PRODUCT SPECIFICATIONS FOR MARINE INFORMATION OBJECTS

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PREFACE

In order to make our extensive series of technical reports more readily available, we have scanned the old master copies and produced electronic versions in Portable Document Format. The quality of the images varies depending on the quality of the originals. The images have not been converted to searchable text.

PREFACE

This technical report is a 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, June 2000. This work was supported by the Portuguese Navy and by Universal Systems Limited. The research was supervised by Dr. David Wells.

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To my wife Ana and son Bernardo.

Abstract

The integration of environmental and navigation data (marine information) with chart data in the electronic chart display and information system is under development.

Several authors have proposed additions to the International Hydrographic Organization's S-57 and S-52 standards to include marine information objects and to specify their representation on the display. But, no product specifications have been developed to define the rules for encoding, transmission and storage of the data sets produced with these objects.

The author proposes a "marine information objects" classification scheme based on their data provision (slow and fast marine information objects) as well as an approach for the generic development of S-57 product specifications. This approach is then used in the development of a slow marine information objects product specification that particularly addresses the sea surface temperature as an example of one of its eventual application profiles.

Acknowledgements

This report is a product of the support, in a variety of forms, of people and organizations that I would like to particularly thank.

I thank Universal Systems Ltd. (CARIS) for providing the software that helped me to understand the issues involved in the electronic navigational chart production.

I thank Dr. Lee Alexander for the comments and clarifications provided on *Marine Information Objects* that greatly contributed to the understanding of some of the issues presented in this report.

I thank the Portuguese Navy, particularly the *Instituto Hidrográfico* and the *Direcção do Serviço de Formação* for the opportunity and support that was given to me at all levels.

I thank my family, in laws and friends for all the support and encouragement.

I thank, my supervisor, Dr. David Wells for all the comments, suggestions, discussions and vision that led me to the path of this report.

Most importantly, I thank my wife for giving up two years of her teaching career to accompany me on this Canadian journey and my son for all their support, companionship and love.

Table of Contents

LIST OF FIGURES

List of Abbreviations

AIS	Automatic Identification System.
ARPA	Automatic Radar Plotting Aids.
BIS	Bridge Information System.
DGPS	Differential Global Positioning System.
DIGEST	Digital Geographic Information Exchange Standard.
DNC	Digital Nautical Chart.
ECDIS	Electronic Chart Display and Information System.
ECS	Electronic Chart System.
ENC	Electronic Navigational Chart.
ESRI	Environmental Systems Research Institute, Inc.
FMIO	Fast Marine Information Objects.
GPS	Global Positioning System.
HO	Hydrographic Office
IBS	Integrated Bridge System.
IEC	International Electrotechnical Commission.
IHO	International Hydrographic Organization.
IMO	International Maritime Organization.
IMO PS	IMO Performance Standards (for ECDIS).
MIO	Marine Information Objects.
MIS	Marine Information System.

NATO	North Atlantic Treat Organization.
NOAA	National Oceanic and Atmospheric Administration (USA).
RNC	Raster Nautical Chart.
SENC	System Electronic Navigational Chart.
SMIO	Slow Marine Information Objects.
SOLAS	United Nations Safety of Life At Sea convention.
TVO	Time Varying Objects.
USL	Universal Systems Ltd.
VTS	Vessel Traffic System.

1 Introduction

The development of marine electronic charting is facing the challenge of integrating chart data with environmental and navigation data. A full integration of these data sets is of much value to the mariner and is dependent on the use of the same "language" or standard for their transfer. This report presents the author's view on how product specifications for these extra layers of information should be produced using the S-57 transfer standard for digital hydrographic data. A case study of a product specification for the transfer of sea surface temperature data is presented in Appendix A of this report.

Some proposals have been made for the creation of new objects and attributes in the S-57 standard object catalogue to provide the ability of environmental data transfer to electronic charting systems. These objects and attributes are only the primitives that describe natural elements. For them to be used it is necessary to set the rules for their encoding, transfer and storage. Product specifications define such rules and, to the knowledge of the author, none have been created for the purpose of environmental data transfer using the S-57 standard.

1.1 Historical Background

The ocean plays a major role on the world's commerce, transportation and recreation activities. It occupies about two-thirds of the Earth's surface and although coastal zones cover less than 15% of the land surface, this is where the majority of the population lives and works (about 60% of humanity) [Hinrichsen, 1997]. These facts make the human-ocean interaction very strong and sometimes dangerous. The consequences of an accident often affect not only the ship and crew, but also impact the coastal area.

There are a number of factors that can make an ocean voyage go wrong. Machine failure, natural hazards and human error are among the most common causes. Human error can be minimized through the establishment of rules, adequate training and the development of auxiliary warning and automated systems. Electronic charting is one of the latest technologies to become available to the mariner with the purpose of contributing to the safety of navigation.

The development of computer systems and satellite positioning systems (GPS/DGPS – Global Positioning System/Differential GPS) are two enabling technologies of marine electronic charting.

Different paths were followed in the development of this new technology, creating two major types of electronic chart systems: the Electronic Chart Display and Information System (ECDIS) and the Electronic Chart System (ECS). The development of ECDIS was performed by recognized international organizations in a top-down strategy while several ECS were developed by some national/private organizations/companies following a bottom-up strategy. The latter are not recognized by the International Maritime Organization (IMO) as being compliant with the *Safety of Life at Sea* (SOLAS) convention requirements for safe navigation and can only be used, in SOLAS class ships, if regular up-to-date paper nautical charts are also on board. Due to its careful study and development, ECDIS standards took more than 10 years to be prepared and approved. The first ECDIS was certified on October 14th 1999, while several ECS systems have been implemented aboard many ships for years [Komrakov, 1999].

A few years before the S-57 standards were published by the International Hydrographic Organization (IHO) for commercial navigation, the North Atlantic Treat Organization (NATO) developed the DIGEST (Digital Geographic Information Exchange Standard) standard for the transfer of military geographic information [O'Brien et al, 1998, pp. 4]. Although DIGEST has a broader concept (air, sea and land) than S-57, one of its products – the DNC (digital nautical chart) – shares common interests with the ENC (electronic navigational chart – S-57). Realizing this fact, and although the commercial ENC is aimed at safety of navigation, while the military DNC focuses on the best available data, a harmonization process between the two products (ENC/DNC) is under way.

ECDIS is now in an implementation stage. Its concepts are being adjusted as experience from its use is gained and new ideas are already showing up on the horizon. One of the expected improvements in the next few years is the integration of electronic navigational chart data (ENC) with environmental and navigation information (e.g. weather, sea state) that can, once more, improve the safety of navigation. These extra data sets will use the same data format as electronic navigational charts and fall under the general classification of *Marine Information Objects* (MIO).

1.2 The Future?

The last 10 years were specifically rich in marine systems development. Integrated bridge systems (IBS) have been implemented in order to provide the mariner direct access to onboard information and systems control, permitting resources optimization, providing improved management, operational efficiency and enhanced crew response to emergencies.

IBS does not "fully" integrate platform management with the navigation system. These two areas are monitored and controlled in the same multi-screen console, but no data really crosses between the two areas in an intelligent way to provide the mariner with extra valuable information.

ECDIS is now a key element of modern IBS. Once environmental and navigation data is integrated in ECDIS and proper communication channels established between all elements (platform, navigation, MIO), then this system will provide the mariner with new and valuable information and functionality. This system will become a *Bridge Information System* (BIS). Integration does not only refer to the simple display of two or more data types/layers in a screen, but to their actual interaction in a way that the system is able to trigger warnings/alarms for decision support.

The integration of MIO with ECDIS will amplify the electronic chart system concept to a more elaborate *Marine Information System* (MIS). Figure 1.1 presents the author view of a future BIS. This BIS would result from the concatenation of MIS (integration of ECDIS with MIO) with a strengthened IBS (amplification of links and data interaction between ECDIS and the internal platform information system).

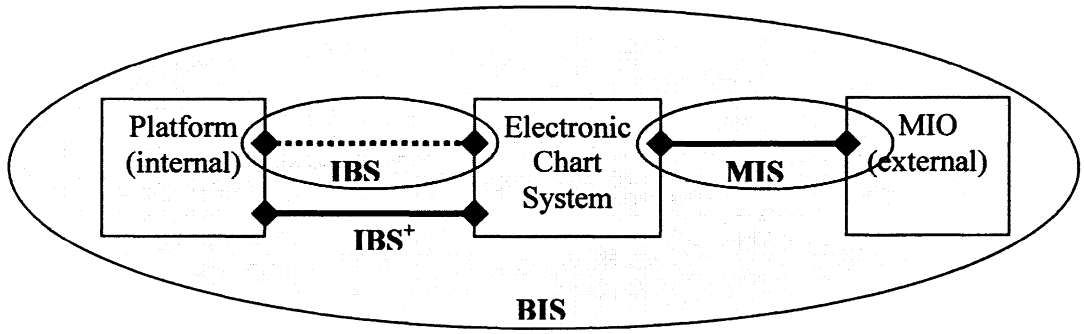


Figure 1.1 - Bridge Information System.

The BIS would be divided into two major areas: Navigation and Support. By Navigation the author refers to the ECDIS with chart information, MIO, navigation equipments inputs (i.e. GPS, speed log, echo sounder, etc) and any other data that could be imported into the navigational system. By support, the author refers to the onboard auxiliary systems such as those related to the ship's mechanics, electronics, logistics and damage control (Figure 1.2).

As examples of a strengthened IBS, the mechanical area, besides monitoring and remote control of principal and auxiliary engines, could interact with the navigation area by linking the route-planned speed to the engine's control of RPM. It also could set warnings regarding the ship's maintenance according to the mileage. In the electronic area, the control of communications and other onboard equipments that could interact with the navigation area by automatically opening the necessary channels for receiving/requesting chart updates, notice to mariners, MIO, etc. The logistic area could monitor the existing supplies (water, fuel, food), spares, onboard crew/passengers and cargo. This area could interact with the navigation area by evaluating the needs for the remaining voyage (according to the planned route and expected port visits). The damage control area could interact with the communications and navigation area issuing automatic distress calls and at the same time providing detailed information of the ship's damage and position. These are just few examples of the functionality of a *Bridge Information System*. Certainly there are more areas that could be covered.

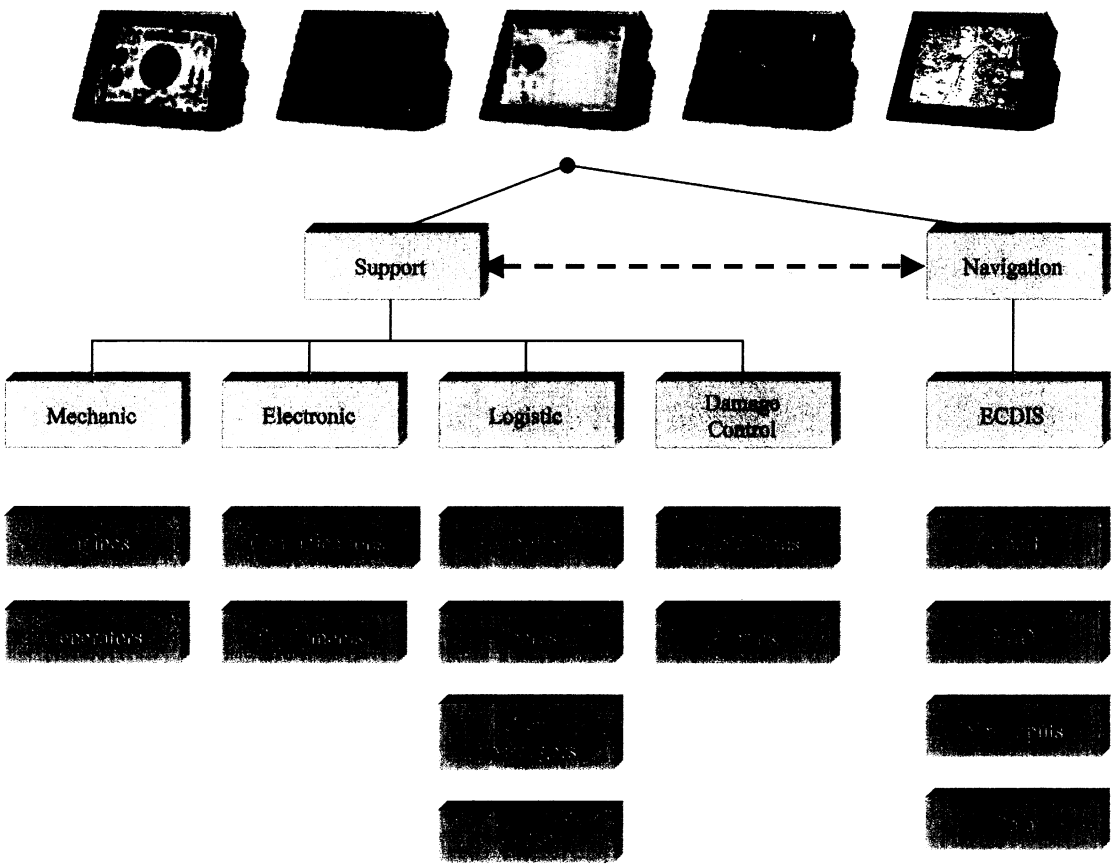


Figure 1.2 - Bridge Information System.

1.3 Outline and Contributions of This Report

This report discusses one aspect of these BIS and MIS concepts. It presents an eventual solution for the integration of MIO and ECDIS and contributes to the implementation of MIO data transfer standards by:

- Clearly identifying the issues involved (Chapters 2 and 3);
- Proposing an MIO classification scheme (Chapter 3);
- Proposing a framework for S-57 product specifications (Chapter 4);
- Discussing the expected differences and similarities between ENC and MIO S-57 product specifications (Chapter 5);
- Illustrating MIO product specifications, using the sea surface temperature as an example (Chapter 6 and Appendices I and II).

Chapter 2 describes the ECDIS related standards in a general way in section 2.1. These standards represent the framework for ECDIS implementation. Due to its relevance to the subject addressed in this report, the S-57 standard produced by IHO for the transfer of digital hydrographic data is described in detail in section 2.2.

Chapter 3 defines, presents and discusses the current status of marine information objects (MIO) as new data sets to be integrated in ECDIS. A classification, based on their update rate, is proposed for MIO. Some of their encoding and uploading issues are discussed.

Chapter 4 describes a method for the development of product specifications using the S-57 standard. Chapter 5 identifies the similarities and differences between ENC and the two identified types of MIO in terms of their product specifications.

Chapter 6 describes the production of a product specification for one of the two types of MIO classified in Chapter 3, with specific application for the transfer of sea surface temperature data. Finally, Chapter 7 presents the conclusions of this report.

2 ECDIS

This chapter presents a general description of the standards directly related to ECDIS. These standards cover all aspects from the system performance to the hardware, software and data format requirements and definitions. Special attention and description is provided of the S-57 standard due to its specific purpose of data transfer regulation (the main issue of this report). A brief presentation is made of ENC and the system ENC (SENC), the main data elements of ECDIS.

2.1 Standards

ECDIS was developed based on international standards. Some of those standards are still under refinement as users and systems manufacturers feed back their experiences. The organizations directly involved in the standards development are the IMO, IHO and the International Electrotechnical Commission (IEC).

2.1.1 Performance Standards for ECDIS (IMO PS)

Being the principal international regulatory organization for international maritime operations, IMO adopted in 1995 the "Performance Standards for Electronic Chart Display and Information System Performance Standards" (IMO PS) [IMO, 1995]. This standard sets the guidelines and requirements for a system to be considered an ECDIS and so, accepted as being compliant with the up-to-date chart required by the SOLAS convention.

Besides having defined the ECDIS concept, this standard created a clear classification for electronic chart systems. This classification is not only referred to the hardware and software used by a certain system but it is also expanded to what data format is used and what organization issues the data. In this perspective, a system is an ECDIS if it complies with the IMO Performance standards for ECDIS; otherwise it is an ECS (referenced in section 1.1).

2.1.2 Transfer Standard for Digital Hydrographic Data (IHO S-57)

The International Hydrographic Organization (IHO) special publication 57 (S-57), "IHO Transfer Standard for Digital Hydrographic Data" specifies the data format and encoding for the transfer of digital hydrographic data. Although many applications are intended to use this data format, at this time only ECDIS through the ENC is using it.

The main body of the S-57 standard defines the theoretical model to be used in the description of "real world" features (objects) and the data structure to be used. Although it predicts the representation of objects using vector, raster or matrix data models, only the first one is completely defined. The other two remain under study for later implementation. Its two appendixes contain an *Object Catalogue* and two *Product Specifications* (one for ENC construction, the other for the transfer of the object catalogue data dictionary; other specifications will be included as needed).

This standard can be analysed considering two very different aspects: one dealing with the transfer content and the other dealing with the encoding of this content (how the transfer file is internally organized and physically encoded – encapsulation). The content of a transfer is related to the objects that are of interest to be represented in a final application. These objects are described in the S-57 standard Appendix A (the object catalogue) [IHO, 1996] and it is expected to grow, as new objects are included in final applications. The encoding of the content is made according to the ISO/IEC 8211 standard ("Specification for Data Descriptive File for Information Interchange"), "*that provides a file based mechanism for the transfer of data from one computer system to another, independent of make*" [IHO, 1996, p. 1.1].

The standard discussed in this section is mainly oriented to ENC data producers (the national agencies in charge of official nautical chart production – normally the national hydrographic offices).

2.1.3 Specification for Chart Content and Display of ECDIS (IHO S-52)

An ENC is just one of the various possible S-57 products and ECDIS one of its possible applications. Being system and application independent, S-57 encoded data is broader in its reach but its applications have to define specific rules and standards that deal with every other process besides data format and encoding. The S-52 standard provides specifications and guidance regarding the issuing of ENC, their display in an ECDIS and their updating.

The ECDIS display of information is not only specified by the S-52 standard but also by the IEC 61174 standard discussed in the next section. They complement each other. S-52 specifies the rules for SENC display while IEC 61174 deals with the representation of navigation related information (i.e. radar).

2.1.4 ECDIS Operational and Performance Requirements, Methods of Testing and Required Test Results (IEC 61174)

The International Electrotechnical Commission is an international organization for standardisation that developed the standards specifying the performance requirements, methods of testing and required test results of equipment conforming to the IMO PS referred to in section 2.1.1. This IEC standard also defines the presentation rules for navigation related data in ECDIS.

2.1.5 Product Specification for Raster Navigational Charts (IHO S-61)

In 1999 IHO published the "Product Specification for Raster Navigational Charts (RNC)" (special publication 61 or S-61) [IHO, 1999].

After the IMO PS approval, there was (and still is) a lack of S-57 data coverage available to be used in ECDIS. Recognizing the value for the safety of navigation that raster charts could provide, IMO included in 1998 an appendix to the 1995 Performance Standards [IMO, 1995].

Although this appendix does not consider ECDIS operating in raster mode to be equivalent to the use of paper charts, it boosted the creation of the S-61 standard that sets high quality parameters for RNC production.

2.2 S-57 in Detail

The S-57 standard *"is intended to support all hydrographic applications"* [IHO, 1996, p. 3.5]. The standard describes the adopted hydrographic data exchange format, its use and constraints. It is divided in three major parts and includes two appendices (Figure 2.1). The first part provides a general introduction and lists some definitions. The second part describes the logical data model of the standard. The third part describes its implementation, defines the data structure and sets the rules for data encoding. The standard first appendix - "Appendix A" – contains an object catalogue. This catalogue includes all objects (real world features) of interest to hydrography that can be included in a S-57 file and later on represented in some specific media/application. The standard second appendix - "Appendix B" – contains product specifications. Product specifications are documents that based on the S-57 standard, fine tune its use regarding applications. At this time there are two product specifications: one for the production of electronic navigational chart data and one other for the encoding of a data dictionary exchange set (based on the object catalogue). As new applications are developed based on S-57, it is expected to have more product specifications included.

S-57 is a data format that focus on data content, not on data presentation. This might lead to the thought that a S-57 file could be used in many applications, but that is not the case. The encoding of a file has to follow the product specifications for each different application.

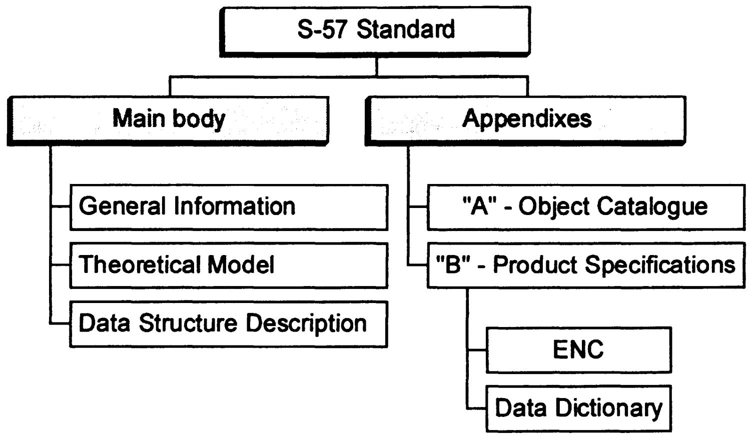
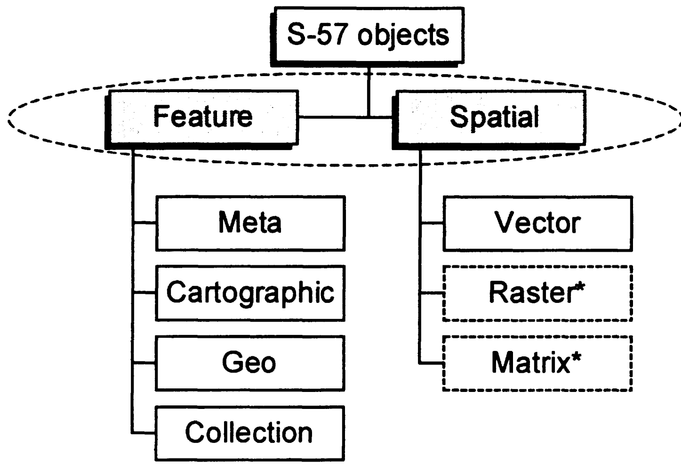


Figure 2.1 - S-57 Standard content.

2.2.1 Theoretical Data Model

S-57 objects are of two types: *feature* or *spatial*. Feature objects only contain non-geometric attributes. Spatial objects contain geometric attributes and may have descriptive attributes. There might exist feature objects that do not have a relationship with a spatial object (i.e. compilation scale). On the other hand, every spatial object must be referenced by a feature object (i.e. a point - spatial object - by itself does not provide much information, except its location; once a relationship between this point and a feature object describing, for example, the characteristics of a lighthouse is established, then a real world object is defined).

There are three types of spatial objects: vector, raster and matrix. At the moment only vector data is defined in the standard. There are four types of feature objects: Meta, cartographic, geo and collection (Figure 2.2)



* Not implemented at this time.

Figure 2.2 - S-57 Objects.

Meta objects store information about other objects (i.e. accuracy of data, compilation scale). They are not real world objects. Cartographic objects contain information about the cartographic representation of entities (i.e. compass, chart border). These objects are to be used in the future exchange of paper chart specific information. Geo objects carry the description of real world entities (i.e. berth, radar reflector). Most of the feature objects are of this nature. Collection objects describe the relationship between objects (i.e. aggregation, association). A radar reflector, a light and an isolated danger buoy when belonging to the same real world entity should be *associated* into a single collection object.

The primitives that can be used in vector representation of spatial objects (2 dimensions) are the node, edge and face. Topology must be used to establish relationships among these primitives. The S-57 standard describes four levels of topology that can be used: spaghetti, chain-node, planar graph and full topology (Figure 2.3).

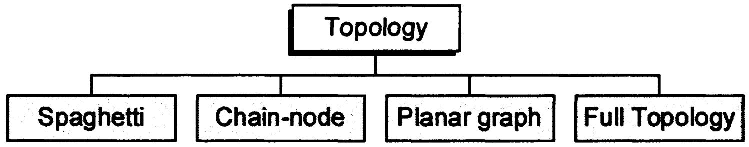


Figure 2.3 - S-57 topology models

2.2.2 Data Structure

The exchange of data in S-57 format is made through files encapsulated using the ISO/IEC 8211 standard. Within the files is included a set of records that contain the objects information. Each of these records is made of a number of fields and these fields are composed of subfields (detailed attributes - Figure 2.4). Subfields are the smallest piece of information that can be stored in an object's record.

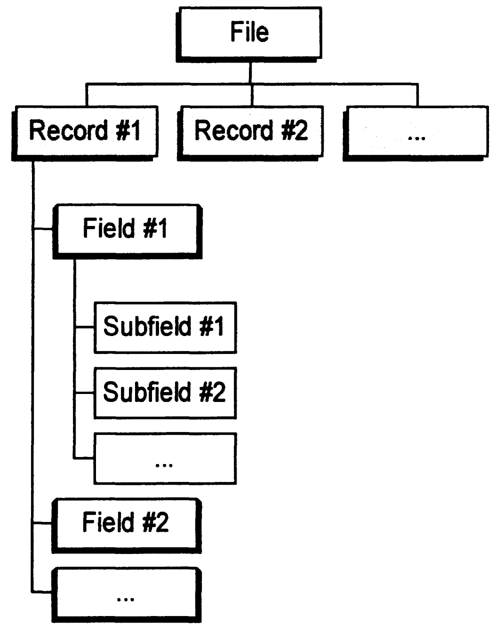


Figure 2.4 – File data structure.

2.2.3 Records

There are five categories of records that are used in S-57 files: *Data set descriptive, catalogue, data dictionary, feature* and *spatial*. Data set descriptive records are "meta-records". They contain information that identifies the general purpose and nature of the data set (i.e. edition, name, intended use). Catalogue records contain information that is used to locate files within an exchange set (the information covering a cell may be spread by several files, specially when updates occur) and holds cross-reference information about objects that have special relationships. Data dictionary records contain the record data structure of objects that are not included in the S-57 object catalogue. Limiting the real world features description to a "reduced" list of objects has its drawbacks. The idea behind catalogue records is not to limit the representation of a certain area just because some "specific" objects are not included in the S-57 Standard. Feature records contain non-spatial attribute data of objects (meta, cartographic, geo or collection). Spatial records contain the spatial attribute data of objects (vector, raster or matrix).

2.2.4 ENC Product Specification

The ENC product specification (ENC PS) establishes the rules to follow in ENC data production for use in ECDIS. Only a subset of the S-57 standard is used. The following sections depict some of the most important constraints of the ENC PS over the S-57 standard main part.

2.2.4.1 Chain-node Topology

At the topological level, the ENC PS states that ENC data must be encoded using the *chain-node* topology. In this topology model, primitives are: node (point) and edge (line segment). Every object in an ENC data set must be encoded using these primitives. Each edge must reference a starting and ending node; objects may share primitives (nodes, edges); areas are represented by a closing loop of edges and duplication of linear geometry is prohibited [USL, 1999].

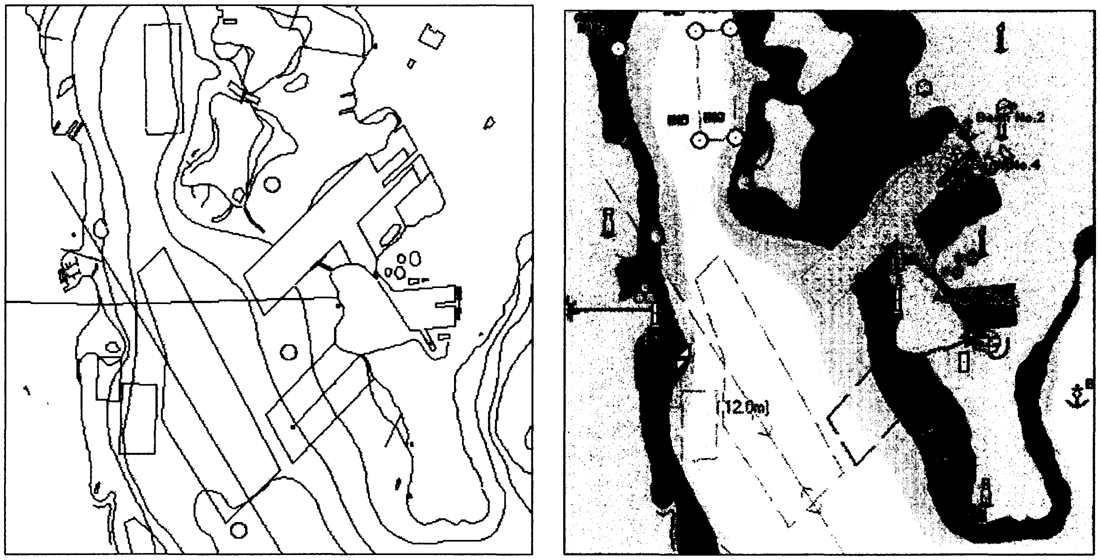


Figure 2.5 - Chain-node object representation (on the left) and its correspondent SENC display.

Figure 2.5 shows an example of the chain-node structure "behind" the final chart display. Data used to produce the two images was downloaded from the NDI website (http://www.ndi.nf.ca/ndi99/support/test_data.htm#MULTIBEAM).

2.2.4.2 Cartographic Objects

Cartographic objects are directly related to paper chart representation and therefore cannot be used in ENC production.

2.2.4.3 Non Object Catalogue Object Classes

The S-57 standard allows the use of non-object catalogue objects as long as they are defined in the data dictionary records included in the transfer file, but the ENC PS rules that ENC can only be produced using objects from the S-57 object catalogue.

2.2.4.4 Prohibited Catalogue Object and Attribute Classes

Although no product other than ENC presently uses S-57 for data transfer, this standard is not intended for its exclusive use. From the object classes contained in the object catalogue, 13 cannot be used in ENC data production. The same limitation affects some attributes. Their use is not allowed due to some constraints imposed on the ENC in its PS. For example, it was established that ENC data sets would only be produced using the WGS 84 geodetic reference system. Based on this constraint it makes no sense to allow the use of the meta-object that can establish the horizontal datum of a data set (by default it is already defined and cannot be changed).

The prohibited objects and attributes are:

Object Class	**Description**	**Type**
CANBNK	**Canal Bank** – The limit line between the water area of a canal and the area of land.	Geo
LAKSHR	**Lake shore** – The limit line between the water area of a lake and the area of land.	Geo
RIVBNK	**River Bank** – The limit line between the water area of a river and the area of land.	Geo
SQUARE	**Square** – An open area within a built-up area surrounded by roads.	Geo
M_HDAT	**Horizontal datum of data** – An area of uniform	Meta

	horizontal datum.	
M_PROD	**Production information** – An area within which uniform data production parameters apply.	Meta
M_UNIT	**Units of measurement of data** – An area of uniform units of depth and/or height measurement.	Meta
C_STAC	**Stacked on / Stacked under** – Used to identify the order of stacking of objects.	Meta
$AREAS	**Cartographic area** – An area in which a certain cartographic symbolization is required.	Cartographic
$LINES	**Cartographic line** – A line with a certain cartographic symbolization.	Cartographic
$CSYMB	**Cartographic symbol** – A point with a certain cartographic symbolization.	Cartographic
$COMPS	**Compass** – A circle graduated in degrees clockwise from 0 (north) to 360 used to facilitate measurements of direction.	Cartographic
$TEXTS	**Text** – A text string that is to be represented using a certain cartographic symbolization.	Cartographic

The prohibited attributes are:

Attribute Class	Description
CATQUA	**Category of quality of data** – Category of data quality based on positional accuracy, sounding technique, coverage and datum.
DUNITS	**Depth units** – units in which depth is specified.
HUNITS	**Height/length units** – units in which height/length are specified.
PUNITS	**Positional accuracy units** – units in which position accuracy is specified.
RECDAT	**Recording date** – The date when the specified object or cartographic primitive was captured, edited or deleted.
RECIND	**Recording indication** – The procedure for the encoding and entering of data.
SCAMAX	**Scale maximum** – The maximum scale at which the object may be represented.

2.3 ENC

According to IMO PS [IMO, 1995], ECDIS is a:

> *"navigation information system which with appropriate back-up arrangements can be accepted as complying with the up-to-date chart required by the 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."*

So, ENC plays a major role in ECDIS but is never directly used for chart display. National authorities produce and distribute ENC cells in S-57 format but this data format, although suitable for information transfer, is not suitable for fast data display on the ECDIS screen. Accessing the file content in such uncompressed encoding format would make the chart display very inefficient (the time limit to redraw the screen image due to ship's progress or scale changes is of 5 seconds [IEC, 1998, p. 17]).

ECDIS is basically a computer system (hardware and software) which uses officially produced S-57 ENC data for chart display and a positioning system input for geographic location of the ship in the chart. However, this simplistic view does not reflect all the issues and concepts of an ECDIS. The following paragraphs go into some of the necessary details to describe the way the system works.

The compilation of chart information into the S-57 format is composed of at least two files (exchange set), one catalogue and one data file. This exchange set can have an extra number of data files each one corresponding to a set of corrections to a cell or to original base cells. The catalogue file works like a table of contents of the exchange set.

It was established right at the start of the S-57 standard development that this data format would have to be platform and application independent. In this sense, every final application developed to use S-57 data will have to adjust itself to this standard.

The way ECDIS deals with this situation is through a transformation of the ENC data in S-57 format into a System ENC (SENC) optimized internal format.

2.4 SENC

The IMO PS [IMO, 1995] defines SENC as:

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

So, the SENC is a database with direct correspondence to ENC but in a more compressed and ECDIS display efficient format. It is a system manufacturer proprietary format and will not be the same or have the same internal characteristics when comparing systems built by different companies, but the results from its use must be exactly the same as far as S-52 requirements are concerned. Having to follow the minimum standards established by the IMO PS, all ECDIS systems have to be certified according to the requirements specified in the IEC 61174 standard. This certification is the assurance that a certain system is doing the correct S-57 to SENC transformation.

The transformation of the ENC into SENC format is made once and it is an off-line procedure (using 1999 PC based technology, a cell transformation may take some minutes [Chartworld, n.d.]).

3 Marine Information Objects

The previous chapter described the standards behind ECDIS and its main fuel: the ENC data. This chapter presents and discusses the future integration of environmental and navigation data with the existing system. It also addresses some of its implementation issues.

The electronic chart representation in the ECDIS display is different than that of paper nautical charts. The greatest difference is in the integration of navigation-related information. As called for by the minimum performance standards, the ship's position, heading and speed are navigation inputs that ECDIS must integrate with chart data [IMO, 1995]. Radar is also a valuable source of information. Knowing in real time the position of a ship in a chart and being able to directly compare that information with the radar display is indeed one of the most valuable features of ECDIS concerning its main purpose: the safety of navigation.

Several other information sources exist aboard ships providing data to assist mariners in decision-making (i.e. weather). The IMO PS states that the integration of this additional information in ECDIS can be performed as long as it does not degrade any of both the ECDIS and the additional information display and efficiency.

The integration of the "extra" data sets with chart data and all other ECDIS sensors input would provide the mariner a snapshot of the global navigation situation. Data from different sources would be able to interact and trigger alarms reducing the chances of human error in decision-making. For total integration to be achieved, it would be a major advantage to have all data in the same format (S-57). This is the idea behind the *Marine Information Objects* (MIO) development [Bell and Gonin, 1998].

3.1 MIO Definition

In the third edition of the S-57 standard [IHO,1996], a set of "Time Varying Objects" (TVO) was included in the object catalogue: Magnetic, Tidal, Tidal Stream and Current.

Almost all, if not all, objects in an S-57 chart cell may vary with time, but chart corrections and re-editions are sufficient to update most of the real-world medium and long period changes. The "time varying concept" introduced in the S-57 standard refers to objects for which variation in a short period of time is significant, and therefore not considered to be part of the relatively stable "maritime snapshot" presented in a nautical chart. Even so, some of these time varying objects are represented in paper charts but they do not have a direct reading. The navigator has to perform a variety of calculations to get the information corresponding to a certain time/date of interest:

- The magnetic deviation in a certain area is calculated based on its value at a certain time and its annual variation;
- The water level height (tide) is calculated through interpolation based on a representative table of the expected tide heights for particular astronomical situations (neaps and springs, low and high tide);

- Tidal stream value and direction are calculated based on the extreme current values that occur in particular astronomical situations. These values are listed in a table and can be interpolated for the specific tide height.
- Currents represent a permanent horizontal movement of the water not associated with the tide. These can also figure in the form of a table that represents the extreme situations. Intermediate values of both speed and direction can then be extracted through interpolation.

Several new "time varying objects" are being considered for inclusion in the next S-57 standard edition (to be released in November 2002, [Drinkwater, 1999]). These new objects focus essentially on the description of oceanographic, meteorological and navigation conditions. Due to their characteristics, the previous "Time Varying Objects" term was changed to "Marine Information Objects" (MIO) [Wild, 1998].

It was established during a workshop in 1998 [Wild, 1998] that MIO should include in its definition every time-varying non-cartographic object (i.e. wind, currents, tides, atmospheric pressure, etc) of interest to the mariner. *"The MIOs do not include:*

- *Time varying cartographic objects*
- *Navigation objects such as own ship*
- *Radar imagery or ARPA"*

Although very much related to the MIO concept, radar is not considered to be MIO. Due to its raw pictorial data representation, it is difficult to determine what a radar object would be and how those objects would eventually interact with ECDIS.

A new classification criterion was adopted during a 1999 workshop on MIO development (Figure 3.1) [Alexander, 1999]. MIO could be classified as chart-related or navigation-related. Also, as presented in this workshop report, MIO produced by HO would usually be considered more chart related, while MIO produced by non-HO sources would be often considered navigation related. The former would have its data in S-57 format and its display specified by the S-52 standard while the latter would have its data in any format (S-57 or other) and the display specified by the IEC 61174 standard (Figure 3.1).

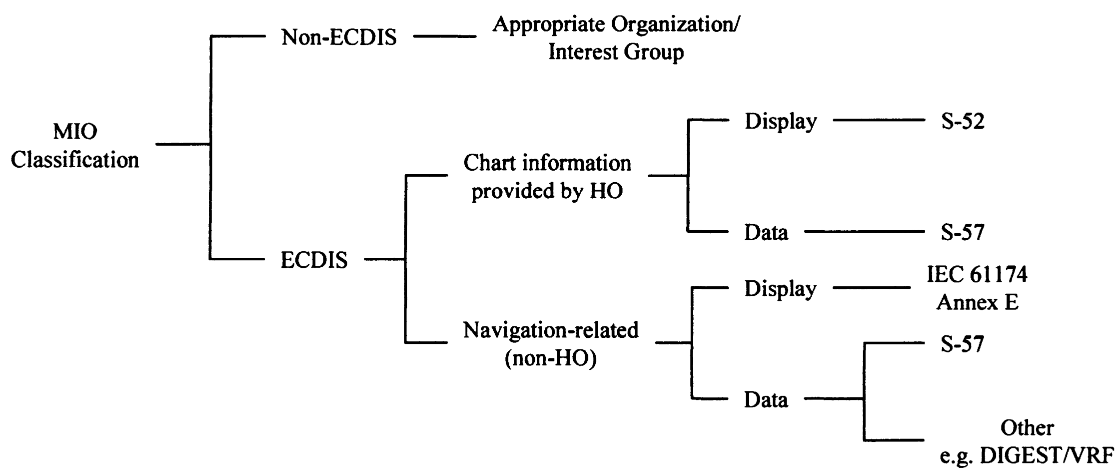


Figure 3.1 - MIO classification - Annex C to the Workshop on Development of MIO for ECDIS (1999).

In this workshop report, no definition of chart-related and navigation-related MIO is given. In the author's opinion, the HO/non-HO association with MIO classification implies an HO dependency, which is not uniform: the mission of HO varies from country to country. One thing they have in common: all are responsible for their national nautical chart production, but everything else may be very different. One country's HO may have the mission of issuing some MIO, while in another country that mission may be assigned to a non-HO organization.

One of the most important factors to consider in MIO classification is the age of information when it is received onboard. Real-time data will present different architectural needs than forecast (or past) data.

The author proposes MIO to be classified according to their age (or provision) when arriving to ECDIS. *Fast MIO* (FMIO) would be real-time related data with instantaneous value, while slow MIO (SMIO) would correspond to aged data sets (past or forecast) that could be used for navigation pre-planning and analysis. An example of a FMIO is the real-time transmission of water level from a sensor at a port's pier that transmits its readings every five minutes. An example of a SMIO is the transmission of weather charts, provided every four hours, forecasting the weather for the next four hours.

MIO age is also mostly related to the transmitted data size. FMIO are not expected to contain large amounts of data at a time. Their use by ECDIS is supposed to be instantaneous and related to real-time transmission of measured/observed data (something comparable to the previous navigation-related MIO). SMIO are expected to contain large amounts of data (when compared to FMIO). Their data would most certainly be related to area forecasts or past situation descriptions (something comparable to the previous chart-related MIO).

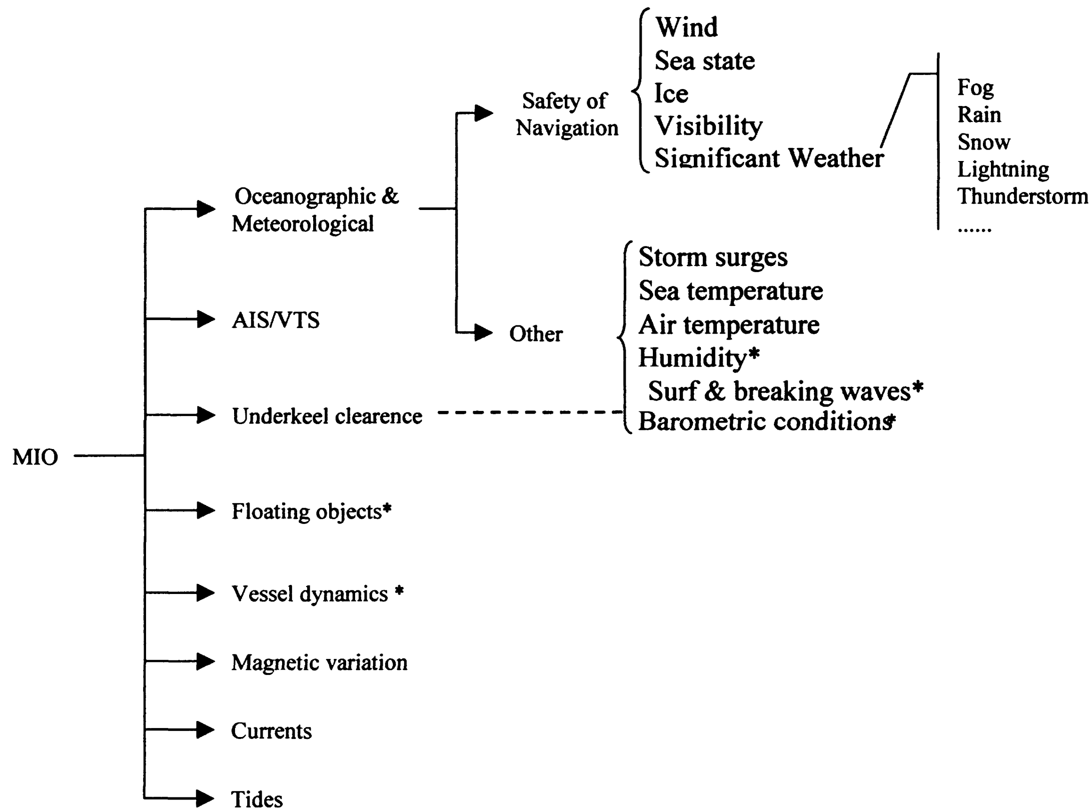
This FMIO/SMIO classification is not selective of environmental parameters. The same MIO can exist in *slow* and *fast* mode. For example, a chart with the monthly average currents measured in a certain area is to be treated as SMIO. If a moored currentmeter transmits its readings in real time, it is to be treated as FMIO.

3.2 MIO Development Status

Several MIO candidates were discussed in the last two workshops dealing with the subject. Some were postponed, waiting for an advanced stage of other MIO implementation. Magnetic variation, tides and currents are MIO that already figure in the S-57 standard (as TVO) and ice data has been discussed in specific workshops [Wild, 1998]. Besides these, it was considered that weather and AIS/VTS data (navigation data transmitted ship to ship and ship to shore) were items of primary importance for inclusion under the MIO umbrella [Wild, 1998].

The inclusion of weather and oceanographic data is to be articulated in collaboration with the World Meteorological Organization (WMO) because this is the entity that coordinates the global weather information for public, private and commercial use. This type of MIO was divided into two groups, one consisting of information that is considered related to aspects of the safety of navigation - *basic mandatory* - and a second group including information for other uses - *non-essential.*

The basic mandatory information includes wind, sea state, visibility and significant weather data. Ice is also considered basic mandatory information but, as stated before, its inclusion in the standard is at a more advanced stage. The non-essential information includes storm surges, sea temperature, air temperature, humidity, surf and breakers, and barometric conditions (Figure 3.2).



* MIO which discussion is suspended until further developments (results) are achieved with priority MIO

Figure 3.2 - Discussed MIO.

An aspect to be considered is that some of the weather and oceanographic information are produced in both forecast and real time modes.

Other MIO being considered, but not under development at this time, are *floating objects* and *vessel dynamics*. Floating objects are classified as identified (IFO) or unidentified (UFO). IFO is divided into fixed and fluid. Fluid covers oil spills while fixed addresses abandoned ships, containers and lifeboats. Every other object is classified as UFO until its status is determined. The interest in these types of objects is both related to environmental protection (oil spills) and safety of navigation (collision avoidance with dangerous floating objects such as containers). Vessel dynamics would include information such as turning circle and stopping distance. Underkeel clearance has been discussed, but no final decision was made on its proposal for inclusion in the S-57 standard.

3.3 Uploading MIO Data to ECDIS

So far, with the exception of the proposed MIO classification, this report has mostly presented facts. From this section on, the author will mostly present ideas and make proposals for the integration of MIO in ECDIS.

MIO encoding for data transmission between suppliers/sensors and users is not to be restricted to the S-57 format (specially considering some real time transmitted data). The main reason is that some "MIO" information structures are already implemented in their own format (e.g. the World Meteorological Organization has issued standards for data transmission to vessels in ASCII, binary and Weatherfax [Pillich, 1998a]) .The eventual efficiency loss and necessary financial effort to change it could make it impractical for many data suppliers and especially to users. From this section on, both fast and slow MIO refer only to MIO data that could or is to be encoded using the S-57 standard.

All data represented in the ECDIS display (at this time) is either fed by the SENC, by an external source (navigational data such as radar), by the mariner or manufacturer.

Chart data reaches the SENC from the S-57 cell transformation procedure. Once S-57 cells are transformed into the SENC format, they are no longer accessed by the system (they can even be removed from the ECDIS) during the route planning and/or monitoring.

The big question at this time is: Can MIO adopt a product specification similar to the ENC PS? Looking at the characteristics of SMIO (i.e. ice and weather charts) the answer is yes, but the fact that the transformation of chart data in S-57 to SENC format is an off-line procedure creates some problems to FMIO (e.g. real-time water level information). FMIO cannot go through an off-line procedure without violating the ECDIS performance standards in terms of its efficiency requirements. FMIO information is real-time data. The time delay caused by an offline procedure would make this information to lose most, if not all, of its value.

Due to its nature, FMIO is expected to contain only a few bytes of information at a time. When dealing with short size information (i.e. FMIO), there might not exist the need to transform this data into SENC format for further display in ECDIS. S-57 is not efficient for the display of large amounts of data at a time, such as a whole ENC cell. However, for a few bytes of information FMIO could, probably, be handled fast enough not to compromise the minimum ECDIS performance standards. On the other hand, when dealing with few bytes of data, it can be efficient for FMIO to use an on-line transformation procedure of the S-57 data directly into SENC format. The transformation of a few bytes from S-57 into SENC format would probably take just a few milliseconds. These two options are presented in Figure 3.3.

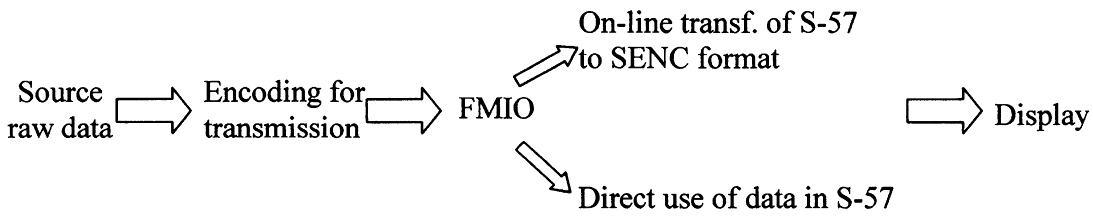


Figure 3.3 - Possible architectures for fast MIO display in ECDIS

For SMIO datasets (i.e. weather) the off-line procedure should be used (MIO would be treated as ENC cells are).

Figure 3.4 presents the author's solution for MIO data uploading into ECDIS, considering that the S-57 format could be used by FMIO for direct information display (i.e. only an interpreter from the S-57 content to S-52 display would be necessary).

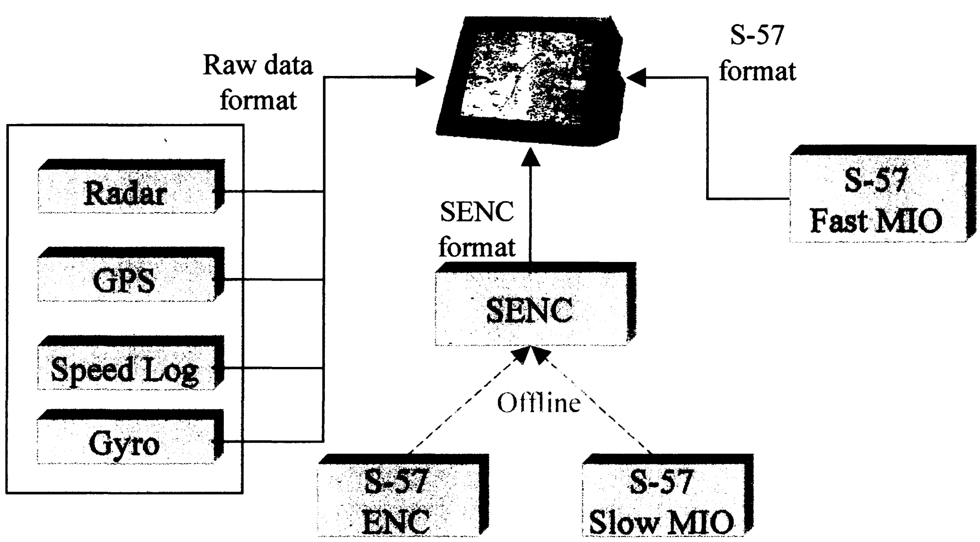


Figure 3.4 - Uploading MIO data into ECDIS - FMIO in S-57 to direct display.

Figure 3.5 presents an author's alternative solution. In this case, an on-line transformation of fast MIO in S-57 into SENC format would be used (this does not mean that FMIO would be stored together with ENC data).

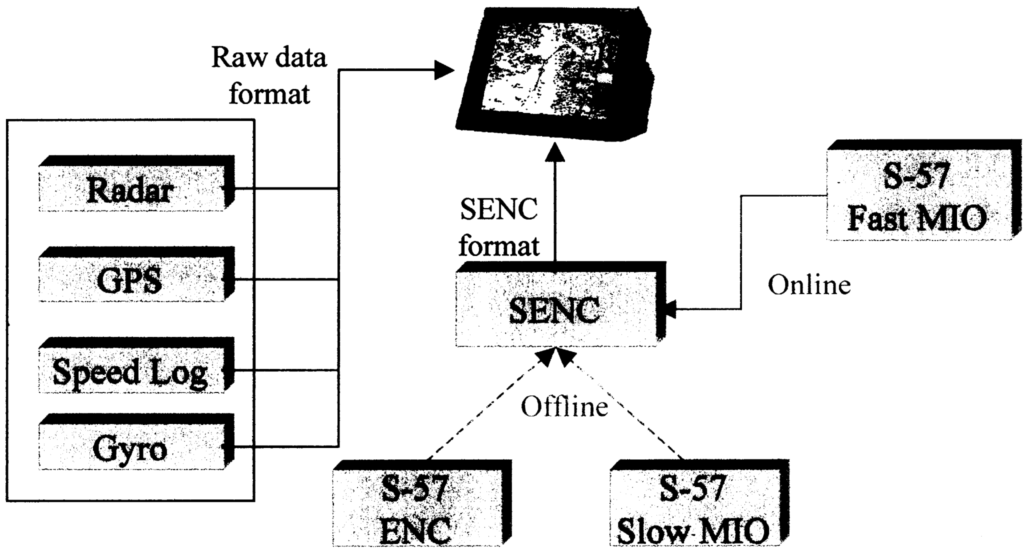


Figure 3.5 - Uploading MIO data into ECDIS (second version) - FMIO transformed from S-57 to SENC format prior to display.

In previous paragraphs, a clear distinction between FMIO and SMIO was made. Due to their many incompatible characteristics, the author considers that the encoding of these two types of MIO should be addressed in different S-57 product specifications. The following chapter presents an approach for the development of a generic S-57 product specification.

4 Generic Product Specification Checklist

The definition of a S-57 product specification must follow a methodical procedure so that coherence and completeness is achieved. This chapter presents the author's generic approach for the development of a S-57 product specification. This approach will then be used in the Chapter 6 for the production of a SMIO product specification.

The idea behind this approach is to follow the structure implementation described in Chapter 7 of the S-57 standard to collect relevant tracking parameters, analyse the grouping of this information and then write the final PS following the existing ENC product specification as a model.

4.1 Checklist

The first task is to determine if the objects and attributes necessary to transmit the intended information exist in the object catalogue. If not, then these must be created.

As mentioned in section 2.2.3 a data set file has records that fit in five categories (Figure 4.1). Each of these categories is composed of specific type of records which have pre-defined fields. The records fields are characterized by pre-defined subfields.

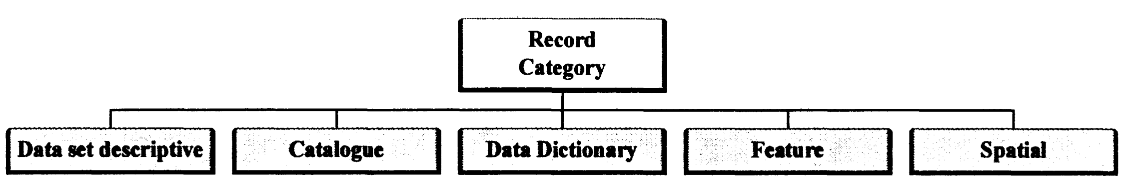


Figure 4.1 - Record categories.

Running through this structure, it is possible to create a checklist of items that may be necessary to specify in a product specification. The following subsections present the author's checklist for information gathering prior to the writing of a product specification. Every item should be addressed considering the application in question and determining if a restriction to its use or special ruling is necessary.

4.1.1 Data Set Description

There are four types of data set descriptive records: general information, geographic reference, history and accuracy. A *data set general information record* is composed of two fields: data set identification and data set structure information. Figure 4.2 shows this hierarchical record structure. Each of the mentioned fields is composed of several subfields that are described in Chapter 7 of the S-57 standard (Appendix I describes the subfield structure applicable to SMIO).

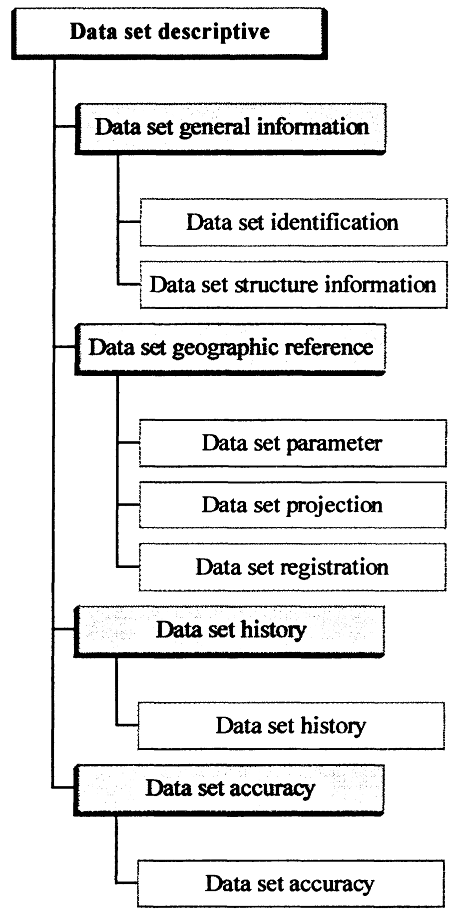


Figure 4.2 – Data set descriptive records structure (derived from S-57).

Analyzing the constituents of the *Data set descriptive* records, it is considered that the following subfields should be addressed/

questioned/analyzed when preparing a product specification:

- Definition of intended usages

The *intended usage* subfield is a numeric code that identifies the purpose of the data compilation (i.e. ENC PS intended usage code 5 means that the data set is to be used t harbour navigation). Different applications must specify their intended usages and encoding in their PS.

- Data set naming convention

A *data set naming convention* has to be established in order to avoid bad file use. It is expected that different S-57 applications use different naming conventions.

- Edition numbering convention

The same concept of the naming convention applies to the *edition numbering convention*, except that different applications may use the same system.

- Product specification name

Every PS is internally identified by some abbreviation. This has to be specified.

- Application profiles

Several profiles may apply to applications (i.e. there might exist data sets of original representation and update datasets).

- Data structure to be used (topology)

There are four topology models that can be used in S-57. Applications may restrict its use to a part of this set (i.e. ENC is restricted to the use of the chain-node structure).

- Horizontal/vertical/sounding datum

Applications may restrict their representation using specific reference systems (i.e. ENC can only be encoded using the WGS 84 reference system)

- Compilation scale

Some applications may have predefined compilation scales (i.e. the future use of S-57 for paper chart dataset exchange may dictate specific values for this field).

- Units of depth/height measurements, positional accuracy and coordinate units

Applications may be restrained to the use of some measurement units (i.e. ENC depth measures can only be reported in metres).

- Projection

Applications may specify or restrict the use of map projections (i.e. ENC data is not projected).

- Projection parameters

For specific applications some projection parameters may be used.

• False easting/northing

Some projections may specify uncommon false easting/northing values.

4.1.2 Catalogue

There are two types of catalogue records: catalogue directory and catalogue cross-reference. Each of these records has one field (with the record name) with several subfields (Figure 4.3). Analysing the structure, the following fields are proposed as possible references for PS definition:

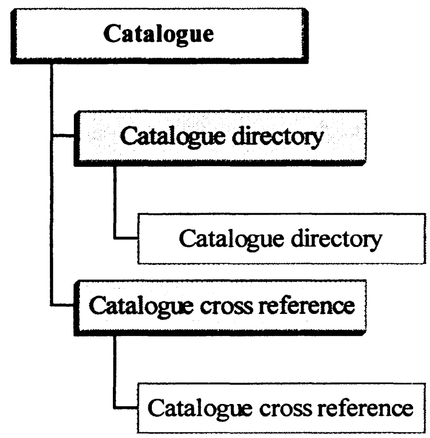


Figure 4.3 - Catalogue records structure (derived from S-57).

• File naming convention

A naming convention for the catalogue file has to be specified.

• File long naming convention

Applications may define a naming convention to be used for specific purposes.

• Volume naming convention

A naming convention for specifying the volume where a data set is stored.

- Implementation code (ASCII / binary)

S-57 data files can be implemented in ASCII or binary. Some applications may restrict its implementation to one of them (i.e. ENC is implemented only in binary).

4.1.3 Data Dictionary

There are three types of data dictionary records: data dictionary definition, domain and schema (Figure 4.4). These records are only used when objects in the exchange set are not included in the S-57 object catalogue. Some applications (i.e. ENC) may not allow the use of these records (every object in the exchange set must belong to the object catalogue).

Analysing the structure of this record, the following subfield is proposed as possible reference for PS definition:

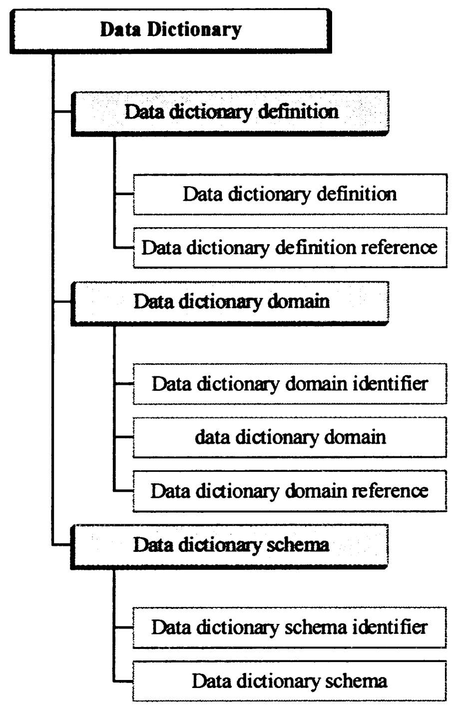


Figure 4.4 – Data dictionary records structure (derived from S-57).

- Type of object

An application may allow the use of non-object catalogue objects, but may restrict it to some object types (i.e. cartographic objects may not be allowed to be created)

4.1.4 Feature

Feature records have seven fields with subfields (Figure 4.5). These records store feature objects information. Analysing the structure of the record type, the following subfields are proposed as possible reference for PS definition:

- Group

Features may be grouped into relevant levels of information. These groups must be defined in an application PS (i.e. for ENC two groups are defined; one for the "skin of the earth" and one for every other object).

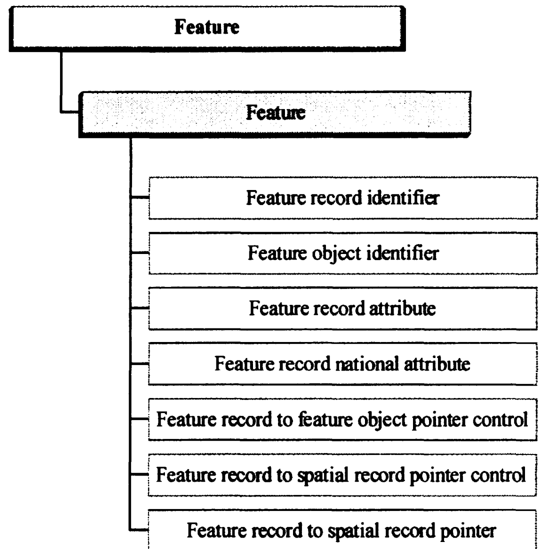


Figure 4.5 – Feature records structure (derived from S-57).

- Relationship indicator

There are three defined relationships among feature objects - master, slave and peer – but others can be specified in an application PS.

4.1.5 Spatial

There are three types of spatial records: vector raster and matrix. As raster and matrix are not yet implemented, they will have to be addressed in the future. Vector records have 11 fields with subfields (Figure 4.6). Analysing the structure of the record type, the following subfields are proposed as possible reference for PS definition:

- 2D and 3D Coordinate format

The format used in expressing 2D and 3D coordinates in the X and Y axes must be defined in the PS. In the 3D coordinate case it is also necessary to specify the content of the third dimension. This definition is further used by many subfields.

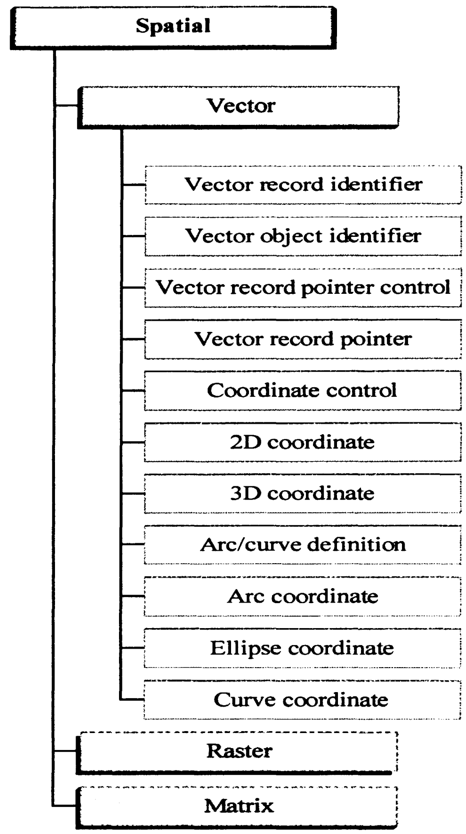


Figure 4.6 – Spatial records structure (derived from S-57).

4.2 Grouping Information

Having gathered the relevant information for the content rules of an application, it is now necessary to define how data are to be grouped, stored and transferred. The five questions to be addressed are:

- How are records, fields and subfields to be grouped in files according to their application profiles?

Different applications will not use the same record/field/subfield structure because some of them, by definition, cannot be used (i.e. ENC does not allow the use of data dictionary records). For the same application, different profiles will almost certainly use different structures.

- Are there any media or data size restrictions?

Some applications may have storage media or data size restrictions. A restriction of this nature is also related to data exchange efficiency.

- Can compression algorithms be used in order to reduce file size?

Compression algorithms can reduce data file sizes by a large percentage (tests made by the author using the *WinZip* and *PKZIP* lossless compression programs consistently revealed that an S-57 ENC file could be stored in 25% of its original size. But for simplicity and security, some applications may not allow its use (i.e. ENC). The use of compression algorithms could somehow compromise the platform independency provided by the S-57 encapsulating method (ISO/IEC 8211 standard). However, there are already in the market multi-platform (i.e. IBM A/S 400, MVS, UNIX, DOS, MAC) compression programs (e.g. archives compressed using PKZIP in any platform mentioned above, can be extracted and read on any other platform).

- Can files be encrypted?

PS should specify if an encryption algorithm can be used for protection against unauthorized data use.

- How are data sets to be managed?

PS should specify how files are grouped in the storage media (directory structure).

4.3 ENC Product Specification Structure

For the following reasons, the author considers that ECDIS related product specifications to be added to the S-57 standard should follow as much as possible the existing ENC PS in terms of structure:

- To keep coherence with the existing S-57 standard Appendix B;
- To take advantage of the existing know-how in data production;
- For ECDIS software developers to be able to use some of the already developed tools;
- For ECDIS manufacturers to have less difficulties in adapting their systems to new products.

Chapters to include (besides any others considered relevant) in product specifications:

- Introduction
- General Information
- Objects and Attributes
- Cartographic Framework
- Provision of data
- Application profiles

The specificity of some applications may dictate the production of extra documentation for detailed implementation and encoding rules. This is the case of the

ENC PS, which includes an annex describing how to encode information considered relevant to a specific navigation purpose [IHO, 1996, Annex A to Appendix B.1].

5 SST MIO Product Specification

The previous chapter described an approach for the development of an S-57 product specification. This chapter analyses how the differences and resemblances between fast and slow MIO and ENC can affect their eventual product specifications.

5.1 SMIO Encoding

SMIO encoding can be specified either particularly (one product specification for each type of data set) or generically (a product specification that covers all types of data sets). Considering the many similarities between SMIO data types, it is natural to first develop a product specification for the general case, and then to specify the particularities of individual data types in an application profile section.

As discussed in previous sections, some similarities exist between ENC and SMIO. The end use system is the same (ECDIS), their concepts are similar, thus the same transfer and encoding methods may be used. Most of all ENC and SMIO are intended to interact with each other in ECDIS. The more they have in common, the easier it is to create this compatibility. This last condition implies a large inheritance by SMIO of many ENC specifications. The same principle would also beneficially be applied to FMIO. However that is only possible to some extent. Due to their real-time data provision, FMIO have to be addressed in a different perspective (i.e. a more efficient implementation procedure has to be designed).

The main difference that will exist between the ENC PS and MIO PS is at the application profile level. The ENC PS specifies two application profiles (new data and update sets) that use the same objects and attributes, only differing in the file and exchange set structure. In an eventual SMIO PS some objects (specially geo feature objects) and attributes are expected to "belong" to specific products. A selection of objects and attributes from the S-57 standard for use in general SMIO would not serve the principle of fine tuning that is the purpose of a PS. Objects and attributes for SMIO should then be characterized and defined in particular SMIO application profiles. A relevant fact also to consider is that the change rate of objects in SMIO associated with environmental characteristics makes the concept of an update data set inappropriate. Most SMIO products will only produce new datasets (no update profiles are necessary).

5.2 FMIO Encoding

The exchange set structure used in ENC is not a specification of the S-57 standard. It is a definition of the ENC PS. Every other application can use a different method and structure for the data exchange.

The author considers that, due to its real time data provision, FMIO cannot be based on the exchange of a set of files, but on the exchange of one short data message (several bytes). For this to be possible, it is necessary to create rigid rules in each FMIO profile, eliminating the necessity of the catalogue file, used for ENC exchanges.

In the ENC, the catalogue file acts as an index for an exchange set. It contains information on exchange set files name, the volume name, the implementation mode (ASCII/BIN), and geographic limits of the data set. In the case of FMIO, the amount of data to be transmitted should be very small. This eliminates the need for assigning volumes to exchange sets. If the implementation mode is pre-defined in an application profile, it is also not necessary to transmit this information in a catalogue file. In the author's opinion, contrarily to ENC and SMIO data, FMIO data is not to be stored in the SENC. It is to be treated as, for example, radar information is: valid in one second, history in the next (a log file may be kept, but not inside the SENC). This removes the necessity of pre-defining a geographic extent for FMIO.

Keeping in mind that FMIO is message based and restricted to the transmission of the minimal essential information, all other non-mandatory files allowed for transmission in an ENC exchange set have to be prohibited. Now that the catalogue file is eliminated from the FMIO exchange set, it is necessary to also specify that no README or image (TIF) files can be transmitted. From this point on, only the data set file (message) in S-57 format is to be considered.

Reducing the size of the data file can also be achieved by pre-establishing the FMIO message parameters (records / fields / subfields) in their respective application profiles, minimizing to the most the logical information to be transmitted. For example, the "Data Set General Information" field could be reduced to the following subfields:

- Record name ("DS")
- Record identification number

- Application profile identification

Every other subfield would be pre-defined in a FMIO application profile.

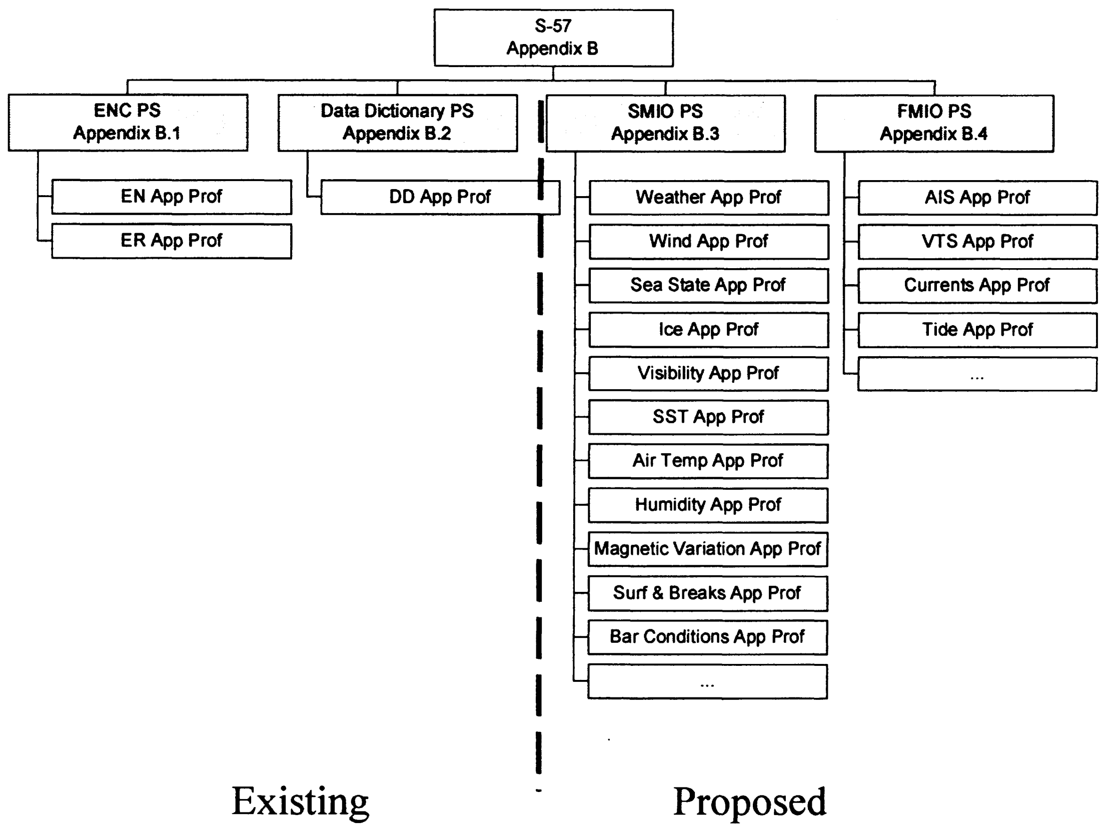


Figure 5.1 - The S-57 Appendix B eventual organization.

This chapter identifies the differences and resemblances between SMIO, FMIO and ENC in terms of their product specifications. The following chapter describes an eventual product specification for SMIO using the sea surface temperature as an example for one of its application profiles.

6 Sea Surface Temperature – A Case Study

The approach described in chapter 4 is now used for the development of an example of a product specification that generally addresses SMIO and particularly focuses on the sea surface temperature MIO.

Although still under study and development, some MIOs already have proposals regarding their objects definition to be included in the S-57 standard and correspondent S-52 presentation specifications ([Scheuermann and Pahmeyer, 1999] for ice information, [Galaske and Scheuermann, 1998] for AIS and [Schulze and Scheuermann, 1999] for weather/sea state). The adopted prioritising criterion for developing these MIO was the safety of navigation (that ultimately represents the safety of mariners and environmental protection). This type of MIO is of interest to all shipping. The interest in other types of MIO is very much dependent on the different mariners' activities. The following sections justify the author's opinion that SST should be an MIO to shortly be included in the S-57 standard for use in ECDIS. An implementation solution for it is presented.

6.1 Search and Rescue

Several factors influence the chances of survival of those involved in a sea accident. It is necessary to take into account the type of accident, the physical characteristics of the persons involved, the use of floating devices and protective clothing, food and water reserves, predators (i.e. sharks) and environmental conditions (i.e. sea state, sea temperature) [Patterson, 1997].

The sea surface temperature (SST), although not part of the "safety of navigation" MIO set, might be used to save lives in an accident scenario in which people are in or very close to the water. SST is actually considered priority information in the management of maritime search and rescue operations (SAR) [Bell and Gonin, 1998]. SST information can be of much value when deciding which platform (i.e. ship, helicopter, airplane) is to perform a search and rescue operation and determining how urgent situations are.

Figure 6.1 shows how temperature affects the expected time of survival of an adult immersed in water [U.S. Coast Guard, 1998].

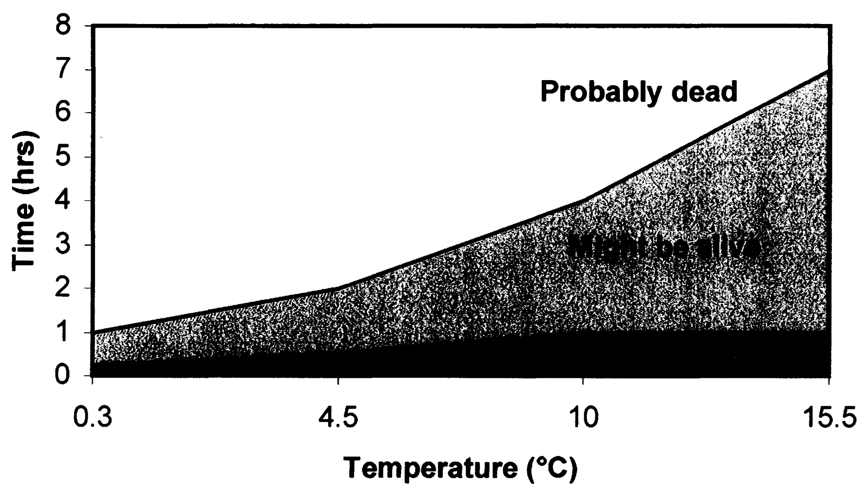


Figure 6.1 - Expected time of survival of an adult immersed in cold water.

The attitude of the victims in the water (calm/moving) is also a very important factor considering survival. The most important concept to have in mind is to avoid exchange of heat with the cold water (the less movements, the better) that will at some point cause hypothermia (a subnormal body temperature situation). Cold water is able to drop the human body temperature 25 to 30 times faster than air at the same temperature. One may get unconsciousness when the body core temperature drops to 30°C and drowning is a natural consequence of it; if not, the low temperature will cause death shortly after.

6.2 Fishing

Although not completely understood, *"Variations in marine environmental conditions affect the distribution, abundance and availability of marine fish populations."* [Rogers, 1999, p.6]. This fact has direct consequences in fishing activities.

There are a number of known factors that influence fishing success, for example bathymetry, food source, oceanic fronts (interface of different water masses due to currents, temperature, salinity or turbidity contrasts), sea state, sea temperature and weather. Not all have the same impact in different species but it is known for a fact that fish are temperature sensitive. According to Mikol [1997, p. 1], *"Nearly every commercially important marine species has an optimum temperature range in which it is found"*. It is known that fish species not only react differently to water temperature but also within the species themselves. Age, size class and sex can be segregating factors among species (i.e. crab segregate by sex). This internal segregation may be used for fish targeting (i.e. target only adults within a certain species).

Fishing efficiency is greatly improved through the knowledge of these facts. The purpose is not to over-fish because that would endanger the fish stocks. Many countries have established fishing quotas to avoid this problem. The purpose is to minimize the active fishing period - costly time of ship at sea - by reducing the necessary search time and eliminating bycatch (non-target species) while improving productivity.

Sea surface temperature is a parameter that is easily measured from satellites that cover wide areas at a time, but the measurement of the sea temperature in depth always requires the deployment of some sensor (the result is a point profile). Rogers [1999] states that it is possible to correlate the sea surface temperature with the temperature in depth with a few calibrating profiles and using the measures of thermistors mounted on a ship's hull. Although not always an accurate method, this makes possible to use SST in determining the probable depth range of the species of interest.

Figure 6.2 presents an extract of temperature range for species in the North Pacific [Mikol, 1997].

Species	Lower Temperature Limit (°C)	Upper Temperature Limit (°C)
Squid, Red	1.0	13.0
Pacific Cod	3.0	15.0
Pacific Hake	9.0	15.0
Pacific Halibut	0.5	10.0
Sole, Dover	4.0	15.5
Tuna, Albacore	13.5	25.2

Figure 6.2 – Temperature range for some fish species.

SST data is also an active ingredient in many scientific sea-related research efforts. Having access to this information on board research ships and being able to directly integrate it with chart (or other MIO) data can be very useful and clarifying. Also, SST can be used for the safety of navigation in polar waters. It is known that a combination of water and air temperatures can lead to ice accretion on the vessel's hull and superstructure [Pillich, 1998b].

6.3 SMIO Product Specification - Sea Surface Temperature

Having explained the selection of SST for the development of a product specification example, it is now necessary to get into the production details.

SST falls into the SMIO category. The most common expected information is in the form of temperature maps representing a past situation over an area. In scenario now comes the resemblance of this type of information with ENC. If these types of data sets are so similar in concept, their product specifications should be as similar as possible. This will allow the implementation of "new" data in ECDIS with very little effort. The more similar the two product specifications are, the more "existing machinery" can be used. This will represent, for example, minor changes to software for the implementation of SMIO.

6.3.1 New Sea Surface Temperature Objects and Attributes

As stated in section 4.1, the first task of a product specification development is the determination of new necessary objects and attributes.

In the interest of simplicity and following the guidelines of the S-57 standard, the creation of new objects and attributes must be reduced to the minimum number. An effort must be done to describe new features using the existing objects and attributes.

For the sea surface temperature representation, the author proposes the creation of only 1 feature object and 3 attributes (Appendix II). The feature object is the sea surface temperature [SSTMP] object and the attributes are: temperature value [TEMPER], temperature units [TUNITS] and temperature accuracy [TMPACC]. From the start it is possible to realize that these attributes can further be used in other MIO (i.e. air temperature).

The *temperature units* [TUNITS] attribute is not actually to be used in SST datasets. This attribute is to be used to characterize objects and it makes no sense to use different temperature units with objects within the same data set. The definition of the temperature units of a data set is made at a higher level (in the *Data Set Parameter Field* of the data set geographic reference record).

Although not following the minimalist rule of S-57 for the addition of objects and attributes to the object catalogue, the author considers that in name of coherence, and predicting its use in future applications, the temperature units attribute should be included in the standard (a similar situation occurs, for example, with the depth units attribute).

6.3.1.1 SSTEMP Object Definition

The *Sea Surface Temperature* [SSTEMP] object class is defined as a geo feature class object that characterizes the temperature value of a point, line or area in a dataset describing SST (Appendix II).

In the S-57 object catalogue, objects have three different classes of attributes: *Attributes_A, Attributes_B* and *Attributes_C. Attribute_A* contains attributes that define the individual characteristics of objects. *Attribute_B* contains attributes that provide information relevant to the use of the data. *Attribute_C* contains attributes that provide administrative information about the object and the data describing it [IHO, 1996, Appendix A].

SSTEMP *Attribute_A* attributes include the temperature value [TEMPER], and the temperature accuracy [TMPACC]. These two attributes do not exist in the object catalogue. Their inclusion is proposed together with the [SSTEMP] object class.

SSTEMP *Attribute_B* attributes include the textual information about the object [INFORM], the national language textual information [NINFOM], the maximum scale it can be represented [SCAMAX] and the minimum scale it can be represented [SCAMIN].

SSTEMP *Attribute_C* attributes include the date when data objects were captured (to file) [RECDAT], the proceeding for the encoding and entering of data [RECIND], the production date of the source (live measurement) [SORDAT] and information about the source of the object [SORIND].

6.3.1.2 TEMPER Attribute Definition

The TEMPER attribute numerically specifies the temperature value of an object (Appendix II).

There are 6 types of attributes in the object catalogue. This classification is based on the type of input that is expected for the attributes (i.e. integer, free text). The [TEMPER] attribute fits in type "F" where the expected input is a floating-point numeric value.

The value input in this attribute is directly related to the temperature units. Such attribute (temperature units) does not exist in the S-57 object catalogue and is proposed together with the [TEMPER] attribute (section 6.3.1.4).

6.3.1.3 TMPACC Attribute Definition

The TMPACC attribute specifies the best estimate of the temperature accuracy of an object (Appendix II). As the [TEMPER] attribute, this is also a floating-point numeric value (type "F").

The units in which [TMPACC] is expressed is directly related to the [TUNITS] defined for an object (both the temperature and its accuracy value must be expressed in the same units).

6.3.1.4 TUNITS Attribute Definition

The [TUNITS] attribute specifies the units in which temperature is expressed (Appendix II). Two units might be used: Celsius or Fahrenheit degrees. Despite this option, ECDIS software manufacturers should consider the on-line transformation of the SST presentation using either units for the same data set (this would free data providers from producing two versions of the same data set to please mariners that use different unit systems.

The International System (S.I.) temperature unit (Kelvin degrees) was not considered to be included as an option because it is not used in the general marine community.

The [TUNITS] attribute fits in type "E" (enumerated) which the expected input is a number selected from a pre-defined attribute values.

6.3.2 Content

The SMIO product specification should contain one application profile for each SMIO (at this time only one: SST). The number of application profiles is expected to grow as new types of data are considered, especially the ones classified as *mandatory* for the safety of navigation.

6.3.3 Topology

The compatibility of SMIO with ENC could be compromised if different topological structures were used. To avoid difficulties, SMIO shall use the same structure as ENC: chain-node.

6.3.4 Objects and Attributes

Objects and attributes, and the relationships between them (mandatory or not) must be internally defined in each application profile. The main reason is because an overlapping use of object classes between different SMIO is not expected to exist (e.g. only SST SMIO is expected to use the sea surface temperature object). One common characteristic is that no SMIO will use cartographic feature objects (these are specific for paper chart production).

6.3.5 Groups

ENC has established that its objects belong to one of two groups. Group 1 includes all "skin of the earth" objects. Group 2 includes all other objects. Group 1 objects have to be displayed in ECDIS at all times, while group 2 objects are "optional". This allows the mariner to generally select the type of information he wants to have on the display.

SMIO information is probably to be analysed for a few moments and after that its removal from the screen should be efficient. This could be achieved by setting new and different group numbers for each SMIO type. The product specification in Appendix I assigns group numbers to the different eventual SMIO. SST objects are assigned to group 8.

6.3.6 Cartographic framework

For compatibility and simplicity purposes, the cartographic framework for SMIO must be the same as ENC. The only difference is related to the inclusion of temperature units in SMIO.

6.3.7 Encryption

Although allowed, encryption should not be used in SMIO. The main reason is that many of the eventual SMIO data sets are today freely distributed to mariners.

6.3.8 Directory Structure

The directory structure of SMIO should follow the ENC model. A root directory with the SMIO identification (i.e. SST_ROOT) will store the corresponding SMIO files.

6.4 Service Description

The service description for SST is very much dependent on the agencies involved in acquiring, processing and distributing data. Instead of proposing a service description, the author will present an example of an already existing service.

6.4.1 Existing Service

NOAA (National Oceanographic and Atmospheric Administration) has established a program – *CoastWatch* – that produces/distributes SST data/images for all coastal waters of the United States four times a day (Figure 6.3). These images are available in a series of formats (catalogue in http://cwatchwc.ucsd.edu/data.html).

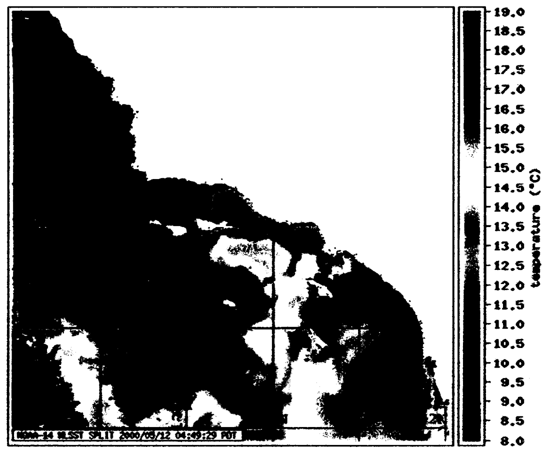


Figure 6.3 - NOAA local SST example (California, 2000/05/12 at 04:49 PDT).

Global SST data sets are also available (Figure 6.4). These data sets are obtained by averaging the SST measures over a certain period of time (to clean out cloud coverage).

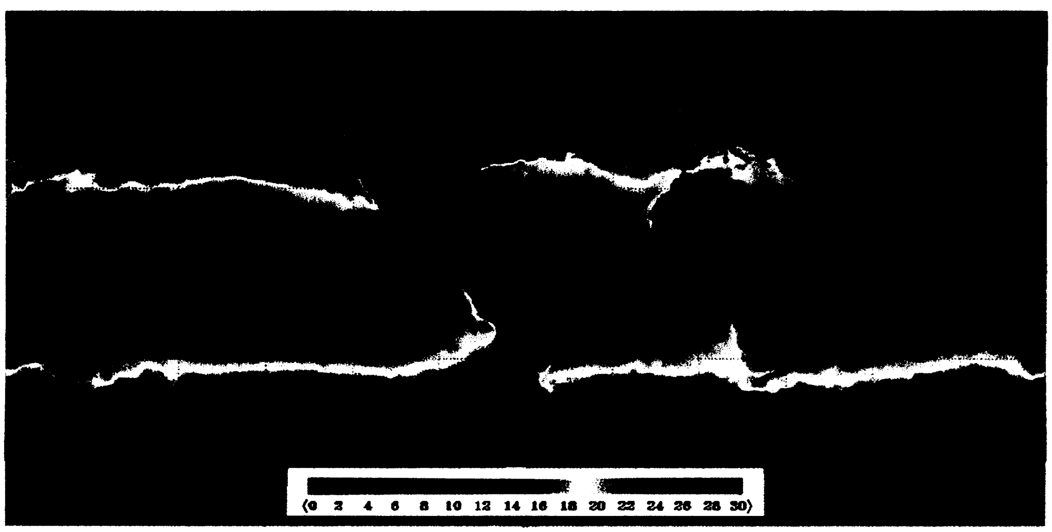


Figure 6.4 - NOAA global SST example (2000/06/

Data provided by this service is collected from Advanced Very High Resolution Radiometer (AVHRR) installed on NOAA polar orbiting environmental satellites (POES). These sensors acquire data with a 1.1 km resolution (good enough for fishing purposes [Rogers, 1999]). The satellites are 833 Km above the earth surface and perform 14 orbits a day.

Data files are available through the Internet after a pre-subscription. They have been used for fishing purposes and systems have been developed to integrate these data sets with chart data in near-real-time [Leming and May, 1999].

Encoding these data files in the S-57 format would not be a difficult ordeal. One of the formats in which these files are provided is the "Binary Raster" (binary raster files can be loaded into ESRI ArcView GIS software with the "Spatial Analyst" extension that automatically transforms them into ESRI "GRID" format). Once these files are loaded into ArcView GIS software, temperature contours can be directly created and exported to "DXF" format (using the ESRI "shp2dxf.ave" script). CARIS GIS suite and Object Manager software could then be used to import the DXF file, convert it into CARIS format and create the S-57 version of the SST (following the same procedure as for ENC production). The processing time for such procedure is dependent on the area to be covered, the data resolution, the temperature interval between contours and the performance of the computer system. But, the author believes that a local SST grid, as the one presented in Figure 6.3, would not take more than half an hour to process. Downloading data for a local SST file from the *CoastWatch* website and processing it up to the DXF format file stage, took 10 minutes in the first author's attempt. All tools are available for processing up to this stage. The last step requires the implementation of Appendix I to this report.

SST is a relatively simple product to encode and its availability to users could also rely on the Internet. The main problem resides in countries that do not have the means to produce MIO data sets in S-57 for their coastal zones. The investment can be significant, especially when no fee is supposed to be charged for its use.

7 Conclusions

Safety of navigation is the main, but not the only, purpose of ECDIS implementation and use. The ECDIS concept can and will be amplified with the future integration of *Marine Information Objects*. It will certainly migrate from an electronic chart system into a marine information system where information from a variety of sources is cross-referenced in an intelligent way triggering new warnings/alarms, improving the success of ocean related activities and avoiding many of the potential environmental disasters that result from sea accidents.

The ideal situation would be to have all information encoded in the same format. This might not be possible, especially in a transition phase due to the expected costs, both to data producers and users, a change to existing formats would have to some already implemented systems. Moreover, many of the safety of navigation related information is today broadcast with no fee to mariners following a policy that avoiding sea accidents is less expensive to coastal states than the costs eventual accidents represent (monetary or/and environmental). Change in data format for some broadcast information could only be possible, to some states, by charging a fee to users.

The debate is today centred on the selection of environmental and navigation information to be considered MIO and which of these should / could be encoded in S-57 format. Some MIO, namely AIS, weather, sea state, ice, wind and visibility, have already been identified as being directly related to the safety of navigation. Several authors have proposed objects and attributes for inclusion in the next S-57 standard edition, but no product specifications have been produced for their encoding.

Certainly new MIOs will be addressed in the S-57 scope as others are implemented. These new MIO will probably not be of interest to all mariners, but will have major impact in their activity while at sea. This is the case of sea surface temperature information, which can, among other things, be used to improve the fishing efficiency of some target species.

MIO have had several classification criteria. The author considers that the best classification is related to their provision: real time or aged information. This criterion would group MIO into two classes: fast MIO (real-time data) and slow MIO (past or forecast data). These classes also would divide MIO according to their implementation architectures when using S-57 for their encoding. Fast MIO would have a message type format, while slow MIO would be treated like ENC cells.

The encoding rules for these two MIO classes could then be dealt with in two general product specifications inside the S-57 standard, with the particularities of individual MIO being addressed in application profiles within their general MIO product specification. A case study for the encoding of sea surface temperature, an application profile in a Slow MIO product specification, is presented in Appendix I to this report.

A lot of work in the implementation process, and a decision on the model to follow is yet to be made for MIO. The author's approach, and especially considering the simple case of SST MIO, could be easily tested in the near future with the cooperation of an ECDIS related software developer, but major challenges still exist at the display representation level (S-52), especially regarding the selection of colours to use to represent temperature values or the option for a separate display screen to avoid cluttering the primary navigation monitor.

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Appendix I

SLOW MIO PRODUCT SPECIFICATION

(Proposed new S-57 Appendix B.3)

SLOW MIO PRODUCT SPECIFICATION

I.1 Introduction

I.1.1 Definitions

Cell – A geographical area containing a Slow MIO data set.

SMIO – Slow MIO data set.

Slow MIO Product Specification – The set of specifications intended to enable agencies to produce consistent SMIO data sets, and manufacturers to use that data efficiently in an ECDIS. SMIO dada sets must be produced in accordance with the rules defined in this Specification.

I.1.2 Content

The SMIO Product Specification contains one application profile for the sea surface temperature (SST). The number of application profiles is to be increased with the development of new SMIO types of data sets (i.e. weather, ice).

I.2 General Information

I.2.1 Purpose of Use

SMIO data is compiled for a variety of use purposes. These purposes are reflected in the compilation scale and geographic extension of the dada sets. The purpose of use of a SMIO is indicated in the "Data set Identification field", "Intended Usage" [INTU] subfield and in the name of the data set files (see data set naming conventions). The following codes are used:

Subfield Content	Coverage Extension
1	Global
2	Oceanic
3	Regional
4	Local

The Global coverage is to be used in data sets covering the whole world or most of it, using small scales. Oceanic coverage is to be used in data sets covering an ocean or most part of it (i.e. North Atlantic). Regional coverage is to be used in data sets covering special areas that are neither small enough to be considered local nor big enough to be considered oceanic (i.e. Mediterranean Sea, English Channel). Local coverage is to be used in data sets covering particular small areas, making use of big scales (i.e. near sea ports).

I.2.2 Cells

SMIO data sets may be split into cells (files) for efficiency of processing. The related files keep the original SMIO purpose code, also related to the compilation scale. The geographic extent of the cells must be such that data files do not exceed 5 Megabytes of data.

Cells must be rectangular (i.e. defined by 2 meridians and 2 parallels). The coordinates of the borders of the cell are encoded in decimal degrees in the "Catalogue Directory" [CATD] field.

The area within the cell which contains data must be indicated by a meta object M_COVR with CATCOV=1. Any other area not containing data must be indicated by a meta object M_COVR with CATCOV=2.

I.2.3 Topology

SMIO data must be encoded using chain-node topology.

I.3 Objects and Attributes

I.3.1 Object Classes and Attributes

Only object classes, attributes and attribute values, which are defined in the IHO Object Catalogue, may be used in a SMIO data set. Each SMIO application profile defines which can and cannot be used.

I.3.2 Meta Objects

The maximum use must be made of meta objects to reduce the attribution on individual objects. Specific use of these objects is defined in each SMIO application profile.

I.3.3 Geo and Meta Object Attributes

I.3.3.1 Missing attribute values

In a data set, when an attribute code is present but the attribute value is missing it means that the data producer wishes to indicate that this attribute value in unknown.

I.3.3.2 Mandatory Attributes

Some attributes are mandatory in the encoding of some objects. This is mainly because objects make no sense without these attributes and also because these attributes may be relevant in the way objects are presented in the ECDIS display.

Mandatory attributes are specified in each SMIO application profile.

I.3.4 Cartographic Objects

The use of cartographic objects is prohibited.

I.3.5 Geometry

Edges must be encoded using SG2D fields only. ARCC fields (curves) must not be used.

I.3.6 Relationships

Relationships between objects may be defined by:

- Nominated master feature record,
- Collection objects of classes “aggregation” (C_AGGR), os “association” (C_ASSO).

The use of the Catalogue Cross Reference record is prohibited.

The use of the collection object class C_STAC is prohibited.

All hierarchical relationships (master to slave) must be encoded by using a nominated “master” feature record carrying the pointers to the “slave” objects in the

"Relationship Indicator" [RIND] subfield in the "Feature Record to feature Object Pointer" [FFPT] field with the value {2}=slave.

All association or aggregation relationships using collection objects are assumed to be peer to peer. The "Relationship Indicator" [RIND] subfield of these collection feature records must be {3}=peer.

I.3.7 Groups

Each SMIO application profile is to be associated with a group number. Groups 1 and 2 are reserved to ENC ("skin of the earth" and "every other ENC object"). The following table assigns SMIO to group numbers:

Group	SMIO
1	Reserved to ENC
2	Reserved to ENC
3	Weather
4	Wind
5	Ice
6	Sea State
7	Visibility
8	Sea Surface Temperature
9	Air Temperature
10	Humidity
11	Magnetic Variation
12	Surf & Breaks
13	Barometric Conditions

The group number is indicated in the "Group" [GRUP] subfield of the "Feature Record Identifier" [FRID] field.

I.3.8 Language

The exchange language must be English. Other languages may be used as a supplementary option. In general this means that, when a language is used in textual national attributes (NINFOM, NOMOBJ, NPLDST), the English translation must exist in the international attributes (INFORM, OBJNAM, PILDST).

I.4 Cartographic Framework

I.4.1 Horizontal Datum

The horizontal datum must be WGS 84. The “Horizontal Geodetic Datum” [HDAT] subfield in the “Data Set Parameter” [DSPM] field must have the value of {2}.

I.4.2 Vertical Datum

SMIO referencing to heights have to encode the vertical datum in the “Vertical Datum” [VDAT] subfield.

I.4.3 Projection

No projection is used. The “Data Set Projection” [DSPR] field must not be used. Coordinates must be encoded as geographical positions (latitude, longitude).

I.4.4 Units

Units to be used in MIO are:

- Position: latitude and longitude in decimal degrees
- Depth: meters
- Height: meters
- Distance: nautical miles or meters
- Temperature: Celsius or Fahrenheit degrees

The default values for depth units, height units, positional accuracy units and temperature units are encoded in the [DUNI], [HUNI], [PUNI], and [TUNI] subfields in the "Data Set Parameter" [DSPM] field (SMIO may not use all these units specifications).

I.5 Provision of Data

I.5.1 Implementation

Slow MIO must be implemented in binary format. The "Implementation" [IMPL] subfield of the "Catalogue Directory" [CATD] filed must be set to "BIN" for the data set files. The catalogue and any other informative (README) files have to be implemented in ASCII.

I.5.2 Encryption

SMIO data may be protected from unauthorized use. This protection can be achieved through the use of encryption algorithms.

I.5.3 Exchange Set

I.5.3.1 Contents of an Exchange Set

A SMIO exchange set is composed of one catalogue (ASCII) and at least one data (BIN) file. Text (ASCII) and picture (TIF) files may also be included in the exchange set.

I.5.3.2 Volume naming

An exchange set may be split across several media volumes; therefore, each media must be uniquely identified within the exchange set. A file must not be split across volumes. Individual volumes must conform to the following naming convention:

VSSXNN

Where:

V is the mandatory first character (volume).

SS is the sequence number of the specific volume within the exchange set.

X is the mandatory separator character.

NN is the total number of media volumes within the exchange set.

For example: V01X03 means "Volume 1 of 3 of the exchange set".

I.5.3.3 Directory Structure

On each volume within an exchange set there must be a root directory named with the first three letters corresponding to the data SMIO application profile code, followed by _ROOT. For example, SST root directory has to be named SST_ROOT. The catalogue file for the exchange set must be in the root directory of the first volume of the exchange set. The root directory of the first volume may also contain an explanatory README file in ASCII format.

For each file in the exchange set the catalogue file must contain the name of the volume on which it is held and the full path name relative to the root directory of that volume.

I.5.4 Data Sets

The types of SMIO data sets that may be produced are specified in the corresponding application profiles.

I.5.5 File Naming

I.5.5.1 README file

If there exists an explanatory README file it has to be named README.TXT.

I.5.5.2 Catalogue File

The catalogue file of the exchange set must be named SMIOCAT.EEE, where EEE is the edition number of S-57 used for this exchange set.

I.5.5.3 Data Set Files

Data set files are named according to the following rules:

CCPXXXXX.EEE, where CC is the producer code, P is the SMIO purpose, XXXXX is the individual cell code and EEE is the issue number (SMIO original data files are not to have their objects updated. The whole file must be replaced when a new data set is available). When the issue number exceeds 999, it becomes 000 again.

I.5.5.4 Text and Picture Files

Text and picture files are named according to the following rules:

CCXXXXXX.EEE, where CC is the producer code, XXXXXX is the individual file code and EEE is the usual extension code (TIF or TXT).

I.5.6 Updating

General rule for SMIO is not to allow updates to its objects/attributes. If updates are allowed, the method is described in the correspondent application profile.

I.5.7 Media

Data can be made available on CD-ROM, 3.5´´ MS-DOS formatted diskettes (when still ashore) or through telecommunication links (when at sea).

I.5.8 Error Detection

File integrity checks are based on the CRC-32 algorithm as defined in ANSI/IEEE standard 802.3.

The error detection algorithm implementation and processing is explained in the ENC product specification section 5.9.

I.6 Application Profiles

I.6.1 General

The application profiles define the structure and content of the catalogue and data set files in an SMIO exchange set.

I.6.2 Catalogue File

The catalogue file has the same structure for every SMIO application profiles. The catalogue file tree structure is defined in the next section. The order of data in the files is the same presented in the tree structure. Records, fields and subfields flagged by an <R> can be repeated in a file. An <1> flag means that the record, field or subfield are unique and cannot be repeated under the same "parent".

I.6.2.1 Catalogue File Structure

Catalogue File
- <R> Catalogue Directory Record
  - 0001 - ISO/IEC 8211 Record Identifier
    - <1> CATD - Catalogue Directory field

I.6.2.2 Catalogue Directory Field

In the catalogue file, all fields and subfields are encoded in ASCII.

The following table shows the subfields of the catalogue directory field that are to be filled. The cell coordinates fields are not to be used when describing a non-data set file included in the exchange set.

Tag	Subfield Name	Use	Value	Comment
RCNM	Record name	M	CD	
RCID	Record identification number	M		
FILE	File name	M		full path from _ROOT directory
LFIL	File long name			
VOLM	Volume	M		name of the volume on which the file appears
IMPL	Implementation	M	ASC BIN TXT TIF	for the catalogue file for the data set files for ASCII text files for pictures
SLAT	Southernmost latitude			mandatory for data set files
WLON	Westernmost longitude			mandatory for data set files
NLAT	Northernmost latitude			mandatory for data set files
ELON	Easternmost longitude			mandatory for data set files
CRCS	Cyclic redundancy check	M		except for README and catalogue files

I.6.3 SST Application Profile

I.6.3.1 Objects

The following is a list of those object classes allowed in SST and the geometric primitives allowed for each of them (P = point, L = line, A= area, N = none).

Object	P	L	A	N
SSTEMP	P	L	A	
M_ACCY			A	
M_COVR			A	
M_CSCL			A	

Every other object included in the S-57 object catalogue is not allowed in a SST data file.

I.6.3.2 Mandatory Attributes

The following table presents the attributes are mandatory for the specific SST object classes.

Object Class	Mandatory Attributes	
SSTEMP	TEMPER	
M_ACCY	HORACC	TMPACC
M_COVR	CATCOV	
M_CSCL	CSCALE	

I.6.3.3 Hierarchy of Meta Data

The following table indicates:

- Individual attributes that supersede meta object attributes,
- Meta object attributes that supersede the data set subfields.

Field	Subfield	Meta object class	Meta object attribute	Geo or spatial object attribute
DSPM	HDAT	The use of M_HDAT is prohibited		The use of HORDAT is prohibited
DSPM	CSCL	M_CSCL	CSCL	
DSPM	TUNI	The use of M_UNIT is prohibited		The use of M_UNIT is prohibited
DSPM	HUNI	The use of M_UNIT is prohibited		The use of TUNITS is prohibited
		M_ACCY	HORACC	HORACC
		M_ACCY	TMPACC	TMPACC

I.6.3.4 SST Data File Structure

SST data files have the following structure:

Data File

- <1> Data Set General Information Record
  - 0001 - ISO/IEC 8211 Record Identifier
    - <1> DSID - Data Set Identification field
      - <1> DSSI - Data Set Structure Information field
- <1> Data Set Geographic Reference Record
  - 0001 - ISO/IEC 8211 Record Identifier
    - <1> DSPM - Data Set Parameter field
- <R> Vector Record
  - 0001 - ISO/IEC 8211 Record Identifier
    - <1> VRID - Vector Record Identifier field
      - <R> ATTV - Vector Record Attribute field
      - <R> VRPT - Vector Record pointer field
      - <R> SG2D - 2-D Coordinate field
- <R> Feature Record
  - 0001 - ISO/IEC 8211 Record Identifier
    - <1> FRID - Feature Record Identifier field
      - <1> FOID - Feature Object Identifier field
      - <R> ATTF - Feature Record Attribute field
      - <R> FFPT - Feature Record to Feature Object pointer field
      - <R> FSPT - Feature Record to Spatial Record Pointer

I.6.3.5 SST Fields Content

The fields presented in the previous section are composed of the following subfields.

I.6.3.5.1 Data Set Identification

Tag	Subfield Name	Use	Value	Comment
RCNM	Record name	M	{10}	=DS, binary
RCID	Record identification number	M		Binary
EXPP	Exchange purpose	M	{1}	Always new dataset
INTU	Intended usage	M	{1} to {4}	See clause…..
DSNM	Data set name	M		File name with extension, excluding path, ASCII
EDTN	Edition number	M		ASCII
ISDT	Issue date	M		ASCII
STED	Edition number of S-57	M		ASCII
PRSP	Product Specification	M		=SMIO, binary
PRED	Product specification edition number	M		ASCII
PROF	Application profile identification	M		=ST, binary
AGEN	Producing agency	M		Binary
COMT	Comment			ASCII

I.6.3.5.2 Data Set Structure Information Field - DSSI

Tag	Subfield Name	Use	Value	Comment
DSTR	Data structure	M	{2}	Chain-node
AALL	ATTF lexical level	M	{0} or {1}	
NALL	NATF lexical level	M	{0}, {1} or {2}	
NOMR	Number of meta records	M		
NOCR	Number of cartographic records	M	{0}	Cartographic records are not permitted
NOGR	Number of geo records	M		
NOLR	Number of collection records	M		
NOIN	Number of isolated node records	M		
NOCN	Number of connected node records	M		
NOED	Number of edge records	M		
NOFA	Number of face records	M	{0}	Faces are not permitted in chain-node structure

I.6.3.5.3 Data Set Parameter Field –DSPM

Tag	Subfield Name	Use	Value	Comment
RCNM	Record name	M	{20}	=DP, binary
RCID	Record identification number	M		Binary
HDAT	Horizontal geodesic datum	M	{2}	=WGS84, binary
CSCL	Compilation scale of data	M		Binary
TUNI	Units of temperature measurement	M	{1} or {2}	=Celsius or Fahrenheit degrees
COUN	Coordinate units	M	{1}	=lat/lon, binary
COMF	Coordinate multiplication factor	M		Binary
COMT	Comment			ASCII

I.6.3.5.4 Vector Record Identifier Field – VRID

Tag	Subfield Name	Use	Value	Comment
RCNM	Record name			
RCID	Record identification number			

I.6.3.5.5 Vector Record Attribute Field – ATTV

Tag	Subfield Name	Use	Value	Comment
ATTL	Attribute label/code	M		Binary code for an attribute
ATVL	Attribute value	M		ASCII value

I.6.3.5.6 Vector Record Pointer Field - VRPT

Tag	Subfield Name	Use	Value	Comment
NAME	Name	M		
ORNT	Orientation	M	{255}	=null
USAG	Usage indicator	M	{255}	=null
TOPI	Topology indicator	M	{1} or {2}	= beginning or end node
MASK	Masking indicator	M	{255}	=null

I.6.3.5.7 2D Coordinate Field

Tag	Subfield Name	Use	Value	Comment
YCOO	Coordinate in Y axis	M		Latitude
XCOO	Coordinate in X axis	M		Longitude

I.6.3.5.8 Feature Record Identifier Field – FRID

Tag	Subfield Name	Use	Value	Comment
RCNM	Record name	M	{100}	=FE
RCID	Record identification number	M		
PRIM	Object geometric primitive	M	{1}, {2}, {3} or {255}	=point, line, area or no geometry
GRUP	Group	M	{8}	Group 8 – see I.3.7
OBJL	Object label	M		Binary code for an object class
RVER	Record version	M		
RUIN	Record update instruction	M	{1}	=insert

I.6.3.5.9 Feature Object Identifier Field – FOID

Tag	Subfield Name	Use	Value	Comment
AGEN	Producing agency	M		
FIND	Feature identification number	M		
FIDS	Feature identification subdivision	M		

I.6.3.5.10 Feature Record Attribute Field – ATTF

Tag	Subfield Name	Use	Value	Comment
ATTL	Attribute label/code	M		Binary code for an attribute
ATVL	Attribute value			ASCII value

I.6.3.5.11 Feature Record to Spatial Record Pointer Field – FSPT

Tag	Subfield Name	Use	Value	Comment
NAME	Name	M		
ORNT	Orientation	M	{1}, {2} or {255}	=forward, reverse or null
USAG	Usage indicator	M	{1}, {2}, {3} or {255}	=exterior, interior, exterior boundary or null
MASK	Masking indicator	M	{1}, {2} or {255}	=mask, show or null

I.6.4 Records, Fields and Subfields

The application profiles tree structures are subsets of the S-57 general structure. Records and fields that do not appear in the profiles structures are prohibited.

Subfields flagged with an "M" are mandatory in a file. Subfields flagged with a "P" are prohibited (i.e. encoded as missing values).

Appendix II

NEW OBJECT CLASSES AND ATTRIBUTES

FOR SEA SURFACE TEMPERATURE

(Addition to S-57 Appendix A)

Object Classes

GEO OBJECT CLASSES

Object Class: **Sea surface temperature**

Acronym: **SSTEMP** Code: xxx

Set Attributes_A: TEMPER; TMPACC;

Set Attributes_B: INFORM; NINFOM; SCAMAX; SCAMIN;

Set Attributes_C: RECDAT; RECIND; SORDAT; SORIND;

Geometric Primitive: Point; Line; Area;

Definition:

A measurement of the sea surface temperature.

Remarks: A proposed object class qualified by new (TEMPER and TMPACC) and existing attributes.

FEATURE OBJECT ATTRIBUTES

Attribute: **Temperature**

Acronym: **TEMPER** Code: xxx

Attribute type: F

Definition:

The temperature value of an object.

Indication:

Unit: Defined in the TUNITS attribute of the M_UNIT meta object class.

Format:

xx.x

Example:

15.5 for a temperature of 15.5 Celsius degrees.

Remarks: The TUNITS attribute has to be added to the M_UNIT meta object class.

FEATURE OBJECT ATTRIBUTES

Attribute: **Temperature accuracy**

Acronym: **TMPACC** Code: xxx

Attribute type: F

Definition:

The best estimate of the temperature accuracy.

Minimum value: 0

Indication:

Unit: Defined in the TUNITS attribute of the M_UNIT meta object class.

Format:

xx.x

Example:

0.5 for an error of 0.5 Celsius degrees.

Remarks: The TUNITS attribute has to be added to the M_UNIT meta object class.

The error is assumed to be positive and negative. The plus/minus character shall not be encoded.

The temperature accuracy must be defined in the same units as the temperature values.

FEATURE OBJECT ATTRIBUTES

Attribute: **Temperature units**

Acronym: **TUNITS** Code: xxx

Attribute type: E

Expected input:

ID	Meaning
1	degrees Celsius
2	degrees Fahrenheit

Definition:

The units in which temperature is expressed.

Degrees Celsius: Temperature specified in degrees Celsius.

Degrees Fahrenheit: Temperature specified in degrees Fahrenheit.

Indication:

Remarks: No remarks.

VITA

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