4.5.

F.7 - Capability to create, edit and delete chart notes - HPD is **fully compliant** with this requirement. It allows the user to add to the products text in the form of “Linear text”, as a “Block Text” or imported from a “RTF file”. Some file importation issues are described in Section 5.4.19. It also allows the edition and deletion of the created notes.

F.8 - Capability to export to a plotter a product or part of the product - HPD is **fully compliant** with this requirement. It exports the products in postscript format. In the exportation process the user might choose to export the entire chart, the current view, as a schema of separate colours and adjust the scaling in percentages of the chart sizes. If the user selects the “separate colours”, the system will export four files each one with the respective colour coverage (i.e. cyan, yellow, magenta and black).

F.9 - Capabilities to generate source and reliability diagrams - HPD is **partially compliant** with this requirement. HPD Paper Chart Editor cannot produce source or reliability diagrams automatically, but the user can solve the problem creating insets as is described in Section 5.4.14.

F.10 - Capability to adjust automatically graphics, images and text to fit them in a specific area - HPD is **not compliant** with this requirement. It does not allow the insertion into paper charts of graphics, or images. Inserted text should be fitted by adjusting the size of the respective fonts or by adjusting the height and width of the text in the text box or on the file to be imported.

4.4.3 HPD Compliance with AML Products Generation Requirements

G.1, and G.3 - Capable of producing AML products, and, generating, editing and modifying all the relationships in according with the AML Product Specifications - At the time of evaluation, CARIS HPD is **not** able to produce AML products, or AML-specific relationships (e.g. dependency relationship as parent-child).

G.2 - Capable of generating, editing and modifying all AML feature and spatial objects along with their respective attributes - The production of AML objects with

CARIS HPD was tried with the extension of the HPD dictionary. The findings related with the customization of the HPD dictionary are described in the Section 5.2.12. Section 5.5 concludes that, objects created with the customization of CARIS HPD dictionary could be considered AML objects. So, due to its flexibility, despite HPD not currently having a specific editor for AML Products it is **compliant** with this requirement.

CHAPTER 5
PRACTICAL USE OF CARIS HPD

This chapter presents and discusses some system issues found during the practical work with CARIS HPD. These findings complement the evaluation of the CARIS HPD compliance with the general requirements of an HO in the production of ENCs, paper charts, and AML, and in the storage and management of the data for the production of these products. Also some other aspects not mentioned in the CARIS reference guides are discussed. Several recommendations are made. Priorities and CARIS' predicted time of implementation are described in the Appendix IV.

Sections 5.1 to 5.5 describe the processes and workflows, and mention some practical aspects of the system identified during the system installation, preparation of the data, operation with the system and the mentioned products production. Finally Section 5.6 provides a suggestion of a complete backup process.

This chapter is related to CARIS HPD, so unless otherwise indicated all the information came from CARIS [2003a], CARIS [2003b], CARIS [2004a], CARIS [2004b], CARIS [2004c], and CARIS [2004d].

5.1 HPD Installation

CARIS HPD requires that Oracle Spatial be installed first. The comments in this section are related with Oracle 9i database 9.2.0.1.0 upgraded using a patch to version 9.2.0.4.

Oracle installation, in spite of the complete notes provided by CARIS, is not an easy task to someone not familiar with Oracle. It is also a time-consuming operation. In an installation like the one used to produce this report (consisting of a server containing the database, and a client which needs to access the server to perform the operations), a sensitive aspect is the connection between both computers.

CARIS HPD installation was carried out by the installation of four different products:

- HPD Administrator 2.1 - Release 3;
- HPD Source Editor 2.1 - Service Pack 2;
- HPD S-57 ENC Product Editor 2.1 - Service Pack 2; and
- HPD Paper Chart Editor 2.0.

Although this is a straightforward sequence of operations, to complement the installation notes provided by CARIS it is necessary to mention:

- The HPD Administrator shall be installed before the editors, but just in the server; it should not be installed in the client;
- During the installation of the HPD Administrator a database schema is created. A server might contain several independent database schemas,

each one with the respective administrator and the authorized users. At the conceptual level each database schema could be considered an independent database. While in reality at the physical level there is just one Oracle database, the system hides this from the users. This fact allows, for instance, the creation of a database schema for training and other to be used in the cartographic production (e.g. during this CARIS HPD evaluation six database schemas were created within the same Oracle database, each one for a specific purpose).

5.2 Data Loading, Preparation and General System

This section analyzes the data loading in CARIS HPD database, and the preparation of the data within the database, such that it is in a condition to be used in the products production.

The process of loading the data in the CARIS HPD database is explained in Annex B of HPD Source Editor Reference Guide. Some comments about the process and a recommendation are stated in Section 5.2.1.

After loading the data in the database, the data should be prepared to be capable of being used in the products. First it is necessary to decide the level of object duplication required. If the decision is to have the least duplications possible, probably a lot of work should be done in the data preparation. Section 5.2.2 has further information about this topic.

It is possible that some new objects need to be added (by digitizing or importation), some need to be modified and some need to be deleted.

The creation of relationships, if required, is another important step in the process HPD Source Editor Reference Guide explains all the processes and procedures, and the Sections 5.2.3 and 5.2.6 comment on this.

The assignment of representations to usages is a good way to replace some duplicated objects (see Section 5.2.3).

All the above mentioned processes are normally done iteratively, but one important aspect, when the objects are considered ready to be used in the products, is the verification process. Without being verified the objects cannot be used in product creation.

5.2.1 Data Loading

To load the data into an HPD database, CARIS HPD has two programs. The HOBHPDloader.exe is used to load CARIS and HOB files (i.e. files of the formats .cel, .des, .dta, and .hob), and the standaloneHOBHPDloader.exe is used to load HOB (.hob) or S-57 ENC (.000) files. HPD does not provide a Graphical User Interface (GUI), so the user needs to execute the commands in the DOS line command. As the command is complex, it is preferable to write it first in a batch file. Other advantages of the batch files are that to do the next loads just a few parameters need to be changed, and the users may write batch scripts to load large amounts of data during the night or on weekends. The data loader programs are not used very often; however, typing commands in a command line, or editing and changing a batch file is not a user-friendly process. It is recommended that a tool be developed with a GUI where the user will select the necessary parameters to enable the system to execute the data loader programs.

5.2.2 Duplicated Objects in the Database

One of the necessary decisions in CARIS HPD implementation in any HO is related to the existence of duplicated objects within the database. An object is duplicated in the database, if the same object represented by a feature object and the related spatial objects are stored in duplicate in the database on the same usage or on another usage.

Object duplication is not desirable, because if a given object needs to be updated, the respective duplicates need to be updated too. This implies a duplication of effort and might lead to inconsistencies in the data, if for any reason one duplicated object was overlooked. As many HOs have already several ENCs, it is normal that they want to load the data from those ENCs into an HPD database to populate it. Normally ENCs of one navigational purpose (or usage) have some objects in common with ENCs of other navigational purposes from the same area. This implies that if the duplicated objects are not removed before, during or after the loading process, some of the objects will be duplicated in all usages.

To avoid duplication of objects in the database, CARIS HPD data loader does not load one object if it already exists in the respective database usage. But it does not analyze the objects in the different usages (except if they have the same FOIDs, as is explained in the compliance with Requirement A.5 evaluation, in Section 4.1). So, if more than one ENC cell of the same area is loaded into the database, belonging to different usages, having some objects in common with different FOIDs, the result will be the existence of some duplicated objects in each usage.

One solution is to leave the objects duplicated and relate all the duplications using generalization relationships (described in the Section 5.2.3). Another solution is the deletion of all the duplicated objects after the data loading. This solution is more difficult than it appears, because the user needs to discover all the duplications.

HPD Source Editor has a “Find Duplicates Tool” currently just available for points. This tool allows the user to find the duplicates in the same usage, against other usage, in the same location or within a given tolerance, and with the same attributes or ignoring the attributes. For this tool to be more helpful, it is recommended to implement the functionality to be able to detect any kind of duplicates, not only points, and allow the users to delete the objects of the smallest scale usages, assigning its representations as the representations of the largest scale usage object in that usage (illustrated in the passage from (I) to (II) in Figure 5.1).

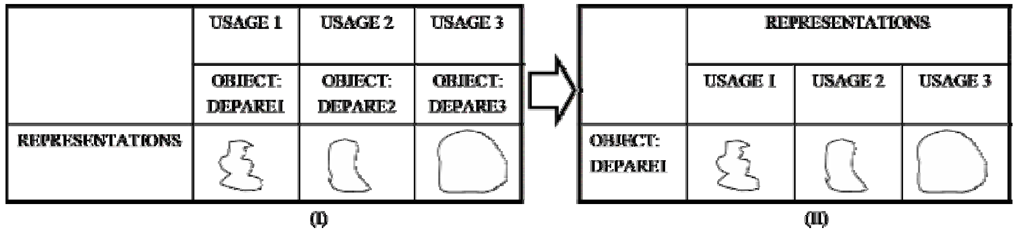
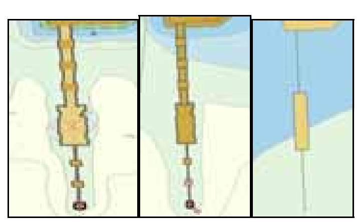


Figure 5.1 - Elimination of object duplication by the deletion of the smallest usage's objects (I) and assignment of its representations as the representations of the largest usage object in those usages (II).

On the other hand, even with all the recommended tools, it could happen that it is not possible to eliminate all the duplicated objects in the dataset without modifying some objects. One object in one usage might correspond to several objects in another usage (e.g. a wharf could be constituted by different elements in each scale, as is illustrated in Figure 5.2, where in the harbour ENC cell (I), in the approach (II) and in the coastal (III), the number of features is not the same). In this case the representation needs to be rebuilt from the beginning, using the larger scale feature as a base. In conclusion, although it might seem that the elimination of duplicates should be the best choice, in reality sometimes it might be preferable to maintain the duplicated objects, or maintain some of the duplicated objects. In such cases the generalization relationships should be created but the recommendation stated in the Section 5.2.3 should be implemented.



(I) (II) (III)

Figure 5.2 - Same object represented in different usages with a different number of elements (I - Harbour, II - Approach, III- Coastal).

5.2.3 Assign Representations to Usages and Add Generalization Relationships

CARIS HPD can create generalization relationships and can assign representations to usages. While the objectives are the same (relating the same world object in the different usages), they are very different in the concept and implementation.

The assignment of one object representation consists of assigning the object representation or representations (in Oracle called geometries) to more than one usage. The representation in all usages might be the same (e.g. in the case of a symbolized object normally is the same) or might be different (e.g. in the example of the Figure 5.3 each geometry or representation is assigned to two usages and the spatial object is constituted by two different geometries). There is just one feature object, and the assignment concept maintains the real world semantics of one database object representing one real world object. When a user assigns a representation to other usages, the representation is the same in all assigned usages. To have different representations, in different usages the object needs to be edited and the nodes need to be modified, unless the functionality described in the recommendation of the Section 5.2.2 is implemented (to allow the importation of the representations to usages from objects in those usages and the subsequent deletion of those objects).

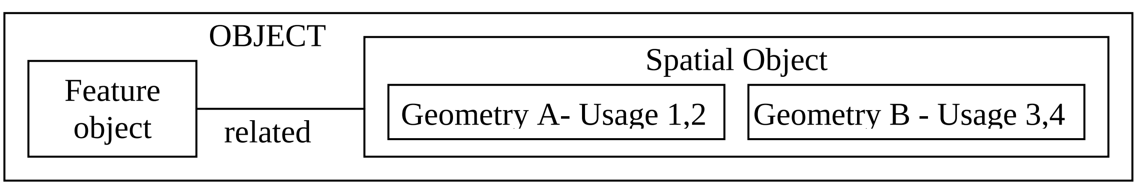


Figure 5.3 - Assignment of one representation to usages.

A generalization relationship consists of relating one object in one usage with one or more objects in another usage or usages, as is illustrated in Figure 5.4. In this case they are different objects just linked by a relationship, for instance the respective feature objects may have different attributes and attribute values. If this is a many-to-one relationship the more than one object case should be in the larger scale usage.

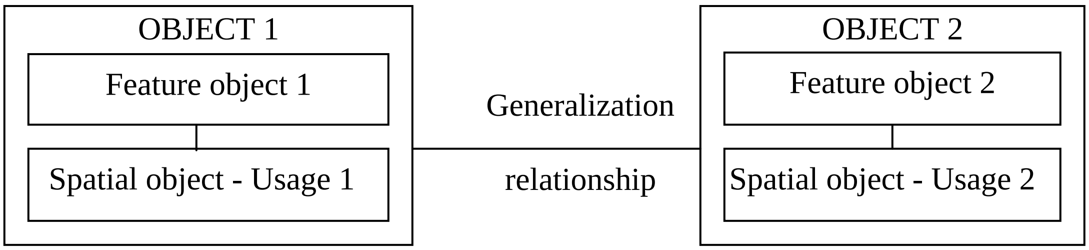


Figure 5.4 - Schema of a generalization relationship.

One of the main reasons to create a generalization relationship, is to warn the users when they try to change one of the objects (feature or spatial) that this object is represented in other usages by different objects. But in both cases (generalization and assignment), if an operator changes (updates or deletes) a representation or a feature, the system does not activate any kind of warning to the fact that the changed object has a generalization relationship. The users needs to check it themselves in the "relations" tab. If the representation of one object changes, its representation in other usage probably needs to be changed too, so it is recommended to implement a pop-up menu, activated when one representation is edited or deleted, warning of the existence of a generalization relationship or representation assignment to usages. It is also evident that the generalization relationship does not meet the principle of one feature, one time, because in each usage the objects are different.

5.2.4 Versioning Functionality

HPD Source Editor Version 2.1 lost an important functionality in relation to the Version 1.4, that is the possibility of undeleting the deleted data, even after the deletion operation was confirmed. CARIS states that this can still be done using Oracle, and that is expected to have this functionality available again in the next version of the HPD Source Editor (see Appendix IV).

In reality the fact is that the Oracle versioning management is activated, so no data is really removed from the database. Anyone with access to the database knowing the conceptual organization of the tables and attribute columns should be able to restore any feature assigned to “not the current version”. A suggestion is the development of a program with a GUI that does the connection of the administrator to the database, that is capable of listing the features not in the current version, allowing the modification of the version attribute value to be set as the current version. This tool will allow the recuperation to the current version of any deleted and verified as deleted feature. It is recommended also to explain in the reference guides what happens when a feature is deleted, and when its deletion is verified.

5.2.5 Implementation of the Users Roles

User roles are the “privileges” assigned by the HPD database administrator to each HPD database user. The roles should define what the user is allowed and not allowed to do in the database. If, for instance a user just has “browser” roles (or privileges), the system is supposed to allow him just to view the data within the database, without allowing editing and modification of the objects. In one of the tests such a user was created, but the system allowed him to do all the operations within the system such as editing, modification and verification of objects and products production. In reality the user’s privileges in CARIS HPD is not currently implemented. The system allows the administrator to create users and assign the intended privileges, but the user can still currently do all kinds of operations independent on the assigned roles. Due to its importance in the system implementation in a HO organization, it is important to implement effectively the user roles functionality in CARIS HPD.

5.2.6 Master-Slave Relationships

Master-slave relationships are hierarchical relationships among features defined in the IHO S-57 Standard. One of the objects must be the master and the others (could be more than one) should be the slaves (e.g. a buoy with a light, where the structure normally is the master and the light is the slave). HPD Source Editor is not only able to create and delete the master-slave relationships, but also has functionalities to select and display all the relationships of this category and all the objects involved in one. If a user deletes a master or the only slave object, the system deletes the relationship too. This deletion is done without any warning of the fact that the object is in a master-slave relationship and that this will imply the deletion of the relationship too. To warn the user, it is recommended the implementation in the system of the functionality to display a pop up warning when the user is editing or deleting any object participating in a master-slave relationship.

5.2.7 Presentation Libraries

The presentation in the HPD Source Editor is only based on the IHO S-52 standard, with the possibility to set some options which approach the paper chart presentation, but are not fully compliant with the IHO INT 1 and M-4 specifications. As CARIS HPD Source Editor is used to operate with the database data which will be used to build paper charts and ENCs, it is recommended to give the user the option to select between the S-52 and the paper chart presentation (IHO INT 1/M-4).

5.2.8 Markers Functionality

Markers are a very useful tool for the users, allowing them to associate the necessary notes with specific objects. These notes will not appear in the products, being a good auxiliary from data preparation until the products production. Currently markers are only available on HPD Source Editor. Due to their utility, it is recommended to implement the markers functionality on HPD Paper Chart Editor and on ENC Product Editor.

5.2.9 Lock Edited Features

The connection of two different users to the same database was tested. All the features remain unlocked except the selected ones. This functionality is very important. When one object is edited and changed it remains locked from editing to the other users until the user that did the changes saves the workspace. Any other user that tries to edit the locked object is not allowed and a warning as illustrated on Figure 5.5 (I) will be displayed. After the workspace has been changed, a different user can edit the changed feature object only if they first reload the workspace integrating all the changes performed until that time. To advise them of this is the warning illustrated on Figure 5.5 (II). But, if one user just edits the nodes of an object and did not do any changes, on one side the system does not allow them to save (the saving option is not activated), and on the other side the edited spatial object will still be locked until the editing user leaves the system. On the feature objects the problem is similar.

It is recommended that the unlocking process activated when the editor saves the changes, be activated also when a user that does not do any change to the object finishes editing, to unlock the objects and make them available to be edited by the other users.

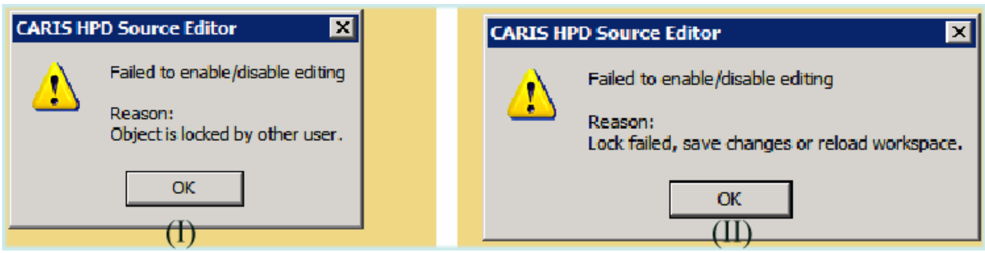


Figure 5.5 - Warning messages locking edited objects.

5.2.10 Report of the Editing User

The user name of an object editor appears to the other's in the object's "History" folder, but only after the editor saves the changes and only if the workspace of the other users are refreshed. As a result, the other users cannot know who is locking a given object during its editing. The Database Administrator (DBA) can disconnect the users from the database using the Oracle administrator tools. So, if a user for any reason leaves an object edited for a large period of time, the DBA can disconnect the user and unlock the object. But this is a limitation. It would be better if the identification of the locking user during the editing was available to all the users. So, is recommended to implement a functionality to report to the users that try to edit a locked object, the identification of the locking user.

5.2.11 Export and Import Objects Using HOB Files

HPD Paper Chart Editor during the data exportation as HOB files displays an error message saying that an “Environmental variable” is not set and aborts the process. This problem is very easy to solve and requires only a copy of a file, and adding a new string to the windows registry. But this should be done by the “HPD Paper Chart Editor” installer. It should be fixed.

HOB files are a good intermediate platform that can be used to exchange objects between different products (e.g. objects belonging specifically to one product not being part of the source database), and to store some objects as a kind of permanent clipboard. The HPD Source Editor allows the user to open the HOB file objects, select them, and then import them to the database. The HPD ENC Product Editor allows the users to open HOB files, but does not have any importation tool. The HPD Paper Chart Editor does not open the HOB files. Also all editors allow the exportation of objects as HOB files except HPD Paper Chart Editor. Due to its utility to the production processes it is recommended to implement the functionality to import the objects inside HOB files in all the product editors and to correct the described exportation problem in the HPD Paper Chart Editor.

5.2.12 Customization of CARIS HPD Dictionary and Representations

The objective of customization of the objects and attributes in CARIS HPD is the extension of the existent objects and attributes. But this is a very complex process that requires the user to go through several complicated steps. CARIS intends to streamline the process in the future in such a way that all operations are done within the HPD Dictionary Editor, illustrated in Figure 5.6. In the author's opinion, only after the process is streamlined, can CARIS HPD be considered capable of being customized by normal users. At present three steps require the complicated edition and modification of internal files, and other three require the use of CARIS HOM, which in turn requires the CARIS GIS, so, CARIS HPD alone is not capable to do it.

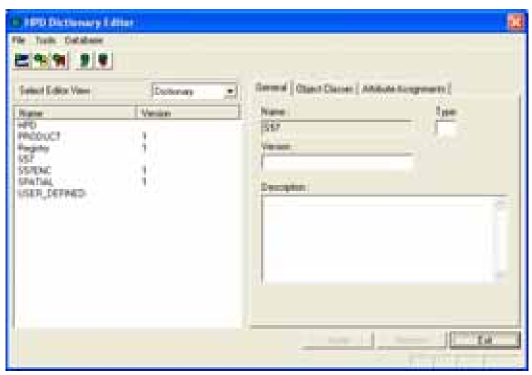


Figure 5.6 - HPD Dictionary Editor.

After the creation of new objects and respective attributes, as they are not recognized by the presentation library, its display by the system will be a "question mark" in the case of a point feature or a line with question marks in the case of a line feature.

The extension of the presentation library is also possible, but very difficult to do by an average user, because the user needs to go through the edition of several internal files with the inherent risk of damage to the software. On the other hand CARIS is currently creating new symbols for customized objects, for the Canadian Hydrographic Service (CHS) for instance.

The possibility of extending the HPD dictionary and the implied flexibility appears to have three inherent advantages:

- The creation of new objects for help internally in the cartographic production, allowing the inclusion in the system of some real world objects which are not in the IHO S-57 Standard, but that exist and are wanted by some users in the database for information, not to export to the products (e.g. diverse land features);
- The creation of new objects to allow the system to be modified to agree with new versions of the related IHO Standards (S-52, S-57, M-4 and INT 1) which integrate new objects;
- Or, the creation of new objects to export to special external users (e.g. such as warships of a navy).

To be used as an aid in the cartographic production, the capability of storing additional objects is important. But due to the problems mentioned above with the association of a representation to the new objects, at the moment the analyzed version does not have tools capable of providing this flexibility to the normal user. One solution could be to contract CARIS to provide the respective representations as the CHS did, or provide to the user an advanced training course in the objects and presentation customization which could be expensive.

In the case of new versions of the standards, with changes in the objects and/or representations, the users certainly will not need to extend the HPD Dictionary. CARIS should provide a patch to all the clients, to modify the respective HPD objects and representations in accordance with the standards.

To export to external users, the ECDIS or Electronic Chart System (ECS) should be able to recognize new objects and associate the respective representations. In this case, depending on the ECDIS or ECS characteristics, the exported products could be really useful. The producers can create a kind of AML for instance, with objects having the same acronyms and attributes as the AMLs. Probably those ECDIS or ECS will not be as flexible in handling such objects as the WECDIS handles the AML objects (e.g. display just the AMLs of one kind of product), but the information will be available for the users utilization.

From all the comments above, it can be concluded that the extension of the objects and attributes is important. It is also important to have the possibility of extending the presentation of the HPD objects. So, it is recommended to streamline all these processes, with the improvement of the “Dictionary Editor” to be capable of do all the processes related with the creation of user defined objects and attributes, and the assignment of the attributes to the objects. In addition, the development of a new tool is recommended, or possibly an extension of the “Dictionary Editor” (which will imply the change in the name) with the functionality to assign existenting representations to the customized objects, and also allow the creation and assignment of new representations in a streamlined process with a GUI, to avoid the need for the user to go through the editing of internal files.

5.2.13 Record of the Data Source

The sources of data are stored automatically in the objects attributes SORIND (Source Indication) only if such information is in the objects loaded in the database. Later, manually, the user can store that information in any object. Most of the objects loaded from the Portuguese ENC cells into the database did not have any attribute value in the SORIND attribute. Also all the data loaded from a file (an ENC cell for instance) should be easily selectable as a group, which could be necessary, for instance, if it is found that the data from a given source has some problems. So, it is recommended that the functionality be implemented to select all the data loaded from a given file. For instance a non S-57 attribute could be created, where the data loader automatically stores the source of data record (e.g. the identification of the ENC cell). For objects not loaded with the data loader this attribute will not have any value. But in most of the cases the objects in any HPD database probably are loaded from an ENC cell. This solution has the advantage of not overwriting the SORIND attribute value of the objects having it populated.

5.3 ENCs Production

The preparation and generation of ENC products, in CARIS HPD is done using the S-57 ENC Product Editor. Unless the user needs to create several product specific objects (objects that are not and will not be in the database), the preparation and generation of the products are easy, and normally a quick process.

As is described in detail in the "HPD S-57 ENC Product Editor Reference Guide" [CARISb, 2004], HPD S-57 ENC Product Editor allows the users to:

- Open an existing product "for querying, viewing, and customizing through the editing tools".
- "Create an ENC S-57 dataset from the edited product".
- "Create Exchange Sets".
- "Update the product from the source database".
- "Create S-57 updates, re-issues, and new releases".

During CARIS HPD evaluation several ENC cells, and one ENC update were produced and the respective exchange sets were created. One of the ENC cells was sent to the Portuguese Hydrographic Office to be submitted by the ENC department to all the range of available quality control tools. The used tools and the conclusions of that evaluation are described in the Section 5.3.4. In the following sections some of the findings will be mentioned coming from the practical work related with the ENC products.

5.3.1 Production of an ENC

The production of an ENC cell could be done using an existent ENC cell as a template to import the extent and the metadata, or by the user definition of the extent and necessary metadata parameters. While the definition of the necessary metadata parameters is normally easy and quick, the possibility to use an existent ENC as a template is a useful functionality, because some HOs already have almost all the ENC cells defined and produced.

5.3.2 Production of an ENC Update

The system allows the user to compare each product with the source database content. The findings are organized by four categories: updated; deleted; replaced; and, new. This tool allows the user to see the differences in a quick and organized way.

If some changes have been made in the database, and the user wants to create an ENC update, first they should save the product as a new version, then the product should be compared with the source. After this, the user should select the objects to apply to the update and apply them, and finally the changes should be saved. After the described process the system is able to generate an ENC update. All the procedures of this process are explained in detail in the respective Reference Guide [CARIS, 2004b].

5.3.3 Quality Control Tools

The quality control tools of the HPD S-57 ENC Product Editor are almost non-existent. One of the important phases of the products production is the quality control. To be a complete production system, is recommended that the HPD S-57 ENC Product Editor provides a sufficient set of quality control tools, capable of analyzing all the eventual errors in the products being prepared and in the created products (e.g. some mandatory attributes missing or not within the defined domain, no agreement of some attribute values, etc.).

5.3.4 Conclusions of the Produced ENC Quality Control Analysis

One of the produced ENC cells was subject to the quality control tools of the Portuguese Hydrographic Institute. These tools are:

- ENC Analyzer from HSA Systems, Version 2.1.5;
- dKart Inspector from HydroService, Version 4.0.

These quality control tools reported some minor errors and warnings. Those errors and warnings were related with attribute values not conforming to the IHO S-57 Object Catalogue, missing mandatory attributes, and some missing area coverage (such as depth areas without M_QUAL metadata information). The same problems exist in the original cell used to load the data in the database. Most of the reported problems (as the author was informed by the responsible person in the ENC production in the Portuguese Hydrographic Institute) are not serious issues. Thus, it could be concluded that all the reported errors and warnings are not really errors, or are possible to correct, and were not caused by the CARIS HPD but already existed on the ENC cells used to populate the database. However, it would be preferable if CARIS HPD were capable of detecting such problems.

5.4 Paper Chart Production

The preparation and generation of paper charts in CARIS HPD is done using the HPD Paper Chart Editor. A paper chart starts with the workspace definition, and then the necessary templates for the borders, projected grids and scale bars should be created. After the templates creation, a chart and the respective sheet should be created. Each sheet might have one or more panels, and each panel should have a data panel. In each panel it is certainly necessary to modify, delete and add some objects. As HPD database is an implementation of the IHO S-57 standard in a spatial database, some of the database objects will not be needed, some of the needed objects will not be translated to the paper chart, and some will not be assigned to the correct symbols (see Section 5.4.2). When the objects are considered ready to be used in the paper chart, they should be verified to be included in the product (at the moment this is not necessary as is mentioned in Section 5.4.8). The last step is the paper chart export to be printed, which is done in postscript format. The user is able to export all the data or just the current view, adjusting the scale, and has the options to "Render Text as Curves", "Draw Selection" and "Colour Separate" which will generate four different files, each with one of the four colours (black, cyan, yellow and magenta) used in a printing press.

During the evaluation a replica of the Portuguese paper chart (International 1883, National 26408, illustrated in Figure 3.7) has been produced, which was printed with its actual dimensions and compared with the official chart version. The next sub-sections mention some of the findings coming from the paper chart preparation and production process.

5.4.1 Cartographic Attributes Associated with the Objects

When a panel of a paper chart is created, some extra attributes related with the representation are available to some of the features, but the source feature attributes are just read-only. The most common attributes related with the representation are:

- The "Symbolization code" which allow the change of the symbol associated by the introduction of the CARIS Feature Code of the intended symbolization (point, line or area), and is available in most of the object classes;
- The "Angular rotation" which allows the choice of symbol angle, and is only available in some object classes; and

- The “Size” which allows the choice of the symbol size, and is also only available in some object classes.

5.4.2 Objects Representation Modification

The automatic association of the features with the correct symbols is not always possible, because the correspondence between the IHO S-57 objects and the IHO M-4/INT 1 objects is not unique. As an example, tanks and silos have just one IHO S-57 object with one representation in the IHO S-52 (i.e. the SILTNK acronym and a circle representation) but the IHO M-4/INT 1 differentiates the tanks from the silos each one having two possible different associated symbols. This implies that one representation in IHO S-52 corresponds to four possible representations in the IHO M-4/INT 1 [IH, 2003, p.16]. HPD Paper Chart Editor allows the user to define the symbolization using the correspondent “CARIS Feature Code” which gives the user the possibility to choose the preferred symbol. However, to know the correct symbolization code, the user needs to use a tool like the “Master File Browser” to find the correct code of the desired symbol. But, this tool is just available in CARIS HOM not in the HPD Paper Chart Editor. To make this essential functionality available to all CARIS HPD users, it is strongly recommended to include the “Master File Browser” in the Paper Chart Editor and a hard copy of all the CARIS symbols with the respective Feature Codes in the respective Reference Guide.

5.4.3 Issues on the Panel Metadata Change

If a user does a change in a panel metadata after the chart has been saved, closed and opened again, the panel might not be displayed anymore. For instance the central meridian of a Mercator projection was changed and the panel was not displayed until HPD Paper Chart Editor was closed and opened again. It is recommended to solve this issue.

5.4.4 Issues with the Template Editor and Borders

If a border has been created, saved and HPD Paper Chart Editor has closed, when the chart is opened again, if the template editor is activated, the user will not see the border lines anymore (just the text associated with the border lines) until the HPD Paper Chart Editor is closed and opened again. After one border has been created to delete it, the user needs to delete all the cartographic elements. But then, if an attempt is made to create another border, the lines of the new border will not appear, just the text. In reality if the user saves the chart, closes HPD Paper Chart Editor and opens it again, the new lines will appear, but this is a time consuming process.

It is recommended to solve the template editor issue, implement a command to delete all the elements of a border, and review the new border process to allow the new border to be displayed properly after being created.

5.4.5 Possibility of Customize the Datum and the Available Projections List

The users are allowed to change the list of projections available to CARIS HPD in the "mapdef.dat" file, and can add other geodetic datum definitions to contemplate a local datum for instance, which is done by the addition of its datum definitions to the "DATUM.dat" file.

5.4.6 Images Insertion in the Paper Charts

Images are used sometimes in paper charts, especially in the large scale ones to give the navigator a visual description of an object conspicuous to the navigation, such as lighthouses and other conspicuous objects. The IHO M-4 and INT 1 standards mention the possibility of depicting the conspicuous objects as pictorial symbols, sketches and views (e.g. IHO INT 1 IE 3.1 and 3.2 [IH, 2003, p.15], IHO M-4 B-390.1, B-340.7, etc.). The evaluated version of HPD Paper Chart Editor does not allow the users to introduce images on the products, which is an important limitation. So, it is recommended to implement the functionality to depict images on the paper charts in HPD Paper Chart Editor.

5.4.7 Incorporation of Database Updates

HPD Paper Chart Editor does not currently incorporate the database updates. If one object is modified and verified in the database using HPD Source Editor, when the HPD Paper Chart Editor is opened, the update is not included. Also it does not currently allow the creation of new paper chart versions by the incorporation of the database updates since the paper chart was produced.

This implies that if a user wants to produce a new version of the chart, integrating updates, he needs to create the chart from the beginning, or change the existent chart, updating it manually. But, in the last case the old version will be replaced, which is not desirable. In most of the cases this limitation will imply a significant accretion in the processing time. Due to the importance in the creation of new paper chart versions, is recommended to implement the functionalities to integrate the database updates in the workspace and allow the creation of a new paper chart version by the selection of the updates to be incorporated in the HPD Paper Chart Editor.

5.4.8 Verification Process

One of CARIS HPD “rules” is that the products just contain verified objects. But, HPD Paper Chart Editor allows all the objects to be in the final product (i.e. the postscript file). This aspect should be corrected in such a way that only the verified objects will be allowed to be part of a product.

5.4.9 Colour Issues

At the moment is not possible to change line colours on the HPD Paper Chart Editor. All are drawn in black. This is an important limitation since the IHO M-4 and INT 1 specifications indicate some lines in magenta colour (e.g. lines limiting the anchorage areas, harbour areas, restricted areas, approach sectors, etc.). To be compliant with these specifications is recommended to implement in the HPD Paper Chart Editor the functionalities to associate the magenta colour with the magenta lines specified in the mentioned IHO specifications.

The IHO M-4 [IHO, 2002, B-411.6] specification is very flexible in the depth areas tint. The HPD Paper Chart Editor should be able to allow the application of this flexibility in a user friendly way. The functionality is available, but to change the colours of the areas the user needs to edit and change the files “asymrefs.dic”, “ih_colour.col” and “ih_colour.cma”. Also, an explanation of the process is not available to the normal users.

The colours of the symbols lines and areas should be set by default in accordance with the IHO specifications, but an authorized user should be allowed to change the colour of any symbol, line or area just by selecting the object and defining a colour attribute. Is recommended to implement in the HPD Paper Chart Editor the functionality to allow the users to change the colours of any symbol, line or area by the selection of the object and setting the colour attributes in a easy and user friendly way.

5.4.10 Soundings Colour

The soundings in the areas deeper than 5 metres appear in grey colour, which is not compliant with the IHO specifications. But, in the deep blue and green areas (areas between 5 and -3.8 metres depth), it appears in black, meeting the IHO INT 1 II10 [IH, 2003, p.28] and M-4 [IHO, 2002, B-143.3] specifications. This HPD Paper Chart Editor issue should be corrected to comply with the IHO specifications, in such a way that all soundings be shown in black colour.

5.4.11 Soundings Out Of Position

HPD Paper Chart Editor does not currently allow the users to move the soundings or change the depth values. One solution is deleting the sounding and creating another one, which is acceptable as a required security procedure to avoid accidental mistakes. However, the system is not able to represent a sounding out of position in according with the IHO M-4 [IHO, 2002, B-412.2] and INT 1 II 11 [IH, 2003, p.28] specifications. This type of sounding is necessary to be represented very often, due to the existence of other objects in the vicinity that does not allow the required conspicuity to be given to some soundings. This is an important issue, so it is recommended to urgently implement the functionality to represent a sounding out of position in the HPD Paper Chart Editor.

5.4.12 Annotations

Some of the IHO S-57 objects should generate annotations in the respective paper chart (e.g. the characteristics of a light should appear in a paper chart as an annotation). In the HPD Paper Chart Editor the user can select the objects and generate the annotations. The generation of the annotations text has two objectives: to relieve the user from the time consuming process of creating text cartographic objects when an annotation is required, (since the information necessary normally is already in the associated object attribute values); and to create an association between the real world object and the annotation, which means that if the real world object is deleted, the annotation should be deleted too. The concept is good but, the implementation needs to be improved, to not require the user to correct all the created annotations. The annotation corrections are easy because the system allows the users to edit and modify the generated text and its characteristics, but it can be a time consuming process. In the next paragraphs some of the issues discovered with the annotations are related.

In the case of the “sea bed area object” (SBDARE) of the point type geometry questions marks appear at its location. When the annotations are generated, the question marks remain in the background. The solution was the insertion in the attribute “representation” of each SBDARE type point object the attribute value “A040” which corresponds in the CARIS Feature codes to an empty symbol.

In the case of lights, the generation of the light description does not comply with the IHO specifications (INT 1 IP16 [IH, 2003, p.54] and M-4 [IHO, 2002, B-471.9]), because it does not include the light colour in the description. It is possible for the user to correct this problem by the modification of the file “textannotable.xml” located at “C:\CARIS\HPD\PaperChartEditor\2.0\System”, inserting the necessary entries to the system to generate the light colour description. The author did this with success. It is recommended that CARIS change the file supplied to all the users, so as to be compliant with the respective INT 1/ M-4 specifications about the characteristics of the lights. The annotations should implement the following conditions: if the associated structure is a buoy the light description “should be in sloping lettering” [IHO,2002 , B-474.4]; if the colour is just white the colour description can be omitted [IHO, 2002, B-471.3]; if the signal group is one, its description can be omitted too [IHO, 2002, B-471.2], but in this case a full stop should be inserted after the characteristic rhythm.

5.4.13 Compass Roses

Compass roses are widely used in an artistic way to indicate on the chart the magnetic variation. The system has a specific class of cartographic objects ($COMPS), and allows its creation, but does not allow the setting of its attribute values. So, the compass roses created are not rotated and do not draw the information about the magnetic declination automatically. It is recommended to fix this issue. Although the compass roses are just recommended [IHO, 2002, B-261], they are widely used by the HOs.

One available solution is the creation of two cartographic objects of the type symbol compass roses in the same location, one inside the other and rotated the degrees of the declination. The mentioned solution implies the use of linear text to indicate the declination, the year of reference, and the annual variation. The symbol code should be selected from the file "compassrose_masterentries.txt", which has two types of out roses and four types of in roses, and is located on the directory C:\CARIS\HPD\PaperChartEditor\2.0\System.

5.4.14 Source and Reliability Diagrams

The HPD Paper Chart Editor does not currently allow the automatic creation of source or reliability diagrams. Although metadata objects about the data quality may be in the data set, the system does not have any tool to draw those diagrams from the available data. The user can produce them by creating an inset and removing all the unrelated objects. This is a time consuming process, but it is possible to do, as the paper chart produced proved. This is illustrated in Figure 5.7. This process should be automated, so it is recommended to implement a tool capable of generating source and reliability diagrams from the related metadata objects that might be available in the data set, such as the “Quality of data” objects (i.e. M_QUAL) for instance.

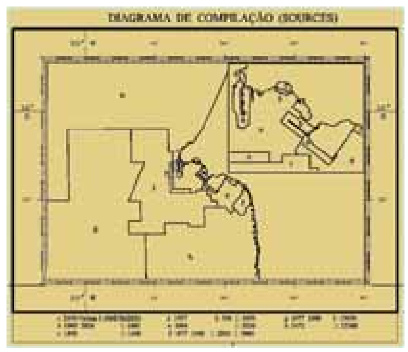


Figure 5.7 – Source diagram built to the paper chart constructed with HPD.

5.4.15 Availability of All IHO INT 1 Symbols

The HPD Paper Chart Editor should have available all types of IHO INT 1 symbols. Some are not available such as one of the INT 1 IQ 40 symbols [IH, 2003, p.60] (mooring buoys) and the marine farm symbol INT 1 IK 48 [IH, 2003, p.37]. It is recommended to include these symbols, and review the CARIS feature codes, to include all the IHO INT 1 /M-4 symbols.

5.4.16 Existing Symbols Customization

If a user wants to modify the size of the symbols that does not have a symbol size attribute available, or create new symbols that are equal to the existent ones, but with a different size, then "ih_master.txt" must be edited. For example to create a new symbol which is equal to an existent but with a different size, a user should copy the lines correspondent to the symbol "Feature Code" and set a different feature code and a different value for how far one symbol will be draw from the previous, and a different size of the symbol. The line thickness may also be changed. But the user needs to edit the file and do the respective changes. This should be a user friendly process with a GUI that allows the user to create new symbols, symbols from the existent ones, with changes in the size, distance between consecutive symbols, line thickness, etc.

On the other hand, the information in the files related with the presentation is only loaded by HPD Paper Chart Editor at startup. This means that when the user does a customization procedure, to view the changes applied the system must be closed and restarted again. To avoid the time consuming restarting process, it is recommended that the HPD Paper Chart Editor implement the functionality, activated by a user command, to reload the presentation information at any required time.

5.4.17 Other Symbolization Issues

The “rock which covers and uncovers” HPD representation, in areas defined by nodes too close together, are different from the IHO INT 1 IK11 [IH, 2003, p.34] and M-4 [IHO, 2002, B-421.2] specifications. CARIS feature codes to define those areas are the “CLLWRLLT” and “CLLWRLRT”. The user could remove some of the objects nodes doing a generalization of the spatial object, but the system should be capable of solving this problem. It is recommended to define other symbols, or review those ones, to be compliant with the mentioned specifications.

The areas that should be filled with symbols are not. For instance a shoreline construction area which are filled by boulders, should be presented as filled by the boulders symbols, but even after assigning the respective CARIS Feature Code to the objects just a double line of boulders are drawn around the lines limiting the area. It is recommended to implement the functionality to fill the areas with the respective symbols when the IHO specifications indicate that should be done.

5.4.18 Lines Limit of Light Sectors

The limits of light sectors are not currently included in the paper chart, even if the information is in the database. As they should be represented, the practical solution applied to the paper chart produced was to add the necessary line cartographic objects and set them to represent the mentioned sectors. But, this process should be done automatically, probably asking the user about the lines length. So, it is recommended to implement the functionality to import and trace the line limits of light sectors on the HPD Paper Chart Editor.

5.4.19 Importation of text from RTF files

The importation of text from RTF files lost some alignment information, and the dashes and quotes have been replaced by inverted question marks. Also the system was not capable of importing long text blocks (i.e. with about 40 lines), so the title and notes text blocks of the produced paper chart had to be divided into smaller RTF files. It is recommended to review the import tool in order to correct the mentioned issues.

5.4.20 Objects Copy and Paste Functionality

The production of a paper chart normally requires from the users the implementation of several cartographic objects. The HPD Paper Chart Editor has a tool to repeat the last created object which is very useful. But the capability of copy and paste existent objects would be much better. It is recommended to implement a tool capable of copying an object after being selected and pasting it in the position intended by the user.

5.4.21 Conclusions on the Paper Charts Production

HPD Paper Chart Editor is an extremely flexible system having a high level of possible customization. Unfortunately at present, this customization process, most of the time, requires that the users have a high level of knowledge about the system internal organization, to edit system files and to do the correct modifications inside the system. This is far from the preferable procedure, not only because of the risk of doing some changes that may lead to serious problems, but also by the high level of knowledge required which may imply a large investment in training. Until CARIS provides Graphic User Interfaces to all those customizations, in the author's opinion, the described flexibilities could not be considered available to the normal users.

With all the available customization, the evaluated version of HPD Paper Chart Editor is not capable of producing a paper chart fully compliant with the IHO standards, due to three unresolved issues. Those issues are the fact that the HPD Paper Chart Editor:

- Is not capable of representing soundings out of position.
- The soundings in depths deeper than 5m are represented in grey, and users cannot change this;
- Users cannot change the lines colours. Anchorage, restricted, harbour and sector approach lines limits, for instance, are represented in black and should be in magenta.

If the next HPD Paper Chart Editor release corrects those aspects it should be able to produce an IHO compliant paper chart. But, to turn it into a really user friendly product, capable of saving significant time in the production process, several other corrections and implementations should be done, as described in the sub-sections above.

5.5 AML Products Production

At the time of this report CARIS HPD does not have an AML Product Editor, so the only way of trying to create AML objects with HPD, was by the extension of the HPD dictionary, which was analyzed and discussed in the Section 5.2.12. It is questionable whether it is possible to extend the HPD dictionary in such a way that it is possible to create AML objects with CARIS HPD. In reality, with the dictionary extension, a user could create objects with the same acronym and attributes as the AML objects. During the evaluation, the HPD dictionary was extended to create three different AML objects, the “Q-route legs”, “Turn Points” and “Mines”, and the respective attributes. As the IHO S-52 presentation library does not recognize them, they appear as question marks, as is illustrated in Figure 5.8. The “Q-route legs” and the “Turn Points” form a collection object “Q-route”. Each leg has been associated with the respective turn points in a collection object C_ASSO (i.e. collection association) and the resultant two collection objects were associated in a collection object C_AGGR (i.e. collection aggregation), in according with the respective AML RAL Product Specifications.

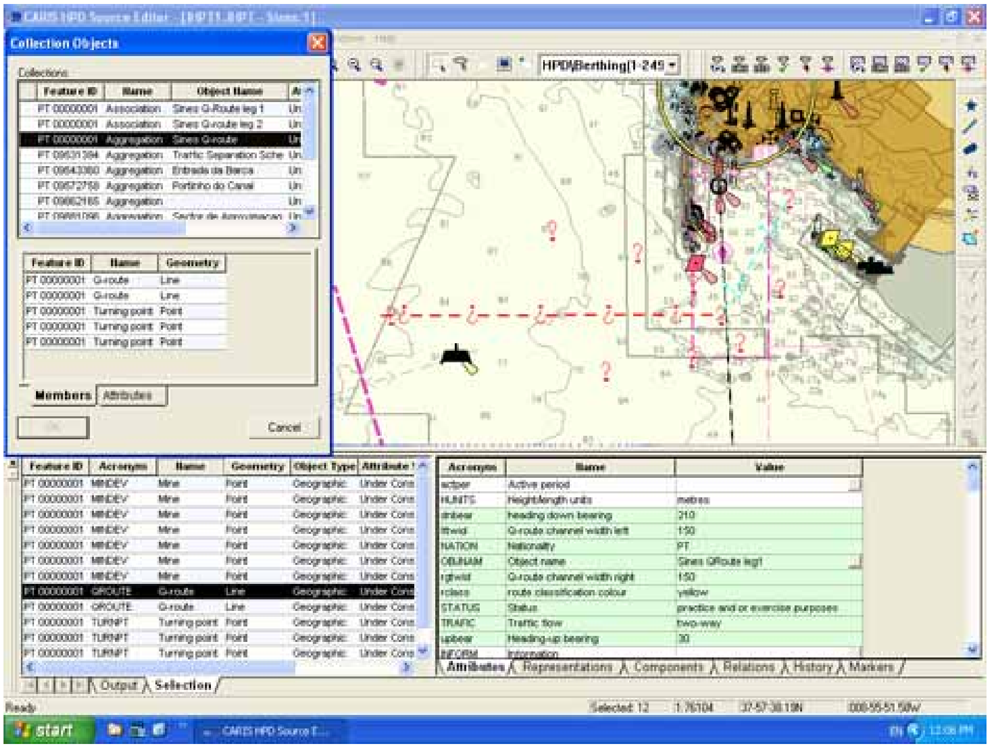


Figure 5.8 - AML objects created by the extension of the HPD dictionary (the acronyms here are in uppercase but is possible to create them in lowercase in according with the AML Products Specifications).

The created objects, with the customization of the HPD Dictionary, could be considered AML objects, because they have the same acronyms and attributes. If they are stored in the database, when HPD AML Products Editor is ready it should be able to recognize and use them. Also if they are exported as an HOB file, for instance, it is probable that they could be imported in CARIS HOM AML. The focus of this report is the CARIS HPD evaluation of AML products production which at the time of evaluation, CARIS HPD is not capable. With the HPD Dictionary extension is possible to create AML objects. But this needs further investigation to verify the possibility of exporting the objects in such a way that a software to produce AML products allows its importation. This is left to a future work. The obvious recommendation to produce AML products is the development of a new HPD specific application that can be called HPD AML Products Editor.

5.6 Suggested Backup Process

Backups are essential procedures in such a valuable system as a database for cartographic production. The implemented backup processes should be capable of maintaining the data and the system, against possible sources of damage (e.g. physical damages due to natural or human causes, hardware problems with the hard disk, virus, bugs in the system, etc.), and be back in operation with the smallest time delay.

The existence of backup tools was not included in the requirements described in the Chapter 2, because, as was mentioned before, this section suggests a backup procedure composed for two different types of backup processes, both independent from the evaluated system.

In the author's opinion, due to the actual large capability and low cost of the hard drives, the periodic copying of the entire server's hard drive with its storage in a fire, theft and physical damages resistant safe, or in separate physical places seems to be the best backup process. The advantage of this solution comes from the fact that by replacing the hard drive, the system should be capable of immediate operations, and even if the server's hardware were destroyed the hard drive can be inserted in a server with similar hardware components. There are some specific tools in the market which allows the copy of an entire hard disk to another such as the Acronis True Image from Acronis, Norton Ghost from Symantech Corp., Partition Magic from PowerQuest, etc. The author tested the process with Acronis True Image version 7.0, cloning the server's 20 GB drive with three partitions into a 80 GB hard disk. The cloning process took about 3 hours. Afterwards the computer was started with only the (cloned) 80 GB drive connected, and CARIS HPD functionality was tested along with the multi-user access. The results were considered excellent as the clone system operated perfectly.

In addition to the above described process, it is necessary to mention that Oracle has a function to do the backup of an entire database which is called "EXP" from exportation. It creates a kind of a snapshot of the entire database allowing is restoration with the "IMP" function. To run the "EXP" function the user just need to type in the Command Prompt "EXP administrator/password@database", where "administrator" should be the administrator user name, and "database" the database name. The advantages of this procedure are:

- It is much faster than the hard disk copy (just took several seconds);
- The system does not need to stop to do the backup;
- The storage is cheaper because the created file will be much smaller (the tested database with data from three ENC cells just needed 20 MB).

But the disadvantages are:

- If the system has more than one database, the process needs to be repeated the same number of times as there are databases;

- If any problem affects the hard disk, in such a way that it is irrecoverable, Oracle and the HPD need to be installed and setup again. This probably will imply more than one day with all the systems stopped.

From the advantages and disadvantages of the two described backup procedures it seems that one complements the other. The backup process and procedures should depend on the organization and the database modification frequency. But, it is probably a good general backup process, to do the Oracle export procedure every day and have three backup hard drives one to copy the hard drive in each week, another to each month and another to each three months. As was mentioned before the hard disks should be stored in a safe place, physically removed from the production system.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

This CARIS HPD evaluation started with the compilation of the general requirements that a typical HO, like the Portuguese one, should have from a DDSNCP to store and manage the cartographic data and produce ENCs, paper charts and S-57 AML products. Sixty two requirements were compiled in Chapter 2. In Chapter 4 an evaluation was conducted for compliance by the HPD software. As is illustrated in Table 6.1 from the sixty two requirements, CARIS HPD is fully compliant with forty (64%), partially compliant with fourteen (23%) and not compliant with eight (13%). It should be noted that CARIS HPD is fully compliant with all requirements related with the ENC products generation.

Table 6.1 – Resume of CARIS HPD compliance with the defined requirements.

RESUME OF THE COMPLIANCE WITH THE REQUIREMENTS				
Requirements	**Fully Comply**	**Partially Comply**	**Does Not Comply**	**Total**
General	6	5	-	11
Workflow Management	3	4	1	8
Data Editing	18	1	2	21
Products Generation	4	2	-	6
– ENC Products Generation	3	-	-	3
– Paper Charts Generation	5	2	3	10
– AML Products Generation	1	-	2	3
Total	**40**	**14**	**8**	**62**

Another main part of the CARIS HPD evaluation was the practical analysis of the data loading, data preparation, ENC production, paper chart production and AML products production. That analysis generated forty-five comments and issues related with the practical aspects. From those, sixteen have been classified as problems. In addition were suggested thirty six recommendations and also a backup process.

Table 6.2 – Resume of the identified problems and recommendations.

RESUME OF THE IDENTIFIED PROBLEMS AND RECOMMENDATIONS		
Section	**Problems**	**Recommendations**
Data Loading, Preparation and General System	3	14
ENC Products Production	-	1
Paper Charts Production	13	20
AML Products Production	-	1
Total	**16**	**36**

As is illustrated in Table 6.2, from the sixteen problems identified, thirteen are related with the paper charts production. Most of the recommendations were related with the paper charts production and the data loading and preparation.

6.1 Conclusions

The possibility of producing the range of cartographic products from a single dataset based in a database, will allow the implementation in the HOs of a most efficient cartographic production, with a significant economy of resources, more flexibility in product production and with an important simplification in data storage, updating and management.

CARIS HPD concept is extremely flexible, with a high level of possible customization which is expected in the future to be available to the normal users in a user friendly way, by the implementation of GUIs.

In terms of data loading, storage and editing capabilities, the system has all the necessary functionalities, which will be improved soon when the related recommendations are implemented.

In the production of S-57 ENC products no problems were detected.

In the production of paper charts, CARIS HPD is almost compliant with the IHO specifications. In according with CARIS prediction stated in Appendix IV, by the fall of 2004 it is expected that HPD Paper Chart Editor will be capable of producing paper charts fully compliant with the IHO specifications. But, several recommendations need to be implemented until all the stated issues are resolved. However, it should be mentioned that the economy in time and resources provided now it is already significant even with all the described issues.

As the modification of an existing cartographic production organization is a long task, if an HO wants to start to change its cartographic production into a more efficient organization, with a significant economy of resources and achieving a large flexibility in the products production, CARIS HPD at the moment is a system with important potential, capable to be in the near future a complete cartographic production solution.

6.1.1 Contributions

With this report the author believes that significant contributions to several kinds of persons and organizations have been provided.

In relation to CARIS, the author believes that in addition to issues described and the recommendations provided, the most important contribution was the fact that the evaluation was done with the perspective of a typical user from a typical HO. So, he believes that he has given an important contribution to the CARIS HPD evolution in the direction of meeting the real needs of a typical HO, such as the Portuguese HO.

In relation to an HO interested in starting to change their cartographic production with a DDSNCP, this report contributes with a list of general requirements which certainly will be helpful in its specific requirements elaboration, and provides an in-depth and neutral analysis of one of the most representative systems, CARIS HPD. Moreover this report can contribute to aid HOs to conclude if it is the right time and if CARIS HPD is the right product to revolutionize its cartographic production. Also, it can provide to these HOs with some information that can help in deciding how this revolution should be done and how the new organization should be planned.

In relation to the HOs that have already bought CARIS HPD, this report contributes with an in-depth and independent analysis of the actual CARIS HPD potentials, highlighting to some of the customization possibilities, with a description of some procedures to perform this. Also the evaluation proved that HPD Paper Chart Editor is almost capable of producing paper charts fully compliant with the IHO specifications. It is expected that this editor will be fully IHO compliant in the near future, as described in Appendix IV.

In relation to the Portuguese HO, the author believes that after purchasing the system, this report is the second step in the centralization of its cartographic production in CARIS HPD.

In relation to any one interested in knowing more about the topics covered by this report, it provides information about the CARIS HPD, complemented by a in-depth analysis of the system, it also provides information about Electronic Navigational Charts, Electronic Chart Display and Information Systems, Additional Military Layers, Spatial Database and Management Systems, and Database Driven Systems for Nautical Cartographic Production.

6.2 Recommendations

The natural final recommendation after this evaluation of CARIS HPD is for CARIS to implement the thirty six recommendations, following the priorities assigned to each one as stated in Appendix IV.

As some of the recommendations are more important and/or urgent than the others I especially recommend the following:

- Implement the user roles functionality in the HPD (Section 5.2.5).
- Implement the markers functionality on the HPD Paper Chart Editor and on the ENC Product Editor (Section 5.2.8).
- The unlocking process activated when the editor saves the changes, should be activated also when a user does not make any change to an object and finishes editing, to make them available to be edited by other users (Section 5.2.9).
- Implement the “HOB files importation” tool (currently implemented in HPD Source Editor) on HPD S-57 ENC Product Editor and on HPD Paper Chart Editor, (Section 5.2.11).
- Implement a “Master File Browser” in HPD Paper Chart Editor, and include all the CARIS symbols with the respective Feature Codes in the respective Reference Guide (Section 5.4.2).
- Implement in HPD Paper Chart Editor, the functionality to depict images on the paper charts (Section 5.4.6).
- Implement in HPD Paper Chart Editor, the functionalities to integrate the database updates in the workspace and allow the creation of a new paper chart version by the selection of the updates to be incorporated (Section 5.4.7).
- Fix the problem in HPD Paper Chart Editor that allows all objects, verified or not verified to be part of a product (Section 5.4.8).
- Implement on HPD Paper Chart Editor the functionalities to associate the

magenta colour with the magenta lines specified in the INT 1 / M-4 IHO specifications (Section 5.4.9).

- Correct the “rock which covers and uncovers” representation when the nodes are too close, to be like in the IHO INT 1 IK11 [IH, 2003, p.34] and M-4 [IHO, 2002, B-421.2] specifications (Section 5.4.17).
- Implement the functionality to fill the areas with the respective symbols when the IHO specifications indicate that (Section 5.4.17).
- Develop an HPD AML Products Editor.

The final conclusion of this report, related with the problem addressed in the “Introduction”, is that CARIS HPD already satisfies most of the cartographic requirements that a typical HO like the Portuguese Hydrographic Institute should have from a system to store and manage its cartographic data and produce ENCs and paper charts, which means all the range of cartographic products in the incumbencies of a typical HO. For ENCs, CARIS HPD already meets all the requirements. It is not yet capable of producing paper charts fully compliant with the IHO specifications, but is expected to be so soon. The production of AML products is not possible at the moment, being certainly dependent on the development of an AML Product Editor.

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APPENDIX I

ELECTRONIC CHARTS AND ECDIS

APPENDIX I

ELECTRONIC CHARTS AND ECDIS

In this appendix is provided additional information about the topics mentioned in the chapters of this report, in particular the ENCs, the IHO S-57 and S-52 standards and the ECDIS. This appendix starts by introducing the two basic formats of the electronic charts, the vector and raster formats. The IHO S-57 exchange standard due to its importance to ENC and AML products is analyzed in detail. The requirements to be an ENC are stated and it is defined what a System Electronic Navigational Chart (SENC) is. Then are analyzed, the ECDIS, related specifications, advantages and problems in its acceptance.

A joint study between U.S. - Canadian of the West Coast Shipping completed in 1990, concluded that the use of Electronic Chart Systems (ECS) was expected to prevent 15-19 per cent of the maritime accidents [NOAA, n.d., p.16].

The contribution to improve the navigation safety is the most important factor to the electronic charts success, due to the extraordinary costs that a maritime accident could represent, such as the loss of cargo and ship's loss or damage, but principally the uncountable ones, like the loss of lives and the environmental damages. Due to the inherent advantages of each, the two basic different formats of electronic charts, raster and vector, had been developed.

I.1 Raster and Vector Electronic Charts

The raster and the vector types of electronic charts are very different in the concept, but both have the same objective, the representation of the real world. To reach this objective they employ different solutions, as illustrated in Figure I.1.

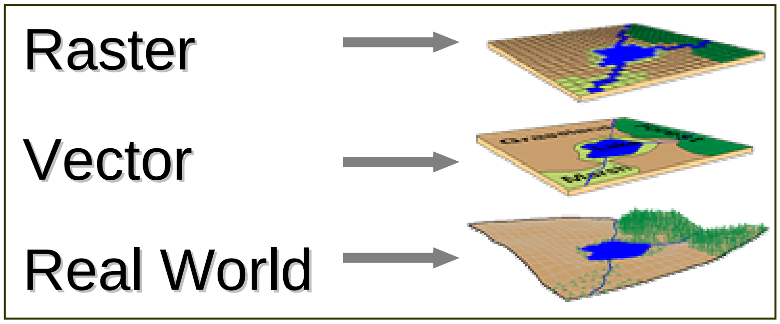


Figure I.1 - Raster and Vector representations of the real world (from Navigator of the Navy [n.d., p.2]).

Raster charts have been created mainly from digitizing of paper charts, having by result a bitmap image with the data stored as cell values, called picture elements (pixels), in a rectangular grid. However sometimes called “dumb images” the raster charts look like the paper charts, with the same colors and the same symbols, which is very important to the navigators, comfortable with paper charts. Also, due to the simplicity of the process they are easy and inexpensive to produce.

Vector charts are created from the representation of the real world objects boundaries, with points, lines and polygons. The objects may have associated spatial attributes related with its spatial distribution and descriptive attributes used to store its non spatial characteristics.

Topological relationships are the relations (not dependent on the coordinate system) among the objects representation (e.g. connections, contiguous, contained, etc.) and can be represented in different levels, from the level zero (cartographic spaghetti) to the level 3 (full topology). Due to the fact that "the most part of the spatial analysis can be done recurring largely or entirely to the topology" [Manteigas, 2003, p. 8], various authors say that the topology is used to make a vector chart "smarter".

The most important characteristics of the vector charts in the author's opinion are the easy computations of distances between features, which allows the implementation of warnings dependent of distance conditions, and the possibility of "interrogating" features to display some of its selected attributes, providing additional information to the navigator.

In the tables below is given a summary of the mainly comparative advantages and disadvantages of both raster and vector charts.

Table I.1 - Summary advantages and disadvantages of the raster charts.

	Advantages	**Disadvantages**
Raster	- Look like paper charts familiar to the navigators; - Cheaper and simpler to produce; - Worldwide availability; - When used in ECS provide more advantages than the paper charts.	- Simply an array of pixels that cannot be interrogated (just a dumb picture); - Generally involves larger files; - Updates are more difficult to perform, normally imply the replacement of the file or a part; -Zooming only magnifies the view.

Table I.2 - Summary advantages and disadvantages of the vector charts.

	Advantages	Disadvantages
Vector	- Some display information can be selected; - Remain sharp and clear at all zoom levels; - Features can be interrogate for additional information in a ECS; - Allow a set of alarms and are easier to integrate with other data sensors; - Normally imply few amounts of data; - The updates could replace just the affected features.	- Look different from paper charts; - More complex, costly and longer to produce; - Standards are subject to changes; - Does not have a worldwide availability (the DNC does but are military charts with the best available data not complying with the IHO requirements).

I.2 IHO S-57 Transfer Standard

In the nineteen eighties, several electronic charts and electronic chart systems appeared in the market, allowing the use of the electronic charts and the integration of its information with the information from other systems. Most of the charts were raster but some were in vector format. However each basic format had multiple different sub formats, with different data structures that implied the inherent incompatibilities in its use. These incompatibilities created several problems to the users and the systems producers. At the same time Hydrographic Offices (HOs) had started to collect survey data in digital format. To avoid the large costs that represent the duplication of the data collection and processing, they need to exchange among them the collected data. The need of standards to allow the data compatibility was like this imperative.

After some initial steps that included the presentation and approbation of a draft of the standard during the XIIIth International Hydrographic Conference in May of 1987 [Pais, 1995, p.21], the International Hydrographic Organization adopted in the XIVth International Hydrographic Conference, in May of 1992 a standard "*to be used for the exchange of digital hydrographic data between national Hydrographic Offices and for the distribution of digital data and products to manufacturers, mariners, and other data users*" [IHO, n.d.a]. The standard called "IHO Transfer Standard for Digital Hydrographic Data", published with the name of "Special Publication S-57", become known in an abbreviated way as "S-57". Edition 2.0 was published in March of 1994, and in November of 1996 Edition 3.0 was released including for the first time an ENC Product Specification. In November 2000, as mentioned by the IHO [2000, p. i], Edition 3.1 was implemented, the one currently in effect. In the beginning was decided that this Edition would remain unchanged until November 2002, but to give some stability to the standard and to encourage the HO and the manufacturers in the discussion of the future Edition 4, in December 2002 the Transfer Standard S-57 Maintenance and Application Development Working Group (TSMAD WG) decided to freeze Edition 3.1 indefinitely [TSMAD, 2002].

I.2.1 IHO S-57 Edition 3.1

In this section, IHO S-57 Edition 3.1 is analyzed in detail, so, unless otherwise stated, all information in this section comes from IHO [2000].

The IHO Special Publication No. 57 Edition 3.1 is organized in three parts and two appendices:

- Part 1 - General introduction with a list of references and definitions.
- Part 2 - The theoretical data model where is described how the real world is modeled.
- Part 3 - The data structure where is described the data model implementation and delineated the rules to encode the data.
- Appendix A - The Object Catalogue - contain all objects and the attributes that could be included in the IHO S-57 files.
- Appendix B - The IHO approved Product Specifications that define the specific rules to each particular product. The two product specifications are:
    - B.1 - ENC product specification, with the specific rules to produce electronic navigation charts;
    - B.2 - Object Catalogue Data Dictionary, with the specific rules to encode the data dictionary exchange set based on the object catalogue.

To encapsulate the data, IHO S-57 uses the international standard ISO/IEC 8211 (“Specification for a data descriptive file for information interchange”), which “provides a file based mechanism for the transfer of data from one computer system to another, independent of the make and the medium used to establish such a transfer", permitting "the transfer of data and also the description of how such data is organized" [IHO, 2000, p.1.1].

One of the characteristics of the IHO S-57 is the fact that the standard only provides the means for the description of the data, in this case the hydrographic entities of the real world. The standard does not contain rules for the presentation or display of the information. With this, the standard gains versatility and flexibility allowing the use of the data for different proposes, without requiring a change in the structure or in the content, just using a different presentation model. But, this gain is paid with the fact that each application must provide is "presentation model" and the same data will be presented in different ways depending on it (e.g. the same data will be presented in a different way in an ECDIS or in an application that have a paper chart presentation model).

IHO S-57 objective's is permitting the transfer of data describing real world entities relevant to hydrography. To do this, as illustrated in Figure I.2, the standard started to simplify the real world by modeling the reality, what is described in the **Data Model**. After, the resulting model must be translated into named constructs (e.g. records and fields), that results in the **Data Structure**. In the end, to allow the translation directly from one computer system to another, the data structure must be encapsulated in a **physical transfer standard**, the ISO/IEC 8211.

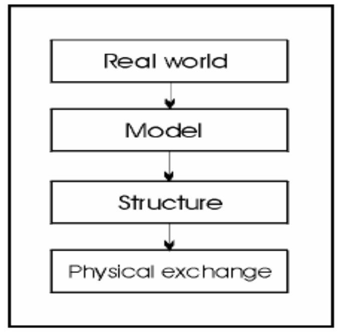


Figure I.2 – IHO S-57 phases from the real world to the physical exchange (from IHO [2000]).

I.2.1.1 – IHO S-57 Data Model

To model the real world entities, the data model considers each real world object that may have attributes and may be related with other objects, could be model as a combination of:

- **Feature objects** - only contains descriptive attributes;
- **Spatial objects** - may have descriptive attributes and must contain information about shape and position.

As illustrated in the Figure I.3, a feature object may be related with none, one or more spatial objects to describe its location and shape, but each spatial object must be related with at least one feature object. For instance, the objects from the object class “Compilation scale of data” (M_CSCL) do not have spatial objects associated.

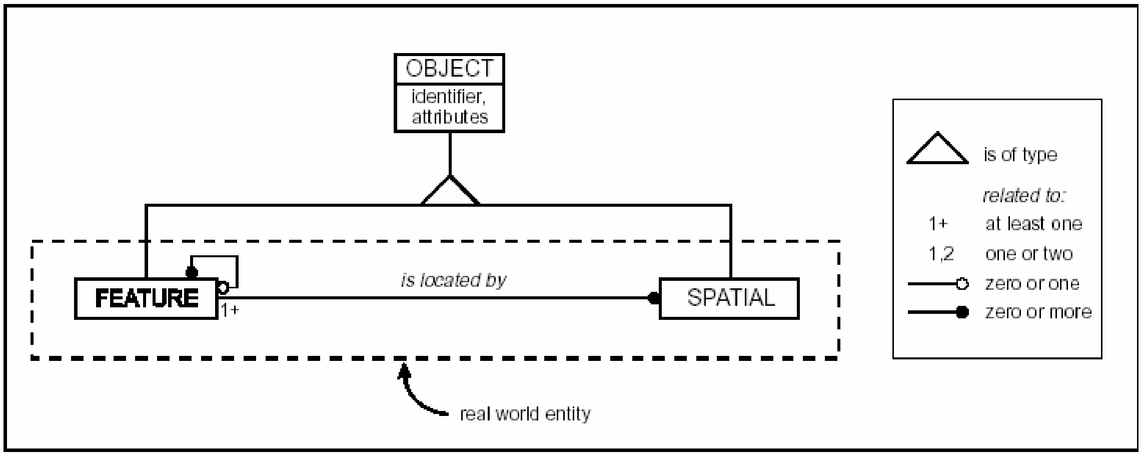


Figure I.3 – IHO S-57 object data model (from IHO [2000, p.2.1]).

The theoretical data model is showed in the Figure I.4, where are illustrated the four types of feature objects, and the only type of spatial objects, the vector type, but where are already mentioned the two encoding formats that could be included in a future version of this standard, the raster and the matrix formats.

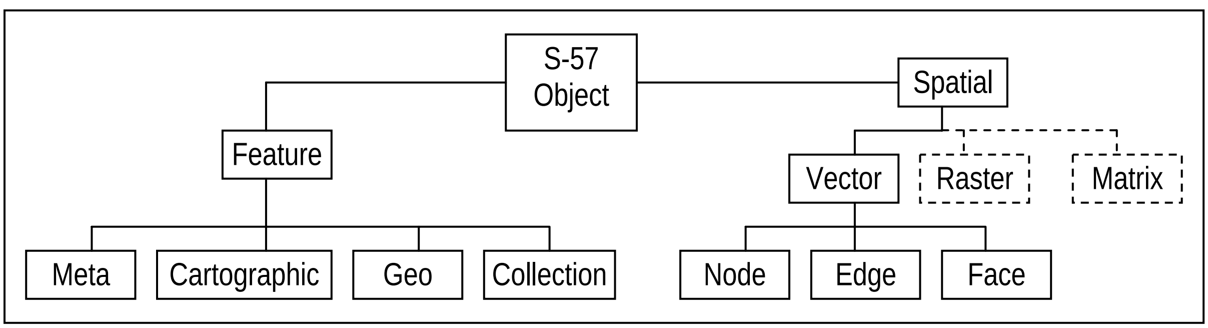


Figure I.4 – IHO S-57 theoretical data model (after IHO [2000, p.2.2]).

The four types of **feature objects** are:

- **Meta -** contain information about other objects (e.g. compilation scale);

- **Cartographic** - contains information about the cartographic representation (e.g. the acronym $CSYMB represents a point with a cartographic symbolization);
- **Geo -** carries the description of the real world entities (e.g. Cardinal beacon);
- **Collection -** describes the relationship among objects (e.g. aggregation, association and stacked on/stacked under). The lines that form a traffic separation scheme are aggregated, a buoy is associated with the wreck that it marks, and a bridge is stacked on a road.

The spatial objects should be implemented as the following topological entities, illustrated in the Figure I.5:

- Nodes - Unique point of the real world.
- Edges - Represents the topological boundary of a face or the location of line features.
- Faces - Used to represent polygonal topological faces.

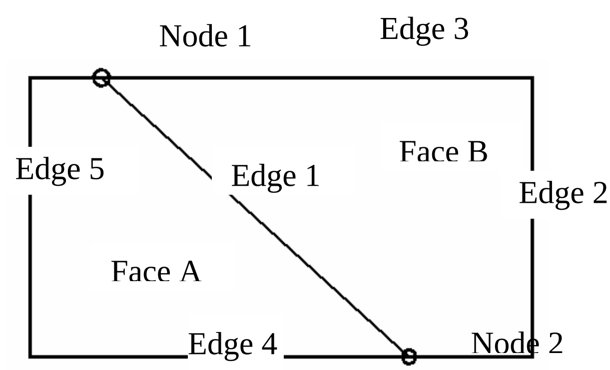


Figure I.5 - Topological entity types.

Topology, that can be briefly defined, as how geometric features are related among themselves, but just the relationships that with changes in the coordinate system do not change (e.g. connected, contiguous and contained), can be organized into four topological levels described on IHO [2000, p. 2.4] and illustrated in the Figure I.6:

- Level 0 - Cartographic Spaghetti. It is a non topological level, without any related nodes and edges. Edges do not have referring nodes, nor have nodes in the beginning or in the end. Vector objects are not shared;
- Level 1 - Non-Planar graph (Chain-node). Nodes could be connected or isolated. Edges must refer to nodes in the beginning and in the end. Edges can intersect at a node but is not required. Areas are coded as close edges. Vector objects may be shared;
- Level 2 - Planar graph where all edges are required to intersect at a node. Vector objects may be shared;
- Level 3 - Full Topology. It is a planar graph allowing the modeling of area features (faces). The isolated nodes may refer the containing faces and edges must refer the faces at left and at right. Vector objects may be shared.

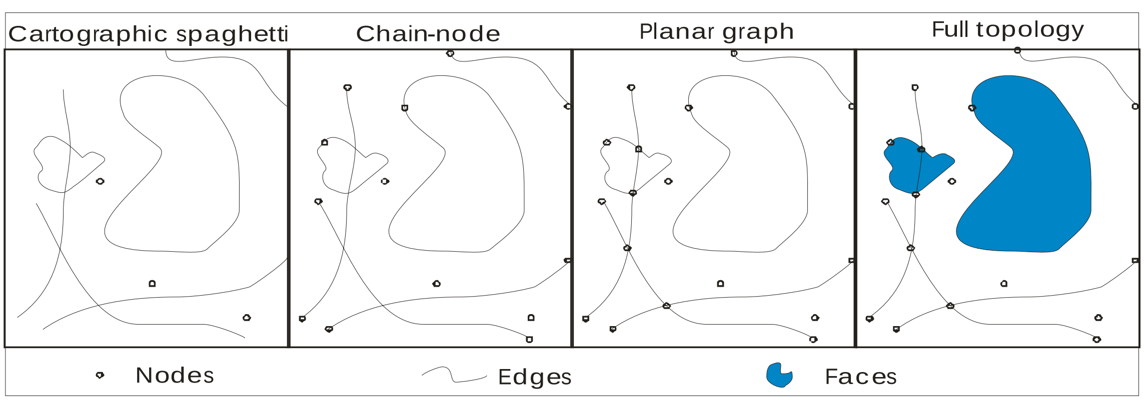


Figure I.6 - Representation of the same objects in different topological levels.

I.2.1.2 – IHO S-57 Data Structure

The data structure defines how the data model is implemented, this is, how the data model is translated into the data structure.

The modeled data is translated into constructs; **objects** (spatial, feature, nodes, edges, faces, etc.) are encoded as **records**, **attributes** are translated as feature or spatial attribute **fields**, and **relationships** are translated as **pointer fields**.

As is illustrated in Figure I.7, the exchange set encapsulated in the ISO/IEC 8211 is composed by one or more files. Each file is composed of one or more records and each record have one or more fields. The fields may have subfields that are the lowest element of the construct's level, and must only contain one elementary data item (e.g. one attribute value).

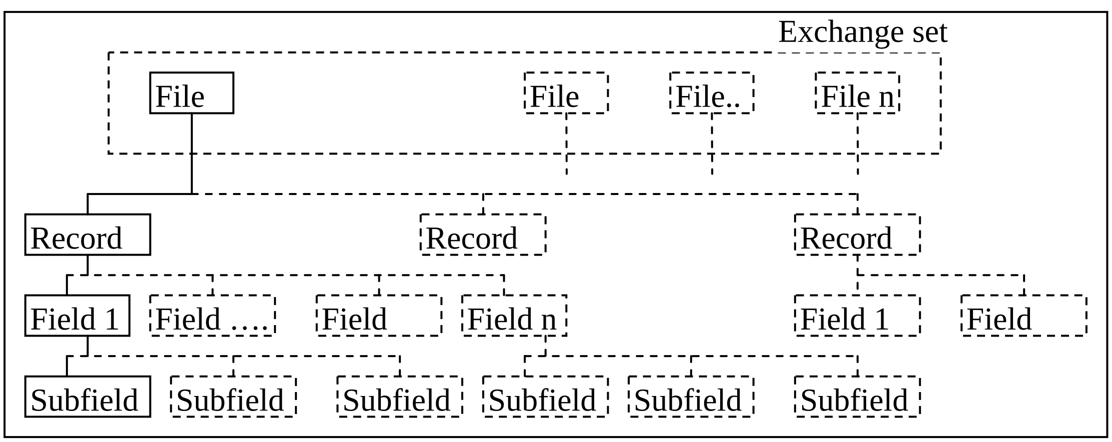


Figure I.7 - Data structure constructs and exchange set (after IHO [2000, p. 3.2]).

The five categories of records defined in the IHO S-57 are:

- **Data Set Descriptiv**e - containing dataset metadata such as the general purpose and nature (e.g. product specification, compilation scale, units, origin of the data and accuracy of the location data).
- **Catalogue** - containing a kind of a “table of contents” with the information about the files location in the exchange data set, and the related records that are a result of the model of real related objects.
- **Data Dictionary** - containing the description of the objects used in the exchange set that are not described in the IHO Object Catalogue.
- **Feature records -** containing the non-spatial data of the real world objects mentioned before (e.g. Meta, cartographic, geo and collection), and including the relationships and update instructions.
- **Spatial records** - containing the objects spatial data that includes the coordinate geometry, the topological relationships and update instructions, in this edition only in the vector format.

I.2.1.3 - ENC Product Specification

IHO S-57 was created to support all kinds of hydrographic data exchange, but as different products need different rules to implement their respective data structure, the Standard defines specific “Product Specifications” for each product. The ENC Product

Specification, established the specific rules for ENC products. In this product specification are considerate six groups of **navigational purposes** and the respective codes, 1 - Overview, 2 - General, 3 - Coastal, 4 - Approach, 5 - Harbour, and 6 - Berthing.

An ENC is organized in **cells**, each one covering a geographical area limited by parallels and meridians with an extension that implies less than 5 Megabytes of data, but at the same time, not being too small to avoid the necessity of have a large number of cells.

Only the objects and attributes defined in the IHO Object Catalogue may be used, but some of them are not allowed on the ENC because the IHO S-57 had a broader purpose than just the ENC and the use of some objects are not adequate (e.g. the M_UNIT object used to store the units of data measurement is not allowed because the units are the same for all ENC and are defined in the ENC Product Specification). In the same way the use of Cartographic objects is prohibited.

In terms of **topology**, the ENC data must be encoded using the topological level 1, the **chain-node** topology.

In an ENC all the geographic feature objects are located in **two different groups**:

- Group 1 - **skin of the earth**;
- Group 2 - **all other** feature objects which are not in Group 1.

In the group 1 all feature objects must be from the type area, and must contain the feature objects considered so important to the safety of the navigation that when the ENC transformed in SENC is displayed in an ECDIS are always visible (e.g. DEPARE

(Depth Area), DRGARE (Dredged Area), FLODOC (Floating Dock), HULKES (Permanently Moored Ship), LNDARE (Land Area), PONTON (Pontoon), and UNSARE (Unsurveyed Area).

The **horizontal datum** must be the WGS 84 and should be used the **Vertical and sounding datum** used on the paper charts of the area, **no projection** is used and the coordinates must be encoded as geographical positions (latitude, longitude).

An **exchange set** is composed of at least two types of files: one catalogue file and at least one data set file. Text and picture files may also be included in the ENC exchange set, in ASCII and TIF formats. The catalogue file must be named CATALOG.EEE, where EEE should be the edition number of IHO S-57 (i.e. 031 for the Edition 3.1). The name of the ENC data set files must be on the form CCPXXXXX.EEE, where the **EEE** must be the update number, the **XXXXX** the individual cell code, **P** the code of the navigational purpose and the **CC** the producer code. Four kinds of data sets may be produced:

- **New** - if is the first ENC for the area.
- **Update** - if the objective is changing some information in the data set.
- **Re-issue** - if includes all the updates applied to the original data set up to the date of the re-issue.
- **New edition** - if includes new information not previously distributed by updates.

The Data Quality is considered meta information described by meta objects and attributes, comprising: the data source; quality, reliability and accuracy of data - given by several meta objects and attributes (e.g. **M_QUAL -** quality of bathymetric data, **M_SREL -** additional information about the survey); and, Up-to-date ness of data (given in the file name extension and in the "Update Number").

I.3 ENC Requirements

In the Section 2.2 of the International Maritime Organization (IMO) Performance Standards for ECDIS [IMO, 1995], is defined that:

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

As is illustrated on the schema of the Figure I.8 and explained by Alexander [n.d.a], to be considered an ENC, an electronic chart must be in the **vector format**, conform to the **IHO S-57** and the **ENC Product Specification** and should be the **latest edition** of information originated by a government-authorized **Hydrographic Office**.

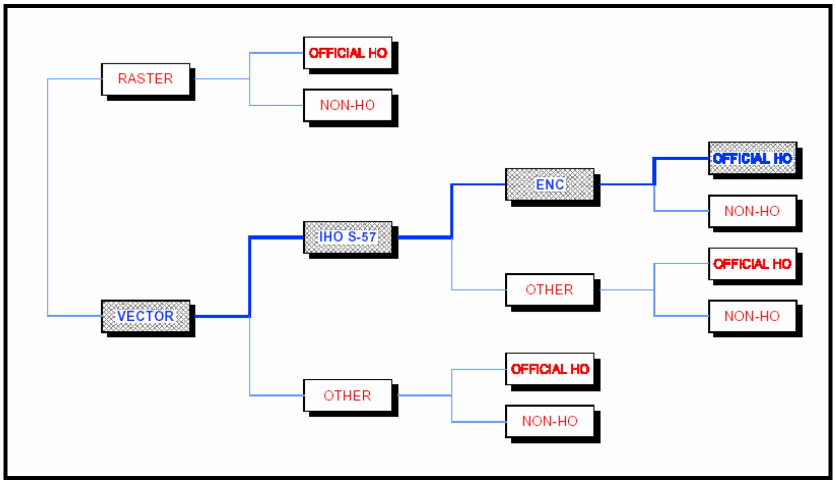


Figure I.8 - Schema of the requirements to be an ENC (from Alexander [n.d.a]).

The present coverage of ENCs is increasing, but the coverage is far from complete worldwide.

I.4 - SENC

The most relevant application of the ENC is its use in an ECDIS to constitute a navigation tool capable of contributing to improve the navigation safety, helping the navigator in is navigation tasks.

But, the IHO S-57 format "*is recognized that it is not the most efficient means of storing, manipulating or preparing data for display*" [IHO, n.d.b]. To be capable of being used in real time conformable with all the requirements stated on the IHO [1996] "Specifications for Chart Content and Display Aspects of ECDIS" (S-52), specially the image screen refreshment requirements, with a limit of 5 seconds to the ships progress, changes in scale or in the area [IHO, 1996, p. 17]. The ENC data which is in a system independent format should be transformed in an internal proprietary system format, optimized for the display operations of each ECDIS. The system resultant from the transformation is called SENC, defined in Section 2.3 of the IMO Performance Standards for ECDIS [IMO, 1995].

> *"System electronic navigational chart (SENC) means the* ***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 of an up-to-date paper chart****. The SENC may also contain information from other sources."*

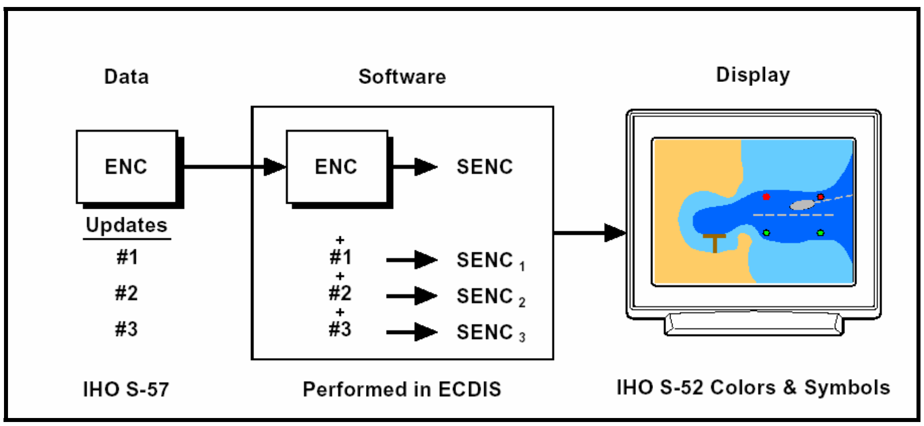


Figure I.9 - Transformation of ENC and updates into an ECDIS display (from Alexander [1998]).

Like is mentioned by the IHO [1996, p. B.3], the ENC data should never be altered, this is to allow the reconstruction of the SENC if necessary, so, the updates should be stored separately from the ENC and just update the SENC data.

The transformation of the ENC and respective updates in the SENC, illustrated in the figure I.9, until recently was done exclusively on board by the ECDIS software. However, as is stated by IHO [n.d.c], in the 16th International Hydrographic Conference, (Monaco 14 -19 April 2002), the decision “IHO 17.e” allow that the ENC data will be distributed in a proprietary SENC format, what is called “SENC Delivery Option". This is important, not only to the shipping companies that can save time and do not have to handle with unusual errors from the transformation process, but also to the chart suppliers because each SENC only can be read in one equipment with a license from the controller of the SENC format. However, still mandatory that every ECDIS must be capable of accepting and converting ENC data into a SENC, and the HO should ensure that the ENC data is always available [IHO, n.d.b].

Being a proprietary format, SENCs from different manufacturers are different, but the final display of the same data should be similar due to the conformity with the IHO S-52 specifications.

The process of transforming the ENC and updates in a SENC is treated by almost all documents as a kind of a “black box”, as a manufacturer’s secret, but some aspects of the process are evident. Besides the transformation in a proprietary format optimized for the specific system, like is mentioned by Navigator of the Navy [n.d.] and supported by Rodriguez and Astle [n.d.] one important aspect of the transformation is the topology construction from the chain-node level of the ENC to the full topology. In the chain-node (topological level 1) the areas are represented by close loops of edges, because the topological entity that represents areas, the face, is not defined. Just in the full topology (topological level 3) the faces are defined, but the ECDIS software during the navigation need to know very quickly, mainly due to the refreshment requirements, which entities are areas to fill it and allow computations such as the safety contour [Rodriguez and Astle, n.d.], so, its computation “on the fly” is not a good option. Figure I.10 illustrates the difference between the chain-node representation, just with nodes and edges and the SENC representation with the nodes, edges, faces and symbols associated with the respective features.

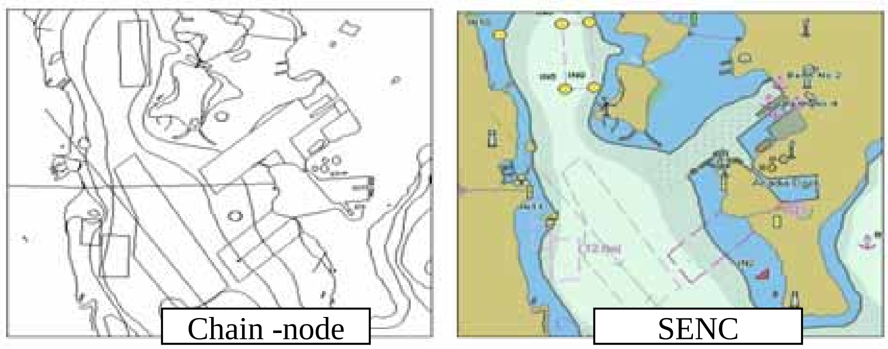


Figure I.10 - Chain-node and respective SENC representation (from Pacheco [2000, p.18]).

I.5 ECDIS

IMO in the Electronic Chart Display and Information System (ECDIS) Product Specification [IMO, 1995] defines the ECDIS as:

> *“A navigation information system which with adequate back-up arrangements can be accepted as complying with the up-to-date chart required by regulation V/20 of the 1974 SOLAS Convention, by displaying selected information from a System Electronic Navigational Chart (SENC) with positional information from navigation sensors to assist the mariner in route*

planning and route monitoring, and if required display additional navigation-related information."

In a simplified way, an ECDIS is a navigation aid capable of integrating and displaying information from several navigation sensors and systems with cartographic information from a SENC. The ECDIS' main objective is to be a navigator tool capable of contributing to improve the safety of the navigation, helping the navigator in its navigation tasks.

I.5.1 - ECDIS Specifications

ECDIS specifications are distributed by several documents originated by three different organizations, the International Maritime Organization (IMO), the International Hydrographic Organization (IHO) and the International Electrotechnical Commission (IEC). This spread of specifications is due to the multidisciplinary areas of responsibility that the ECDIS involve, as illustrated in the Figure I.11.

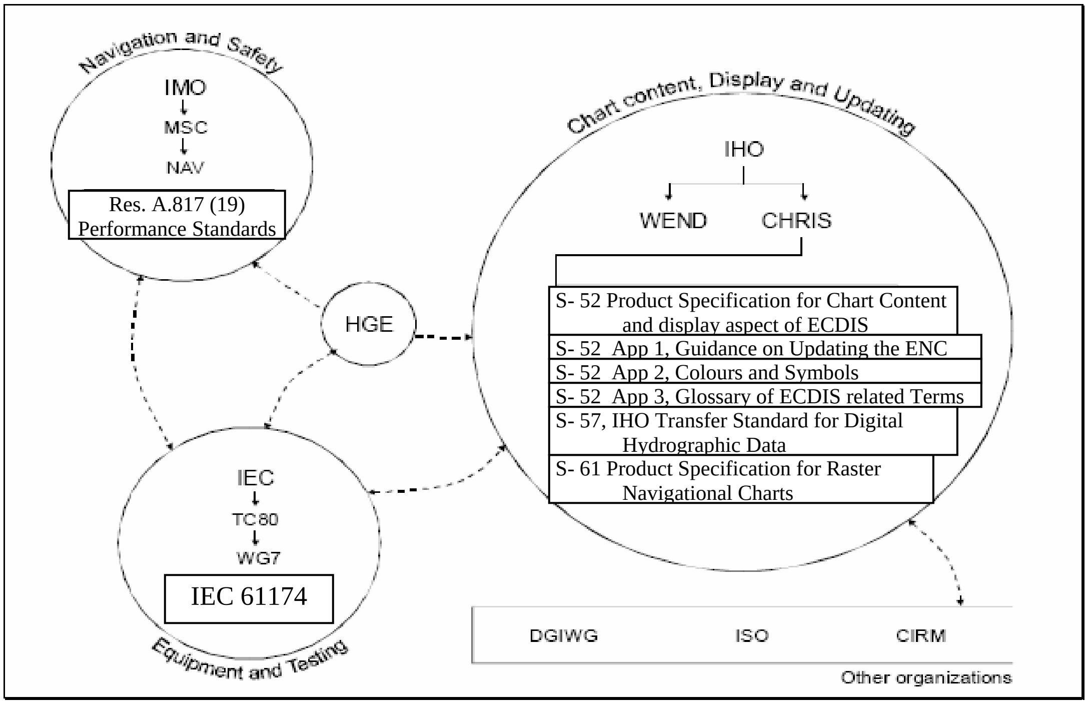


Figure I.11 - Organizations involved in ECDIS specifications (after IHO [1996, p.3]).

I.5.1.1 - IMO

After the "*Provisional Performance Standards for ECDIS which were first published in May 1989 by the IMO"* [IHO, 1996, p.2], in 1995, the IMO Resolution **A.817 (19)** "**Performance Standards for Electronic Chart Display and Information Systems (ECDIS)**" was edited. In this resolution is described the requirements to be considered an ECDIS, and in Section 2.1 is stated that the "ECDIS 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" [IMO, 1995]. In this Standard is also given the definitions of ENC, SENC and ECDIS stated in this report in the respective sections. With the definition and specification of the rules to be and ECDIS is defined as well that an Electronic Chart System is all the other electronic chart systems that not meet the IMO Performance Standards.

In 1996, the IMO Maritime Safety Committee (MSC) in the **Resolution MSC.64(67)** adopted several amendments to their performance standards where is included the Annex 5 "Back-Up Requirements**",** that will be the Appendix 6 of the "Performance Standards for Electronic Chart Display and Information Systems (ECDIS)" [IMO-MSC, 1996, p. 37 - 40] to clarify the backup requirements to the ECDIS. These requirements still not very clear, but in the author's opinion, based on the mentioned resolutions could be:

- A second ECDIS that complies with the resolution **MSC.64 (67)**;
- A portfolio of up-date official nautical paper charts;
- An ECS that complies with the resolution **MSC.64 (67).**

In December of 1998 was adopted the **Resolution MSC.86 (70)**, the Annex 4 is dedicated to the Resolution A.817 (19) and have several amendments that implement in the "Performance Standards for ECDIS" the permission, under the stated rules, to use Raster Navigational Charts (raster charts originated or distributed on the authority of an hydrographic office) in an ECDIS when ENC data are not available. But, "when operating in the RCDS mode, the ECDIS should be used together with an appropriate portfolio of up-to-date paper charts" [IMO-MSC, 1998, p. 15], because are not accepted as complying with the up-to-date charts requirement of the V/20 International Convention for the Safety of Life at Sea (SOLAS) [IMO, 2004].

I.5.1.2 - IHO

The IHO Standards related with the ECDIS could be divided in two main different categories, two related with the data and one related with the ECDIS content and display.

As was mention in the IHO S-57 section of this report, in May of 1992 the IHO adopted the "**IHO Transfer Standard for Digital Hydrographic Data - Special Publication No.5**7", a standard "*for the exchange of digital Hydrographic data*" [IHO, n.d.a]. This standard in the current Edition 3.1, define the data model and data structure of the hydrographic data in vector format, include an Object Catalogue and two Product Specifications, one for the ENC data production and the other the Object Catalogue Data Dictionary. With a broader objective, the exchange of all hydrographic data, more related with the ECDIS are the ENC data format definition and the updates structure.

After the IMO **Resolution MSC.86 (70)** adopted in December of 1998, define the rules to be permitted the use Raster Navigational Charts in ECDIS when ENC are not available, the IHO published in January of 1999 the first edition of the "***Product***

Specification for Raster Navigational Charts (RNC)-Special Publication No. 61". The objectives of this publication are stated in the Sections 1.1 and 1.2 are:

"*Define the minimum requirements a Raster Navigational Chart (RNC) must have to satisfy the draft performance standard for a Raster Chart Display System (RCDS)*", but "*does not define underlying raster data structures of a raster navigational chart*", this should be defined by the data producer, a national HO [IHO, 1999].

The responsibilities of the IHO with the ECDIS issues are not just related with the cartographic data, also includes the data display and updating, so, besides the standards related with the data, the IHO developed the "***Specifications for Chart Content and Display Aspects of ECDIS - Special Publication No.52***". The first draft of this publication "*was presented to IHO Member State Hydrographers in May 1987 at the 13th International Hydrographic Conference in Monaco*" [IHO, 1996, p.2]. Actually, after several modifications to reflect the changes in the related standards, this publication is in its 5th Edition**,** published in December 1996 but with some amendments done in March of 1999 and in December of 2001. The IHO S-52 Standard defines the rules for ECDIS chart content and display, and provides guidance on ENC updating.

I.5.1.3 - IEC

As an electronic system, the list and description of the tests necessary to conduct and the required results to confirm that an ECDIS meet all the specifications, should be done by the correspondent electrotechnical international authority. The International Electrotechnical Commission (IEC), at the request of IMO, had "identify and describe the necessary performance tests and checks" completing in November 1996, the Draft of the "IEC ECDIS Performance Standard" (IEC Publication 1174) [Alexander and Ward, 2002]. This publication was finally finished in 1998 with the name of "**IEC 61174: Electronic Chart Display and Information System (ECDIS) - Operational and performance requirements, methods of testing and required results**". Based on the IMO "**Performance Standards for Electronic Chart Display and Information Systems (ECDIS)**", it defines, as the name indicate, the "methods of testing and required results" to certify an ECDIS as conforming to the IMO Performance Standards, and in addition, states several rules related with the cartographic data display [IEC, 1998].

I.5.1.4 - Summary of the ECDIS Requirements to Meet SOLAS

To be accepted as complying with the up-to-date charts required by regulation V/20 of the 1974 SOLAS Convention, as was mentioned on CHRIS [2003], an ECDIS should:

- Be a "type approved" ECDIS, this means an ECDIS that complies with all the IMO and IHO related regulations, pass in the IEC tests and was officially certified by a competent authority;
- Have a back-up in accord with the IMO resolutions;
- Have the official ENCs necessary to the voyage, which means the latest ENCs edition originating from a government authorized HO.

I.5.2 - ECDIS Components

The components of the ECDIS, as is illustrated in Figure I.12, can be divided in four major categories:

- The ECDIS Hardware which includes a computer, a monitor and a console capable of link the computer with several navigation and position systems and sensors;

- The ECDIS Software which transforms the ENC into a SENC, integrate the updates in the data preparation phase, and then allows the chart display, the interaction between the chart information, the user interface inputs and the information from the position and navigation systems and sensors;
- External navigation and position systems and sensors, inputs (i.e. GPS, gyro, radar, depth sounder, etc);
- The cartographic data that should come from the ENC and with the respective updates converted in a SENC (or in alternatively from RNC but with the mentioned limitations).

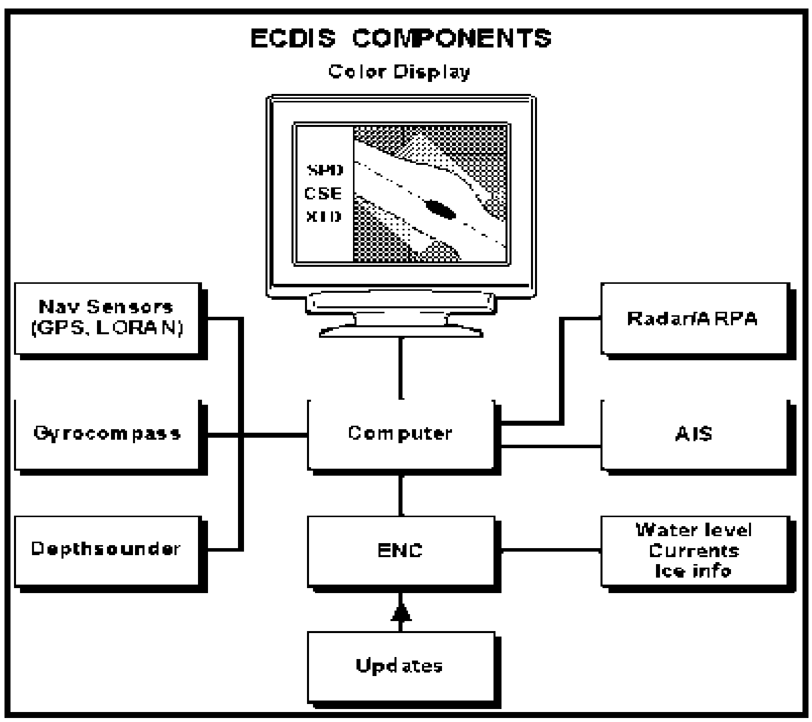


Figure I.12 - Basic components of an ECDIS (from Alexander [1998]).

I.5.3 - ECDIS Advantages

The advantages of the ECDIS utilization are related with the inherent support provided to the navigator in conducting their tasks in the route planning, monitoring and in take navigation decisions, which contributes to the navigation safety.

Some of the most important ECDIS capabilities are the following:

- Permit the route planning and its display;
- Integrate continuously the position of the ship, acquired from a position system, in the chart display data;
- May integrate the radar information in the chart display data;
- Set indications or alarms according with selected conditions or equipments malfunctions;
- Integrate automatically cartographic updates;
- Allow choosing if some information will be displayed or not.

I.5.4 - Major Issues to the ECDIS Acceptance

Issues related with ECDIS acceptance, besides the costs, are mainly related with the lack of ENC data and the frequent changes in the standards that have occurred in the last decade.

The changes in the standards and the delay in the implementation of some had implied that only in 1999 was approved the first ECDIS [NIMA, 2002. p.201], this was a negative factor to the ECDIS manufacturers that only in 1998 had access to the test requirements (the IEC 61174). But at present, with all the standards in a stable edition, it seems that this problem was surpassed.

Another important and current difficulty in the acceptance of ECDIS is the lack of ENC data. Due to the complexity of the ENC production and the resources issues of some HOs, allied with the fact that ECDIS carriage is not mandatory and the costs of ECS are much lower, had motivated the increase of ECS in the market in detriment to ECDIS. This problem was a little reduced with the authorization of use the RNC in the ECDIS where no ENC data is available (IMO Resolution MSC.86 (70)). Although in this case is considerate an RCDS that can not replace the paper charts, the approbation of its use allied with the promulgation of the specifications to the Raster Navigation Chart by the IHO (S-61), not only recognize the importance and potentialities of the raster charts. This Standard also implemented the rules to an RNC, a raster chart that could have several data structures but should comply with the IHO S-61 specifications and be “produced by or distributed on the authority of a government authorized hydrographic office” [IHO, 1999]. These rules give the users more warranties in terms of data quality.

APPENDIX II

ADDITIONAL MILITARY LAYERS

APPENDIX II
ADDITIONAL MILITARY LAYERS

Appendix II is about the Additional Military Layers (AML). Its objective is providing additional information about the AML concept and the AML products which will be mentioned in the chapters of this report. In this appendix are analyzed and explained the AML concept, and it introduces WECDIS and its capabilities. Then is defined the scope and the specific objective of each AML product, and finally is given an overview of the AML product specifications and the implementation in the IHO S-57 format.

The possession of up to date information is recognized as a very important military issue that can represent a significant advantage in military operations. The spatial information is a particular component of the big sphere that represents the important military information. Due to its importance, most countries have institutions that produce cartographic related products for military use, with the objective of providing special spatial information to their military forces. In the case of nautical related products, the responsibility in most cases is attributed to a national Hydrographic Office. With the evolution from paper charts to Electronic Charts, it was natural that military products have an evolution too, not only in the format of the product, from paper to digital, but also and essentially in the concept. With the AML products creation, the most significant evolution was in replacing a large range of specific specialist task and information oriented products by a several number of generic classes of information oriented ones and in the implementation of some interoperability among the AML products it selves and with other products like the Electronic Navigation Charts.

Additional Military Layers has started as a NATO initiative and are coordinated by the United Kingdom Hydrographic Office (UKHO) [Crocker and Bowley (2001)]. Some important milestones in the AML development and implementation, as has been mentioned by Gooding [2003], were:

- In 1995 the initial AML concept paper was done;
- In 1997 was established the NATO Ad Hoc Hydrographic Working Group;
- In 2000 occurred the first development of sample data;
- In September of 2001, a draft of the STANAG 7170 "Standard for Additional Military Layers (AML)", was ready;
- In November of 2001, the NATO had endorsed some product specifications;
- In June of 2002, some trials were conducted in JMC022[5];
- And, in February of 2003 some trials were conducted in JMC031[5].

In March of 2003 during the U.S. Hydro 2003 Workshop some presentations were given about the AML contributing to the AML development and to its divulgation inside the military and civil communities.

[5] Naval military exercises conducted by the Royal Navy.

II.1 AML Concept and Objective

In the Ratification Draft number 1 of the NATO Standardization Agreement (STANAG) 7170 (Oct 2002), 1st Edition, is defined that:

> **“***Additional Military Layers is a unified range of digital geo-spatial data products designed to satisfy the totality of NATO non-navigational maritime defence requirements*”[NATO, 2001a, p.14].

The AML objective, defined by the Ad Hoc Hydrographic Working Group in the NATO Geographic Conference, in July 1999, is:

> **“***To provide all the information currently published as overlays or overprints to standard charts or as defence specific products in a single, unified product range with no replication of information***”**[Gooding, 2003].

As mentioned by UKHO [2002], the creation of AML is not only to replace the products specially conceived to support defence users in some particular tasks, but also to eliminate the necessity of the information replication with the associated expenses and potential mismatching. As an example given by the UKHO [2002], they publish almost 2000 specialist charts and one real world object might be represented in various products.

The importance of the AML products is like this, not only the digital format but mainly the fact that are modular common data products, applicable to all military nautical tasks, avoiding the replication of information and the specification of each product. This means that a big step was done in the concept replacing the large number of specific products that were task and/or information oriented, by several classes of generic information oriented products (currently ten), that provide all the information provided by the older products and much more with some interoperability capabilities, which is illustrated in Figure II.1.

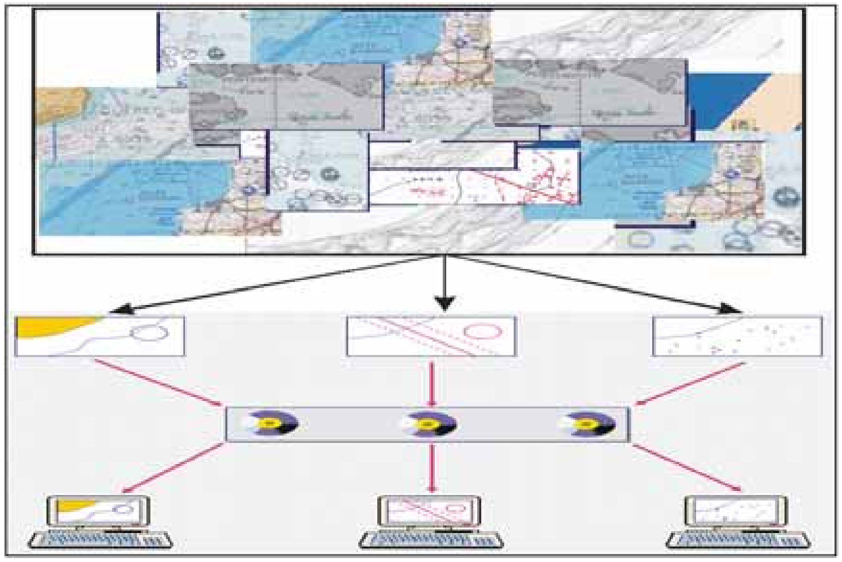


Figure II.1 - Generic classes of information of the AML products replacing the older specific products and capable of serving different kinds of users (after UKHO [2002]).

The AML concept is based in a basic data model similar to the IHO S-57 and DIGEST data models, where each real world entity may be modeled as a combination of a feature object and a spatial object. In the AML case, the entities are distributed by the correspondent products. In terms of the data structure and encapsulation, it depends on the carrier format that until now is limited to the IHO S-57 and DIGEST, as is illustrated in Figure II.2. An important aspect, as mentioned in UKHO [2002], is the fact that AML products are not tied to any system, manufacturer or exchange format in particular, and it does not provide the software functionality, just the information (i.e. the data). These characteristics are very important to create the flexibility to be used and exchanged by different users using different systems and exchange formats, and connected to different products such as the Digital Nautical Charts in the DIGEST Vector Product Format (VPF) and the Electronic Navigation Charts in the IHO S-57 exchange format.

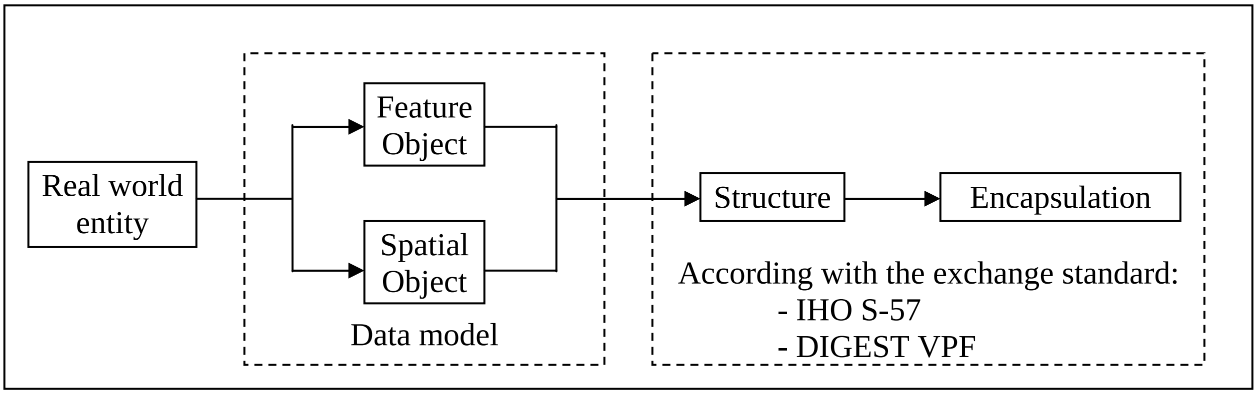


Figure II.2 - AML concept with the data model and carrier format.

The AML are products to be used, until now, only in the maritime tasks, but the concept could be applied to land and air warfare products too, or even in non-military products, as was mentioned by UKHO [2002].

II.2 AML and WECDIS

Military ships have special needs due to the kinds of missions that they perform and where these missions might be conducted. Most civilian ships operate in very well known routes used by lots of other ships, where the HOs concentrate a significant part of their efforts to maintain the information up to date, so, where the risk is more the quantity of traffic and possible deviations to the established routes. In the warships case, in a crisis situation they need to operate with the “best” available information, that in some situations in some areas nobody knows how well is these “best”. At the same time, they need to be capable of using information from other formats than the ENC, like the DNC in DIGEST format or raster products.

Attending to the potentialities of the ECDIS and the necessity of having a system to allow the use of the AML products, parallel to the development of the AML concept NATO started to work in the concept of a Warship ECDIS (WECDIS), approving in 1999 the STANAG 4564 - Performance Standards for “Warship” ECDIS (WECDIS) [NIMA, 2002].

Basically, the WECDIS is an IMO compliant ECDIS improved with the capability of display other data types. The different data types usable by the WECDIS could be divided in three subtypes like was done by Pilypaitis and Alexander [1999, p.2]:

- The main **Navigational Data** where is included the IHO S-57 ENC and the DIGEST DNC;
- **Auxiliary Navigational Information** (ANI) where is included various other formats like the Raster Nautical Charts. This navigational information should be used where no main navigational data are available or as a backup.
- In addition, it should be capable of displaying and overlaying the navigational information in the data formats mentioned before, the **AML products**.

This capability of using different types of data formats is called “multi-fuel”. The possibility of the navigational and military information exchange, between the ships and between the ships and the shore commands during the conduction of specific operations, given by the WECDIS is other important aspect mentioned by Pilypaitis and Alexander [1999, p. 3].

The integration of WECDIS in the operations is done at the level of the Command, Control, Communications, Computers, Information and Interoperability (C^4I^2) systems. The next diagram tries to illustrate the “multi-fuel” capabilities and the WECDIS insertion in ship C^4I^2 systems illustrated in Figure II.3.

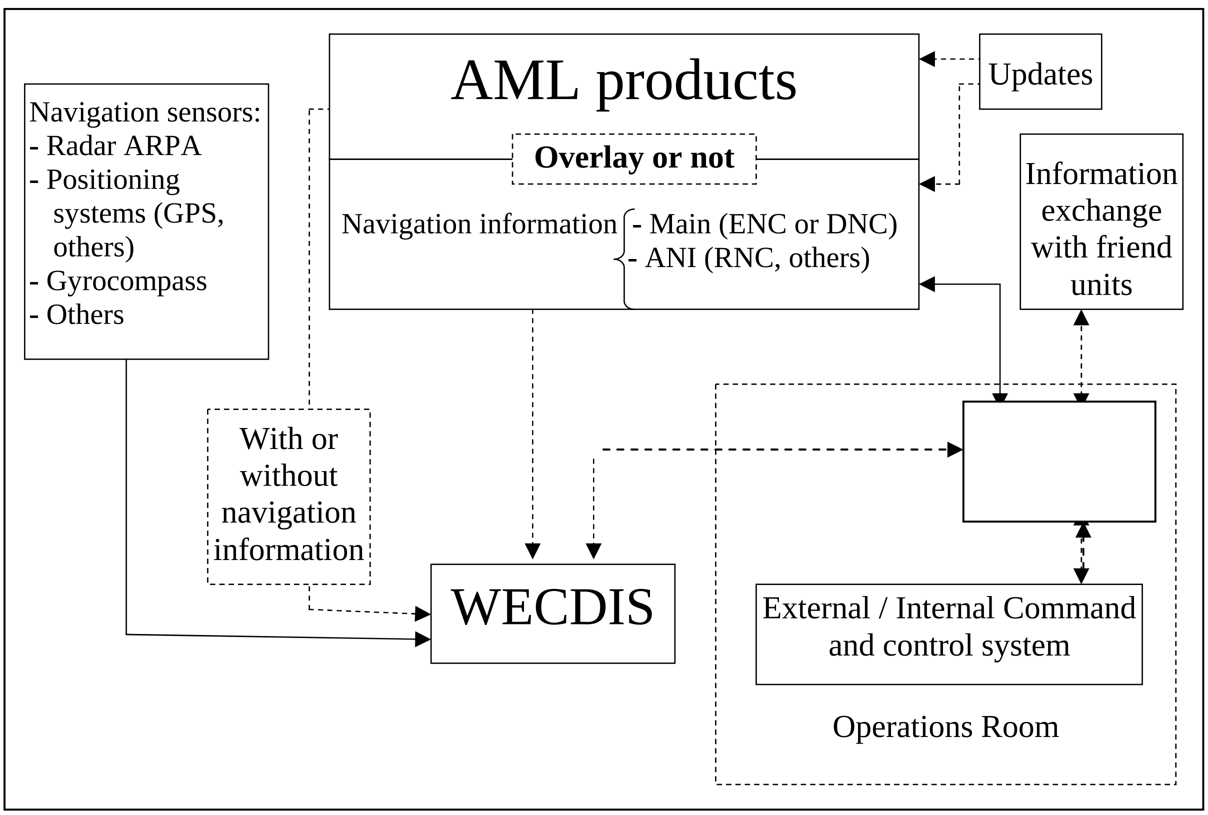


Figure II.3 - The “multi-fuel” capabilities and the WECDIS and the insertion in ship C^4I^2 systems (after Buizert et all [1998]).

II.3 AML Data Actualization

Conceived mainly to support the military users in their tasks, AMLs have as one of the most important aspects in its implementation, the data actualization. During the military operations the information about the relevant real world entities tends to change quickly. If the AML data is not actualized to reflect these changes it could result in wrong decisions, motivated by information not actualized, and especially in military operations wrong decisions might imply dramatic results.

The organization of each update or new data file will depend on the exchange standard used, but besides the file characteristics, the actualization mechanism involves various aspects illustrated by Figure II.4, such as:

- The acquisition of the information, which could be done by special teams in the operations area, using remote methods, by the intelligence services or directly by the combatant units;
- The collection of all the information available from the diverse sources by a compilation service;
- The updates and new data files production;
- The updates and new data files dissemination;
- And finally in the end user, the integration of the updates into the data.

On the other hand the AML data could be exchanged between units too (e.g. the WECDIS allow the exchange of data between units), this means that is possible a direct link between the unit that acquires the information and the other units with the data actualization done directly with the information received from the unit that does the acquisition.

If the responsibility by the acquisition of the information most of the times involves various entities and not only the entity responsible by the AML production, it make sense if the update compilation, in non crisis situations, will be done by the entity that produces it to filter and complement the data with the different information received. The dissemination entity could be the compiler or other, for example an entity in the line of the units command. In situations of crisis where several units could operate together in a specific area, an entity might be especially constituted to compile and disseminate the data actualization in the operations area (e.g. aboard a ship).

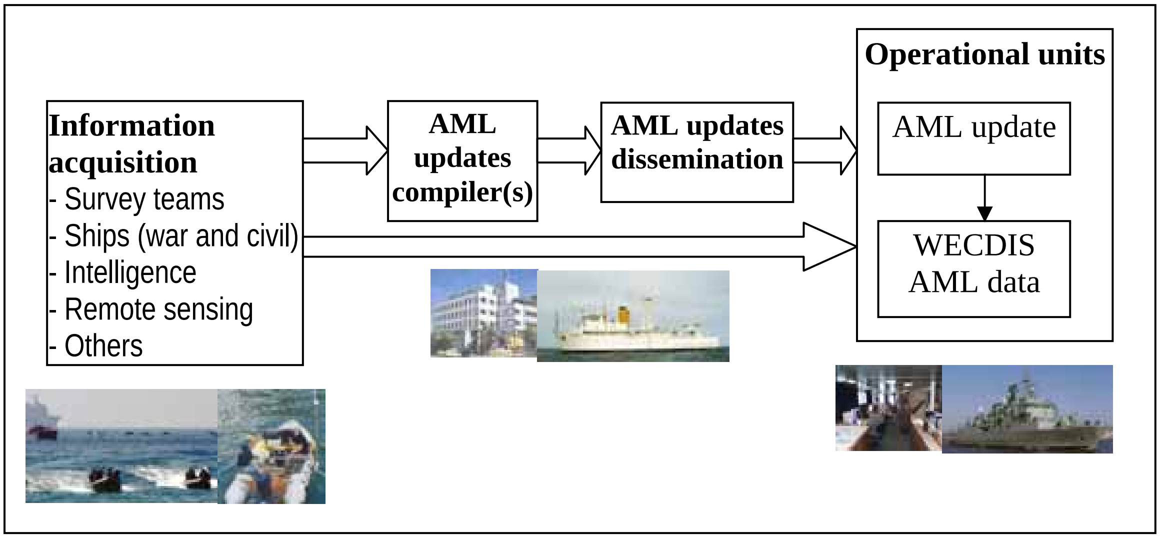


Figure II.4 - A schema of an AML actualization mechanism.

The communications of the data could be done using the various lines of communications that the military organizations normally have. However as the AML information is military information, this means that very often or even always is classified information. AML product specifications mentioned that the AML products are unencrypted irrespective of the security classification, so, to disseminate the AML information should be used secure lines of communications.

II.4 AML Products Family

The Family of AML products, as was mentioned by Gooding [2003], contain already ten different identified products, resumed on Table II.1.

Table II.1 - AML specifications and annexes actually available.

AML Product	Specifications available	Implementation Annexes
Maritime Foundation & Facilities (MFF)	Yes	S-57
Routes, Areas & Limits (RAL)	Yes	S-57
Contour Line Bathymetry (CLB)	Yes	S-57 and VPF
Large Bottom Objects (LBO)	Yes	S-57
Small Bottom Objects (SBO)	Yes	S-57
Environment, Seabed & Beach (ESB)	Yes	S-57
Bathymetric Models (NMB)	No	None
Oceanographic Climatology (IWC)	No	None
Meteorological Climatology (AMC)	No	None
Flight and Aeronautical Information (FAI)	No	None

Currently, just the first six have specifications available in an S-57 implementation annex. The Contour Line Bathymetry (CLB) is the only one that have both an S-57 and a DIGEST VPF annex.

II.4.1 Maritime Foundation & Facilities (MFF)

The objective of the Maritime Foundation & Facilities products is provide a reference framework to support the users when they are not using the AML products with electronic chart products, or other AML products that provide the necessary nautical chart information without replicate the content of a nautical chart [NATO, 2001a]. Due to the objective, this AML product would be more important to the areas where there is no chart information or if it exists but not at a suitable scale. Where chart products are available at the adequate scale, a nation does not need to produce this AML product.

Its main content is the coastline, together with a variety of information that is divided into two major categories [NATO, 2001a]:

- Framework - this includes major lights, significant buoys, features that constrain vessels navigation, tidal and magnetic information, national boundaries, major cities, and port and harbour locations and facilities.
- Miscellaneous Tactical Information - radar reflective entities, communications facilities and coverage, pipeline and cable information, fishing activity, oil, gas

or mineral production information, ice limits, search and rescue information, and miscellaneous seabed obstructions which cover a significant area.

Figure II.5 illustrates an example of an MFF AML product view.

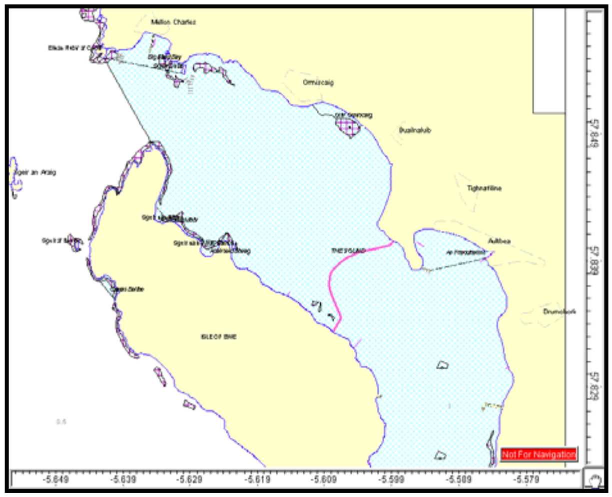


Figure II.5 - Example of an MFF AML product view (from Gooding [2003]).

II.4.2 Routes, Areas & Limits (RAL)

The Routes, Areas & Limits AML products are designed to encode routes, areas and limits AML components. In its product specifications [NATO, 2001b] some examples are given such as:

- Specific aeronautical information including airports and airspace areas;
- Marine management areas including exercise, danger, patrol, swept, restricted and territorial sea areas;

- Q-routes and specific points such as waypoints, reporting and rendezvous points.

Figure II.6 illustrates an example of an RAL AML product view.

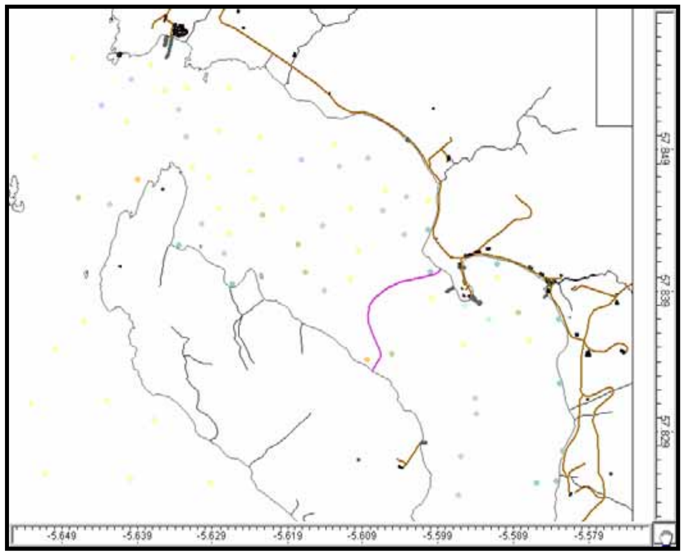


Figure II.6 - Example of an RAL AML product view (from Gooding [2003]).

II.4.3 Contour Line Bathymetry (CLB)

The Contour Line Bathymetry AML products are the only ones that has both IHO S-57 and a DIGEST VPF implementation annexes. Its objective, as is mentioned in its product specifications [NATO, 2001c] is to provide simple depth information to give support in the following operations:

- Tactical planning and oceanic;

- Mine counter measures and amphibious;
- And, in on-shelf anti-submarine warfare.

Figure II.7 illustrates an example of a CLB AML product view.

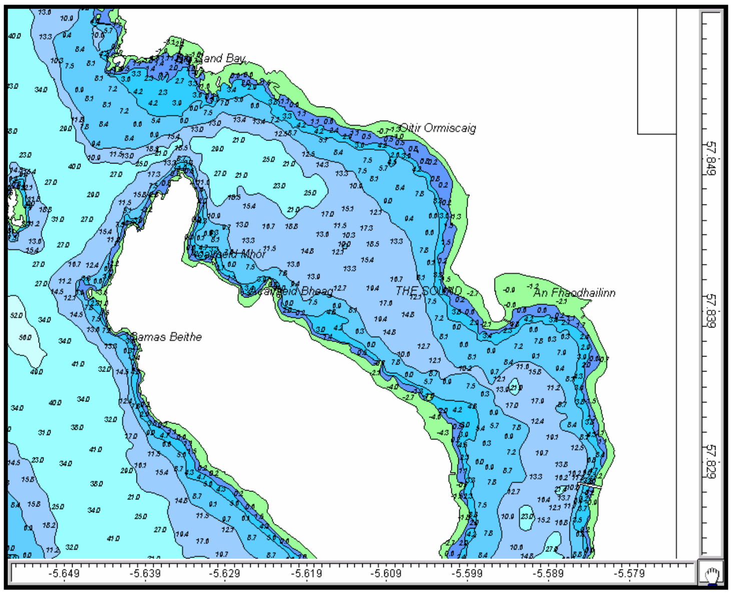


Figure II.7 - Example of a CBL AML product view (from Gooding [2003]).

II.4.4 Large Bottom Objects (LBO)

In the AML specifications large objects are considerate objects that have one of the dimensions with at least 5 metres, so the objective of this product is to facilitate the encoding of bottom objects that could obey to this requirement. As is mention on its product specifications [NATO, 2001d], all the objects are captured as point geometry, because the product is scaleless, but is more suitable for use in planning and operational operations what means respectively small and medium scale.

The information covered by this product is indicated to the surface navigation, but is specially indicated to submarine tactical or navigation operations, and could be used for amphibious and mine warfare operations.

Figure II.8 illustrates an example of a LBO AML product view.

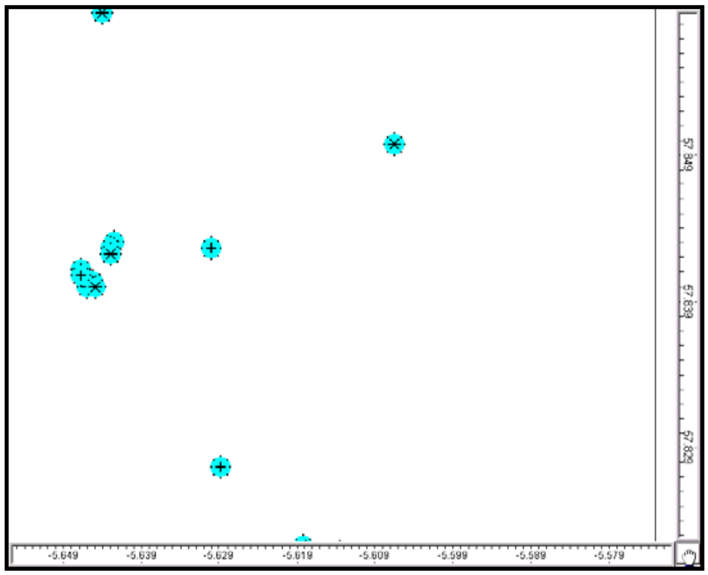


Figure II.8 - Example of a LBO AML product view (from Gooding [2003]).

II.4.5 Small Bottom Objects (SBO)

The Small Bottom Objects AML product complements the information covered by the Large Bottom Objects AML product but, as is mention on its product specifications

[NATO, 2001e], is designed to depict all known bottom contacts with all dimensions smaller than five metres.

II.4.6 Environment, Seabed & Beach (ESB)

The Environment, Seabed & Beach AML product is designed to encode the high resolution seabed texture information, for mine counter measures purposes, and features related with the amphibious operations, such as the landward limits and conspicuous marks (lights and land marks) to provide the alignment onto and on the beach [NATO, 2001f].

Figure II.9 illustrates an example of an ESB AML product view.

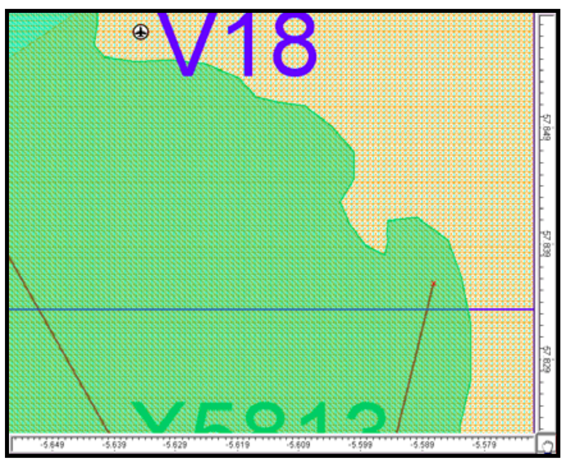


Figure II.9 - Example of an ESB AML product view (from Gooding [2003]).

II.5 AML Product Specifications Overview

AML Product specifications have by objective the definition of the rules to create the AML products. AML product specifications have been prepared in accordance with the draft NATO STANAG 4564, performance Standards for WECDIS Data Products and are based on the respective proposed Common Product Specification Framework contained as Annex B of the respective STANAG [NATO, 2001a].

In this section an overview of the AML product Specifications common aspects will be provided once the objectives of each one in particular were stated in Section II.4, so, unless otherwise stated, all information in this section and respective sub-sections came from all the AML Product Specifications (i.e. NATO [2001a, 2001b, 2001c, 2001d, 2001e and 2001f]).

As stated in NATO [2001a, 2001b, 2001c, 2001d, 2001e and 2001f], the AML product specifications have been “designed to achieve interoperability between AML data products and other digital data products. This is achieved by the separation of the data dictionary from the standard used to encode the data and by the use of internationally recognized standards for the data transfer”.

Each AML product specification has two distinct parts:

- The main body, where, is described the content of the product specification and is defined the data dictionary of the product independent of any exchange format;

- The annexes each one for the respective exchange standard implementation with the schema and data format.

II.5.1 AML Product Specifications Main Body

Some of the most relevant and general characteristics that can be found in the main body of the edited AML product specifications are:

- The identification of the respective AML product scope and purposes.
- The security classification of the specification (Unclassified) and the product that is dependent of the content.
- The content is not layered, but the respective exchange standard could have layering requirements.
- The spatial objects contained in the AML products are in vector format, however to provide additional information, text and picture files could be included in the products.
- The file size and the level of topology depends on the respective standard (e.g. in S-57 implementation is required the chain-node topological level).
- The horizontal datum is WGS 84, but the height and the sounding datum where applicable should be specified in the metadata of the dataset.
- The data quality should be encoded in accord with the specifications of each standard (e.g. in the metadata and in the feature attributes), and the categories

that should cover the accuracy, up to dateness, sources of information and the conformance with the product specification.

- The data structure and the file format (encapsulation), as mentioned before and illustrated in Figure II.2, is dependent of the exchange standard.
- The main body includes the Data Dictionary, where is provided the real-world descriptions for the metadata and features, and is given the definition and the possible values of the attributes. In this section the mandatory Meta information and features are also defined.
- The relationships between features might be of dependency (parent-child like the case of a mine and its contact history) or association (when the features are not dependent each other but are related to provide more information, like in the case of a radio station and the broadcast area).
- The Product specifications are just designed to support the product and the supply of AML products, so like was mentioned before the data presentation is not defined and will depend on the presentation model of the users system.
- The AML products are unencrypted and do not use compression techniques.

II.5.2 AML Product Specifications S-57 Implementation

The implementation annexes establish the rules to implement AML products in the respective exchange format. Annex A is dedicated to the S-57 implementation which includes the data structure, the catalogue file content and the data set files of an exchange file.

Several characteristics of the AML products implemented in S-57 are common with the ENC Product Specification (e.g. the cells rules). Annex A is divided in three main sections, the AML format table and file structure, the AML S-57 Data Dictionary and the AML Guidance on Feature Coding and Attribution.

In the AML format table and file structure are defined several general rules and the application profiles. The most relevant are:

- Each cell should be defined by two meridians and two parallels with a size not larger than 5Mb.
- Use the standard ISO/IEC 8211 that is independent of the computer system and permits the transfer of data and the description of its organization, to encapsulate the data.
- An exchange set should be composed by one catalogue file, at least one data set file which may have a readme file with picture and text files.
- The Exchange Set name should be on the form XXybcDDD, where “XX” are the two letters of the producer’s country code, the “y” is the first letter of the AML product identifier (e.g. M to MFF), the b allow the identification of a base exchange set (B) or an update (U), c is the security classification code defined in the Annex A, and, the DDD is the mandatory alphanumeric geographic area identification code that needs to be defined.

- Like in the ENC product specification, four kinds of data sets could be produced, a new data set, an update, a re-issue (do not contain new data, just the data set e the respective updates in effect), and, a new edition.
- The convention to the file name is on the form XXybc123.eee, where “XX” are the two letters of the producer’s country code, the “y” is the first letter of the AML product identifier (e.g. M to MFF), the b is value code of the scale usage band, c is the security classification code defined in the Annex A, 123 is an alphanumeric identification dependent on the product and the geographic partitioning (was not defined yet), and, the eee is the extension should 000 if is the base cell, if is an update is numerated sequentially beginning in 001.
- The catalogue file has the table of contents of the exchange set.
- The structure of each base cell is composed by one Data Set General Information record, one Data Set Geographic Reference record one or more vector records and one or more Feature records, as schematized in Figure II.10.

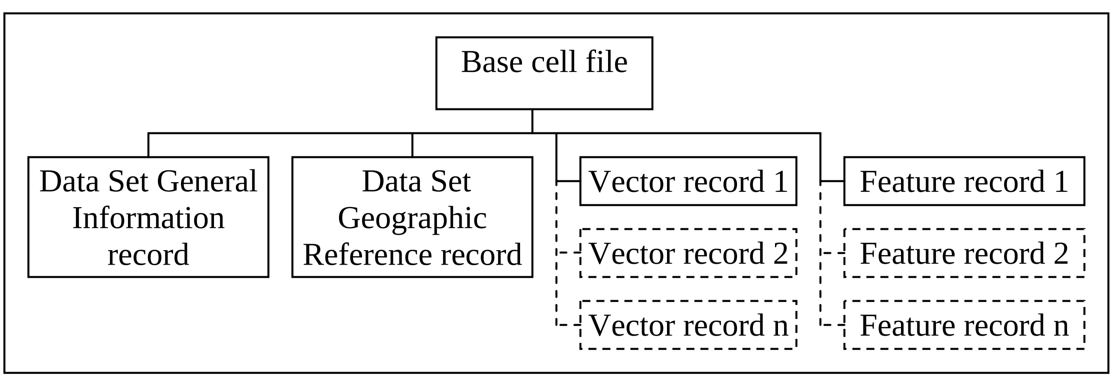


Figure II.10 - Base cell file structure

In the AML S-57 Data Dictionary is defined the mandatory Meta information and how it should be encoded, as well as the mandatory feature classes and the respective mandatory attributes of each one. It should be enhanced the following:

- The identifier of each feature object must be unique and should not be reused;
- The use of cartographic objects is prohibited;
- Only the attributes defined in the Product Specifications are allowed;
- The relationships between the features are of the collection type, that includes association (e.g. a wreck associated with the buoy that marks it) and aggregation (e.g. a route aggregated with the aids that signals it) sub types, or a master to slave type (e.g. in a buoy a light should be a slave of the master buoy structure).

Finally, AML Guidance on Feature coding and attribution specifies the conventions used to encode the geometry and semantic descriptions of the objects in each AML product. This part states the specific differences or additions to the conventions present in S-57 APPENDIX B.1, Annex A, “Use of the Object Catalogue for ENC”.

APPENDIX III

SPATIAL DATABASE AND MANAGEMENT SYSTEMS

APPENDIX III
SPATIAL DATABASE AND MANAGEMENT SYSTEMS

The concept of the Database Driven Systems for Nautical Cartographic Production described in Section 2.1, are based in a dual system composed by a system of Specific Applications for the cartographic production implemented over a Spatial Database and Management System (SDBMS).

As the SDBMS is a core part of CARIS HPD, being its evaluation the main topic of this report, Appendix III provides additional information about the SDBMS, with a special focus on Oracle Spatial. This Appendix starts to define what are the advantages of using a Database and Management System (DBMS) to store and manage the data, and how the SDBMS are different from the Relational Database and Management Systems (RDBMS). Then, since Oracle Spatial is the SDBMS used by the HPD, it is described in detail in this Appendix.

III.1 Advantages of the DBMS in the Data Management

DBMS are software systems dedicated to manage databases, which are collections of "interrelated and sharable data serving a general purpose" [Lee, 1993, p.4]. The databases with interest to this report are spatial databases, because the main data are spatial data linked to a coordinate and multi-dimensional system.

The DBMS due to the data management capabilities had gained the preference of the software developers when the systems imply the management of data, because they give several advantages avoiding the implementation of these functionalities in the developed applications. Lee [1993] and Reeve [n.d.] enumerated some of these advantages:

- Provide **data independence** using a logical view of the data not dependent on the system, which implies that different programs can access the same database without need to know the complex data organization on the disk and the programs does not need to be changed if the data structure changes;
- Provide **a non-procedural query language** that allow the user to obtain the data just expressing which data one wants without need to specify how to obtain it;
- **Allow concurrent access** permitting more than one application to access the data at the same time, but with tools to avoid inconsistencies created by concurrent updates;
- **Provide data security** against unauthorized access and accidents, by the implementation of passwords and specific user views to limit the data access, normally having also efficient data recovery functions;
- **Reduce data redundancy and increase integrity** by the use of a single database, just preserves the redundancy that contributes to the efficiency and security (e.g. data integrity check), and have internal integrity rules implemented.

Other advantages are the fact that almost all the recent DMBS offer more sophisticated functionalities such as data indexation and specialized query models which optimize the data retrieval operations.

III.2 DBMS Issues in Handling Spatial Data

Due to the large variety of different kinds of data, a DBMS can not support them all, because this will result in very large and expensive systems. The most popular kind of DMBS, the RDBMS are normally general purpose products conceived to serve a wide range of customers, supporting just the generic kind of data types. But, the DBMS provide "more generic building blocks" that can be used to define the needed data types (e.g. using tables or relations in RDBMS) [Lee, 1993].

The relational data model in an abbreviate perspective could be understood as composed by a collection of relations in the form of tables, each one with a number of rows also called tuples and columns that represent attributes, being the number of attributes the same to all tuples in a relation. In the normal RDBMS a geometric point is not defined, but a user can define it using the RDBMS generic building blocks, the relations, like is illustrated in the example of the Table III.1.

Table III.1- Eventual representation of points using the relational model.

Point ID	X coordinate	Y coordinate	Z Coordinate
P01	126	23	13
P02	149	45	23
P03	153	78	25
P04	200	99	21

However the representation of practically all kinds of data and situations could be done recurring to the relational data model in a RDBMS, as was mentioned by Weinberger [2002, p.1], “without spatial capabilities the database cannot do anything beyond serve as a data store”, and it “cannot manipulate the data without additional GIS tools”. In fact, for instance we can represent points as shown before, but the database does not recognize it and could not provide operators to operate and manipulate these data, so, should be necessary other application to provide the required operators, such as to compute the distance between two points and other usual operations.

Due to the special characteristics of spatial data and the specific nature of some requirements from the spatial applications, RDBMS are not suitable to handling spatial data, because RDBMS:

- Do not have defined **spatial data types** and, implemented specific functionalities to handle the spatial data types such as **spatial data operators** to manipulate the data using a **spatial query language,** and **spatial indexes** to enable the quick retrieval of the queries result. This implies that the spatial data need to be stored in complex structures, as multiple tables probably with several tuples for each geometry. To provide the required spatial operators and spatial index capabilities various complex and costly algorithms need to be implemented by an external application.

- Can not preserve the **semantics** of a unique spatial entity, simple or complex, modeling it as a unique geometry, because nested relations are not allowed. This implies that a complex geometry could not be explicit stored, just the primitives that compose it. The geometry itself needs to be reconstructed from all the related primitives. One solution to preserve the semantics is store each geometry as a BLOB (Binary Large Object), but the standard DBMS do not know the internal organization of the BLOB, which for the database is like a black box. In consequence an external application is necessary to provide the necessary capabilities to decipher and handle the BLOB, resulting in complex and costly application code implementation. This solution, as is mentioned by Weinberger [2002], involves an enormous effort to develop the necessary applications and has by result that just this application can use the data, unless is provided an application programming interface (API) to allow other applications to manipulate the data.
- Spatial data elements could be **large in size** and each element, even if is of the same type, probably have **different quantities of the basic elements** (e.g. each line that represents a river may have a different but large quantity of coordinates). This implies that each element with more that a point or a segment

needs to be represented by several tuples, each one representing a point or a segment.

- The **number of possible relationships** between two geometries, like was mentioned by Lee [1993], is **infinite** (e.g. distance between geometries could be measured directly or along a road, a railway, etc.), so among all geometries in a data set is infinite too, which imply that the spatial operators definition and subsequent implementation in an application is a very difficult, complex and time consuming task.
- The traditional DBMS just provide **integrity and consistency checking** to the internal data types, like was mentioned by Lee [1993].
- The RDBMS normally are designed to handle with short transactions[6] of the order of seconds or less (e.g. a bank transaction). To ensure the integrity in a multi-user environment, normally the records involved are locked during the transaction. In the GIS applications, typically the transactions are long (i.e. drawing a line that represents the positions where a new road will be build, could take days or weeks). So it does not make sense to lock the entire database during all this time. One popular approach called **checkout** is described by Batty and Newell [1994] and consists in each user select and lock one area where they are working, and all the data of this area will be copied to a separate working area, the other users could view all the data but could not change the locked data,

[6] "A transaction is an update operation that will change a database from one consistent stage to another" [Lee, 1993, p.6].

when the work is finish the changes are submitted to the master database and the area is unlocked.

- The necessity of **version management** is another issue of some spatial applications like the case of the CARIS HPD, besides in traditional applications is common too. It consists in preserving the data stored in the database even after update transactions on these data, by the use a specific attribute (e.g. updated date) that will mark the updated data with a given version or a date of update. With this, it should be possible to reconstitute the database at a specific point in time, and keep track of the changes that occurred at a specific feature.

III.3 Spatial DBMS - Oracle Spatial

A short definition to a Spatial Database and Management System based on Güting [1994] could be: it is a DBMS with supplementary capabilities for handling spatial data. Using the "personal view" of Güting [1994, p.1] and the requirements to a SDBMS described by Ravada [n.d.], we can define a Spatial Database and Management System as a **Database and Management System** with the following additional capabilities:

- **Spatial data types**;
- **Operators** to perform operations with the spatial data types;
- A **query language extended** to support spatial data types and operations;

- And, **spatial data indexation capabilities** to improve the performance of the spatial queries.

In the next section, because this is the database used by the CARIS HPD, the Oracle Spatial solution will be analyzed as an example of an implemented SDBMS.

III.3.1 Oracle Spatial DBMS

In this section the Oracle Spatial Version 9.2 will be analyzed, so unless otherwise stated, all information in this section came from Oracle [2002a] and Oracle [2002b].

The following Oracle syntax will be adopted [Oracle, 2002a]:

- Element - The basic spatial data type that composes a geometry (i.e. points, lines and polygons).
- Geometry - The representation of a spatial feature modeled as an element or a set of elements (e.g. a river modeled as a set of lines and polygons like in Figure III.1).
- Layer - A collection of geometries of the same type, this is, that have the same attribute set (e.g. all the rivers from a data set).

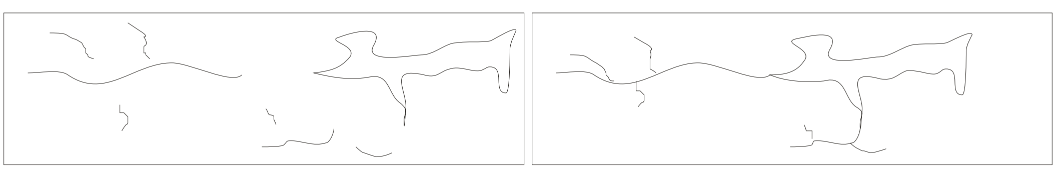
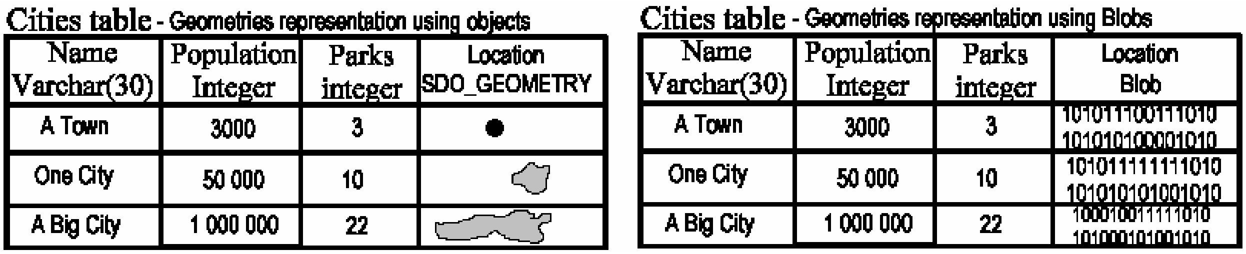


Figure III.1- Model of a river at right, using the elements in left (lines and polygons).

Oracle Spatial (version 9.2) is an Object Relational DBMS (ORDBMS), this means that is basically a RDBMS with the flexibility of the Object Oriented Database and Management Systems, which allows the definition of specific data types. In the case of the Oracle Spatial they have already defined and implemented: **several spatial data types**, **spatial operators** to perform operations with the spatial data types, **spatial indexing** capabilities and an extended **structured query language** (SQL), which allows the access and management of the spatial data like any other attribute data.

Oracle Spatial has a schema called MDSYS that "prescribes the storage, syntax and semantics of the supported geometric data types" [Oracle, 2002a, p.1.1]. All the spatial characteristics of a geometry are stored in accord with the MDSYS schema in an object data type called SDO_GEOMETRY, "a container for storing points, lines, polygons, or homogeneous or heterogeneous collections of the elements" [Oracle, 2002b, p.8]. In a geometries table, where each row represents an individual geometry, the spatial characteristics are stored in a single attribute column called SDO_GEOMETRY which is a column for objects. So, the spatial characteristics of each geometry are stored as a SDO_GEOMETRY cell. As is illustrated in the Figure III.2, this is similar with a BLOB (mentioned before) in the way that all the spatial characteristics are stored just in a cell, but with the big difference that the BLOB for the database is just an incomprehensible binary array, and with the object the ORDBMS knows the internal structure, which allows it to handle the spatial data with the extended spatial query language, using the implemented operators and functions.



Cities table - Geometries representation using objects

Name Varchar(30)	Population Integer	Parks integer	Location SDO_GEOMETRY
A Town	3000	3	
One City	50 000	10	
A Big City	1 000 000	22	

Cities table - Geometries representation using Blobs

Name Varchar(30)	Population Integer	Parks integer	Location Blob
A Town	3000	3	101011100111010 101010100001010
One City	50 000	10	101011111111010 101010101001010
A Big City	1 000 000	22	100010011111010 101000101001010

Figure III.2 - Comparison of a cities table in an ORDBMS using objects and in a RDBMS using a BLOB.

III.3.1.1 Oracle Spatial Data Model

The spatial elements used by Oracle Spatial are:

- Points composed by two coordinates (X, Y), can model a single object such as a city in small scale map or be a part of a composed geometry;
- Line strings are composed by an ordered sequence of two or more points defining line segments which could be straight segments, arc segments, or both. An example of a single object modeled by line strings may be a road;
- And, polygons composed by a close ring of connected line strings, with the coordinates ordered counter clockwise if is external and clockwise if is internal.

The support to straight and arc segments or both, results in nine supported primitive types, called elements, illustrated in the Figure III.3.

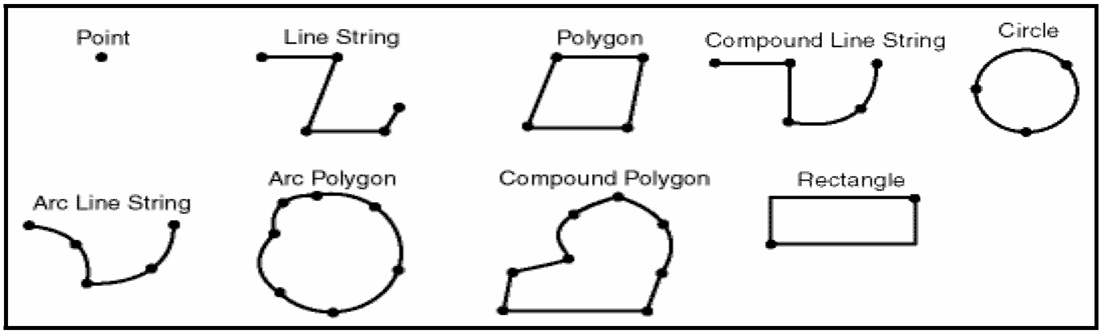


Figure III.3 - Nine Oracle Spatial supported elements (modified from Oracle [2002b]).

Oracle Spatial data model is based in a hierarchical structure, illustrated in Figure III.4. Each spatial object of the real world is modeled as a geometry composed by a single or a heterogeneous (elements of different types) or homogeneous (elements of the same type) collection of elements (e.g. the river illustrated in the Figure III.1 is composed by a heterogeneous collection of lines and polygons). The Geometries of the same type, this is with the same set of attributes, form a layer.

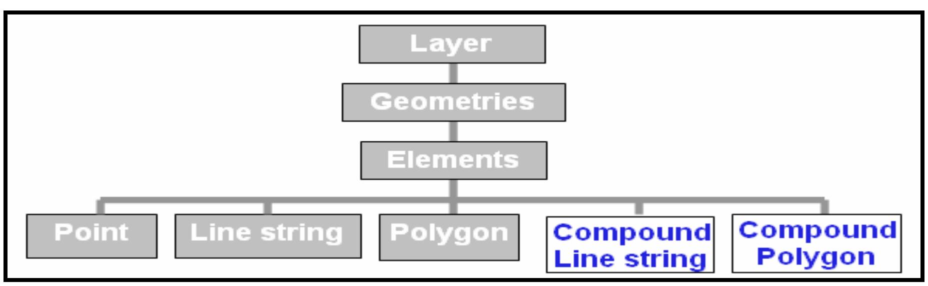


Figure III.4 - Oracle Spatial data model (modified from Oracle [n.d.a]).

III.3.1.2 Oracle Spatial Query Language

A query language capable of handling spatial data like any other attribute data is other core requirement of a SDBMS. As mentioned by Ravada [n.d.], Oracle has a native language SQL that can manage the location data and with the spatial operators and spatial functions, as mentioned by Hoel [2003], supersede the Open GIS Consortium [1999] specifications "OpenGIS Simple Features Specification for SQL Revision 1.1".

III.3.1.3 Oracle Spatial Query Model

Oracle's spatial query model consists of two different types of operations, also known as filters, to resolve each query or spatial join, as illustrated in Figure III.5.

The first one, called primary filter, executes operations involving indexes. These operations with the approximations to the geometries (i.e. minimum bounding rectangles [MBRs] or tiles, depending on the index used) of the spatial layer are performed to quickly select a **reduced data set**, a data set that contains the exact result and may contain more geometries. The primary filter is fast because it uses the facilities provided by the indexes, and uses simple and low cost algorithms, since they just need to work with rectangles, as a result of the geometries simplification preformed by the indexes.

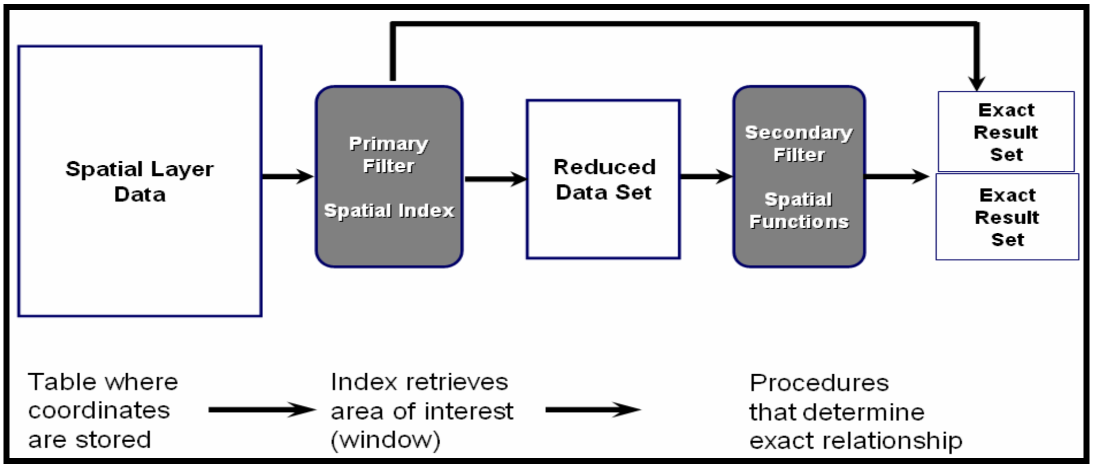


Figure III.5 - Oracle Spatial query model (from Oracle [n.d.a]).

The second operation, called the secondary filter, uses the appropriate algorithms to compute the exact result. The algorithms used are computationally expensive, since they need to operate with the exact geometries coordinates, but only operate in the reduced data set that should contain a significantly reduced number of geometries compared with all the layer.

III.3.1.4 Spatial Data Indexing

Data indexation capabilities are important in all kinds of DBMS to improve query performance. But, in an SDBMS that handles complex data, where each query needs to use complex and computer consuming resources, they are essential.

In Oracle Spatial [Oracle, 2002a] indexes are used to:

- Find spatial objects in an index that interact with a given point or an area (e.g. a window or a point query);
- Or, to find pairs of objects from two different indexes that interact each other (e.g. spatial join).

The R-tree and the Quadtree are two spatial data index types used by Oracle.

III.3.1.4.1 R-tree index

An R-Tree index is a hierarchical index that supports from two, up to four dimensions, where each geometry is approximated by the minimal boundary rectangle (MBR) that contains it.

The root level contains the minimal boundary rectangle of all geometries in a layer, as is illustrated in Figure III.6. The leaf nodes (level 0 nodes) contain the MBR of the geometries and entries (pointers) to the respective geometries (e.g. in Figure III.6 “a” contains the MBR of the geometries “1” and “2” and pointers to these geometries). Non leaf nodes contain the MBR of the child nodes and the child-pointers (e.g. in the Figure III.6, “W” contain the MBR of “A” and “B” and pointers to “A” and “B”). To optimize the input output operations with the disk, each node corresponds to a disk page [Rigaux, Scholl and Voisard, 2002], the minimal quantity of information that the computer read from the disk. To guarantee a good space organization the MBRs in a level may overlap and each geometry MBR may be in more than one node (e.g. in Figure III.6, geometry “15” is in leaves “g” and “h” and leaves “g” and “h” overlap each other).

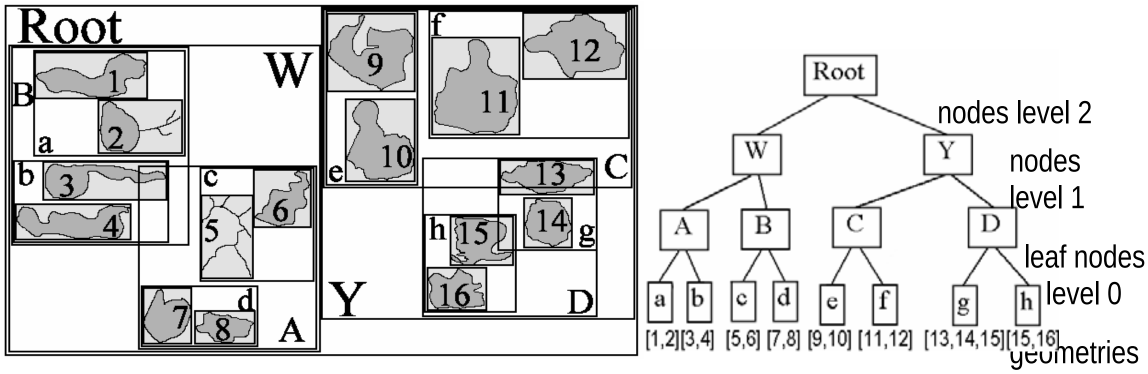


Figure III.6 - R-tree hierarchical tree of nodes and a layer example. “a” to “h” are the leaf nodes (level 0), A to D are the nodes of the level 1, W and Y are the nodes of the level 2. The geometries in the layer are numerated from 1 to 16.

Every search in an R-tree should start at the root and go to the child nodes that meet the search conditions and so on, until reach the leaf nodes from here the candidate set of geometries should be selected.

The biggest weakness of the R-tree is the performance degradation when the dataset is submitted to various update operations, because changes in leaf’s MBRs may affect the MBRs of the related nodes in all the hierarchical levels above. Depending on the inserting algorithm and on the distribution of the updated data, the R-tree index will be more or less affected. Oracle Spatial has some functions that can provide information about the quality and degradation of the R-tree index, and a function to rebuild it.

III.3.1.4.2 Quadtree index

A Quadtree index is based on the division of the two-dimension orthogonal coordinate space into four covering tiles or quadrants of the same size, which is called tessellation. Successive tessellations will divide each of these tiles into four sub tiles and so on, until achieve the desired number of tiles given by one termination criteria, such as the size of the tiles. After the division, the tiles can be linearly ordered using unique numeric identifiers known as z-order or Morton numbers as illustrated in Figure III.7.

It is a hierarchical index with the respective hierarchy expressed in the identifier (the first integer indicates the top level, the second the second level and so on).

The Quadtree index can be:

- Fixed, with all the tiles having the same size (Figure III.7);
- Or, hybrid whit some of the tiles ore tessellated than the others, which implies that in some tiles the hierarchy, the level of division and the size are different from the others, like is illustrated on Figure III.8.

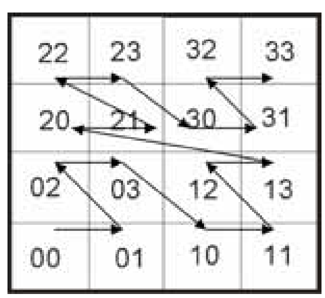


Figure III.7 - Fixed Quadtree with the Morton codes or Z-order.

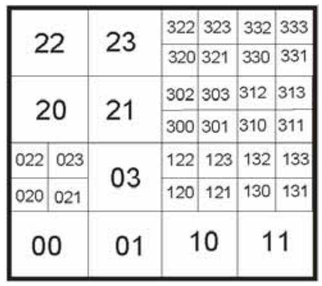


Figure III.8 - Hybrid Quadtree.

Quadtree Fixed index effectiveness and efficiency depends on the tiling level (that the user can control) and the variation in size of the geometries in the layer. However is necessary a balance in selected the tiling level because:

- **If the fixed-size tile is small** the selectivity will be good, but if the layer is large, a large number of tiles would be required. This will imply, like is illustrated in the left side of the Figure III.9, that due to the abundance of the number of tiles, some performance will be lose by the primary filter, because it needs to check more tiles. But, just two objects A and B will be selected as "reduced data set", so the secondary filter will need to handle with less objects.

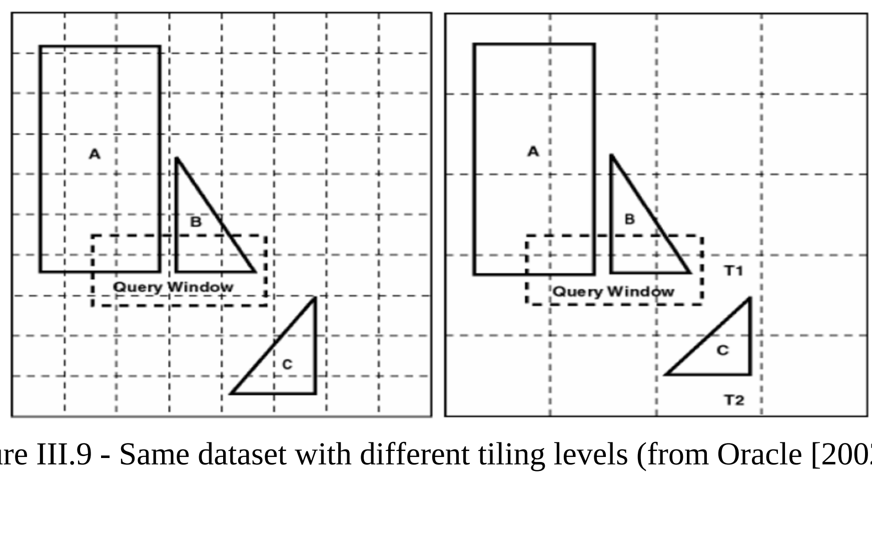


Figure III.9 - Same dataset with different tiling levels (from Oracle [2002a]).

- **If the chosen tile size is large**, the number of tiles will be small, but the index selectivity will not be so good because the large tiles do not approximate the small geometries very well. Like is illustrated in right side of the Figure III.9, the primary filter will be quickly, because the number of tiles is scarce, but the object C will not be rejected by the query window and need to be taken in account by the secondary filter that need to perform computer expensive operations.

To help the user choosing an appropriate tiling level, Oracle has a tiling wizard.

Quadtree Hybrid indexing uses a combination of fixed-size and variable-sized tiles to index a layer. The variable-sized tile indexing uses tiles of different sizes to approximate a geometry, this results that for each geometry, we will have a set of fixed-size tiles and also a set of variable-sized tiles each one fully covering the geometry. As can be seen on the example in Figure III.10, the variable sized tiles approximate the geometry very well, which implies a good selectivity.

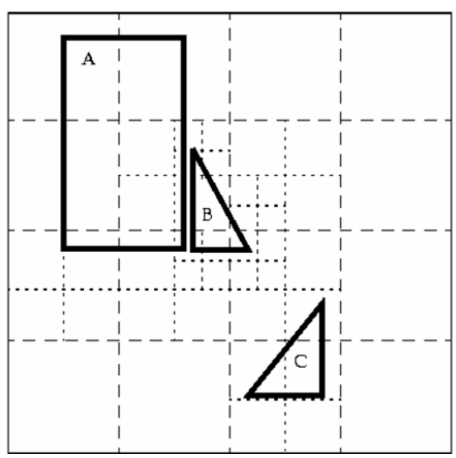


Figure III.10 - Example of a Quadtree Hybrid tile division (from Oracle [2002a]).

III.4.1.4.3 Considerations in choosing an index

Oracle allows the use of both index types in one spatial data, but in this case during a query the user should specify which type of index is to be used. Oracle [2002a] does not recommend the use of hybrid indexes except in special situations.

Kothuri, Ravada, and Abugov [2002] have performed several tests between the Quadtree fixed and the R-tree using two different datasets to determine which index has better performances and in which situations. They concluded that the R-tree besides could take more time in some index creations, have better performance in almost all situations except (with the Quadtree tiling level really optimized for each data set):

- If the data set was intensively updated;
- Or, "when specialized masks such as "*touch*" are frequently used in queries".

As in the generality of the cases the R-tree has better performances was adopted as the default index in Oracle Spatial.

III.3.1.5 Oracle Spatial Operators and Functions

Spatial operators are other core part in a SDBMS. In Oracle they are classified as **operators** and **functions** and are used to perform operations with the spatial data. Oracle distinguishes them by:

- Operators - Use the spatial indexes, only can be used in the SQL WHERE clauses and returns true or false (e.g. all operators listed in table 1).
- Functions - Do not use spatial indexes and can be used in the SQL SELECT or WHERE clauses. Their return may be geometry, Boolean values, text or numbers.

The spatial operators that use indexes in Oracle Spatial are:

- SDO_FILTER - Specify which geometries may interact with a given geometry (e.g. with a point or query window). Just operates with indexes (primary filter).
- SDO_NN - Determines the nearest neighbour geometry to a given geometry using the spatial indexes. Another operator SDO_NN_DISTANCE can compute the distance to a SDO_NN returned object.
- SDO_WITHIN_DISTANCE - Determines if two geometries are within a distance.
- SDO_RELATE - Determine whether or not two geometries interact in a specified way, using the nine intersection model.

The SDO_RELATE and the SDO_WITHIN_DISTANCE can operate with indexes as primary filter operators, or as secondary filter operators with the exact coordinates of the geometries.

The nine interception model used by SDO_RELATE that describe the possible topological relationships between two geometries with an interior, a boundary and an exterior (polygons with holes are not included) are described in Figure III.11.

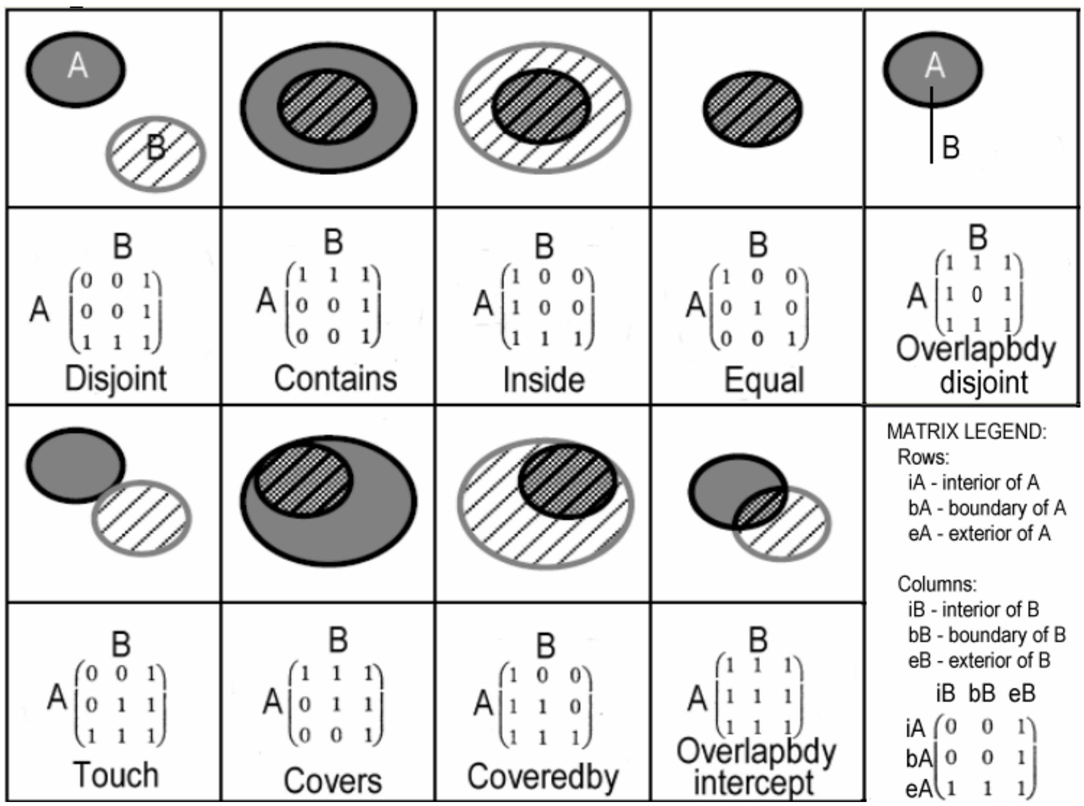


Figure III.11 - Relations between two geometries with two dimensions without holes (after Engenhofer [1994].

As was mentioned before, Oracle Spatial provides several geometry functions which operating with the exact coordinates complement the existing operators functionalities, being essential to carry on the necessary spatial operations. Some of these functions are described in Table III.2.

In addition to the geometry functions, Oracle Spatial provides other functions related with: **spatial aggregation,** used to aggregate the results of a query; **coordinate system transformation,** to allows coordinate systems transformation; **linear referencing,** to locate attributes or events along a linear feature with just a parameter (e.g. measure from the beginning of a line); **tuning,** to tune the database; and, **utilities**.

Table III.2 - Some Geometry functions in Oracle Spatial (modified from Oracle [2002a]).

SDO_GEOM.RELATE - Determines how two objects interact.
SDO_GEOM.SDO_AREA - Computes the area of a two-dimensional polygon.
SDO_GEOM.SDO_BUFFER - Generates a buffer polygon around a geometry.
SDO_GEOM.SDO_DISTANCE - Computes the distance between two geometry objects.
SDO_GEOM.SDO_LENGTH - Computes the length or perimeter of a geometry.
SDO_GEOM.SDO_MBR - Returns the minimum bounding rectangle of a geometry.
SDO_GEOM.SDO_POINTONSURFACE - Returns a point that is guaranteed to be on the surface of a polygon.
SDO_GEOM.WITHIN_DISTANCE - Determines if two geometries are within a specified distance from one another.

III.3.1.6 Other Important Oracle Spatial Features

As was mentioned by Oracle [n.d.b], Oracle Workspace Manager (OWM) is a feature in Oracle9i that solves the long term transactions problem and the version issue, both described in Section III.2. The process can be summarized in the following way:

- When a user starts to do update operations in the database (called live), the database creates copies of the changed geometries in a workspace and the changes are done in the user copy;
- The correspondent geometries and all the other geometries in the database are still available to all the users;

- The user works in their copy until they create a save point that will store this updated geometries as the actualized version, but if the table of the updated geometries was set to “version enable”, it will keep the “old” geometries, without overwrite them, just associating a version.

In case of a conflict that happens when two or more users are changing the same geometry, this can be detected when a merge or a refresh operation is requested. The system will warn the users that they should resolve the conflict by choosing which copy should be kept, one of the changed ones, or the original one.

Besides workspaces or the changed rows could be locked if the administrator want it, to general applications is not necessary because each user just works in its geometry copies until submit them to the database. The version functionality allows the reconstitution of the geometries history and to know how the database was in a given time in the past.

III.4 HPD Use of Oracle Spatial Functionalities

CARIS HPD specific applications mask almost totally the use of Oracle Spatial from the users with a great investment in the user friendly facilities. But, in some operations it takes advantage of the Oracle Spatial operators and capabilities. Before version 2.0, CARIS HPD was much more dependent on Oracle functionalities. The change in the client-server concept implemented in version 2.0, with the clients doing a data cache and the operations being done in the client system, the specific applications needed to have implemented their own functionalities, and the utilization of Oracle functionalities, such as the spatial functions and operators, was significantly reduced. However, some of the Oracle Spatial capabilities have an important role in CARIS HPD, for instance some Oracle operators such as the SDO_RELATE and SDO_FILTER still are utilized by the system.

APPENDIX IV

PRIORITIES ON HPD RECOMMENDATIONS AND CARIS FEEDBACK

APPENDIX IV

PRIORITIES OF THE RECOMMENDATIONS TO CARIS HPD AND CARIS FEEDBACK

During the evaluation of CARIS HPD thirty seven recommendations were made together with the priority that should be associated with each one, in the author's opinion. Those recommendations have been compiled to the system configuration used to execute the evaluation described in Chapter 3, Section 3.3 and could be considered to be referred to July 2, 2004. In July 8, 2004, CARIS provided the respective feedback with the implementation of those recommendations on the system. Some of the recommendations have been implemented during that short period of time and the respective prediction is signaled as "Now". The resume of the recommendations and CARIS feedback are described in Table IV.1.

The recommendation priorities have been divided in the following levels:

- Maximum - issues which by its importance should be solved as soon as possible with the assignment of all resources available. It should be corrected by a Hotfix without needing to wait for a new service pack;
- High- issues which by its importance should be solved as soon as possible, if possible should be included in the next service pack;
- Normal - issues important to solve or implement in the normal line of the CARIS HPD improvement;

- Low - issues important to be considered in the future, they do not impede the main objectives of CARIS HPD, but its implementation will contribute to improve its flexibility, capabilities and user-friendliness.

Table IV.1 – Recommendations priorities and respective CARIS feedback.

Section	Recommendation	Priority	CARIS Feedback
Requirements Compliance			
4.2 (B.6)	Functionality to report the objects modified by a given user.	Normal	Winter 2004/2005
Data Loading, Preparation and General System			
5.2.1	GUI loader implementation.	Normal	Fall 2004
5.2.2	Improvement of the “Find Duplicates Tool”.	Normal	Spring 2005
5.2.3	Warning when objects of a generalization relationship are modified.	Normal	Discussion needed
5.2.4	Implementation of functionalities to handle with non current version data.	Normal	Fall 2004
5.2.5	Implementation of user’s roles.	High	August 2004
5.2.6	Warning when objects of a master-slave relationship are modified.	Normal	Fall 2004
5.2.7	Paper chart presentation on the HPD Source Editor.	High	Fall 2004
5.2.8	Markers functionality on ENC Product Editor and Paper Chart Editor.	High	Fall 2004
5.2.9	Solve problem described with the lock of edited features.	High	Training issue
5.2.10	Report the editing user.	High	Possibly 2005
5.2.11	Export and import objects using HOB files in ENC Product Editor and Paper Chart Editor.	High	Possibly 2005
5.2.12	Customization of the HPD Dictionary and representations.	Low	Winter 2004/2005
5.2.13	Record of the Data Source.	High	Discussion needed
S-57 ENC Product Editor			
5.3.3	ENC Product Editor improvement of the quality control tools.	Normal	August 2004

Section	Recommendation	Priority	CARIS Feedback
Paper Chart Editor			
5.4.2	Inclusion of “Master File Browser”.	Maximum	Fall 2004
5.4.3	Issues on changes of panel metadata.	High	Fall 2004
5.4.4	Issues with the Template Editor and Borders.	High	Fall 2004
5.4.6	Images insertion in paper charts.	High	Winter 2004/2005
5.4.7	Incorporation of database updates.	High	Fall 2004
5.4.8	Verification process.	High	Fall 2004
5.4.9	Magenta lines colours.	Maximum	Fall 2004
5.4.9	User be able of change the colours of any object’s representation.	Normal	Winter 2004/2005
5.4.10	Soundings colour.	Maximum	Now
5.4.11	Soundings out of position.	Maximum	Now
5.4.12	Annotations.	High	Winter 2004/2005
5.4.13	Compass roses (if the customers have an explanation about how to do it using the CARIS Feature Codes the priority should be Normal).	High	Now
5.4.14	Sources and reliability diagrams.	High	Fall 2004
5.4.15	Availability of all IHO symbols.	High	Fall 2004
5.4.16	GUI for the creation of variations of the existent symbols in the file ih_master.txt.	Low	Under discussion
5.4.16	Load system information about symbols and colours on user demand.	Low	Winter 2004/2005
5.4.17	“Rock which covers and uncovers” representation.	High	Winter 2004/2005
5.4.17	Areas filled with symbols.	High	Winter 2004/2005
5.4.18	Lines limit of light sectors.	High	Spring 2005
5.4.19	Importation of text from RTF files	Normal	Fall 2004
5.4.20	Objects copy and paste functionality in HPD Paper Chart Editor.	Normal	Winter 2004/2005
AML Products Production			
5.5	Development of AML Products Editor.	Normal	Planned 2005

Vita

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