

IHO S-100

The Universal Hydrographic Data Model

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Introduction

The International Hydrographic Organization (IHO) is an intergovernmental consultative and technical organization established in 1921 to support the safety of navigation, and to contribute to the protection of the marine environment. One of its primary roles is to establish and maintain appropriate standards to assist in the proper and efficient use of hydrographic data and information.

This paper describes the Universal Hydrographic Data Model designated S-100 that was adopted by the IHO on 1 January 2010, thereby becoming an active international standard. The S-100 Geospatial Information Registry and its supporting operational procedures described in IHO publication S-99 became active in January 2011. The introduction of these major initiatives is expected to support the digital requirements of hydrographic product specifications and services for the foreseeable future.

The purpose of this paper is to expand upon earlier descriptions of the development of S-100¹, and to draw attention to what is happening; thereby promoting comment and the active involvement of both existing and potential stakeholders in the further development and implementation of both S-100 and the S-100 GI Registry.

Brief History of S-57

IHO S-57 is the current IHO Transfer Standard for Digital Hydrographic Data. It was formally adopted as an official IHO standard at the 14th International Hydrographic Conference in May 1992. S-57 includes:

- A general introduction with list of references and definitions
- A theoretical data model on which the standard is based
- The data structure and format that are used to implement the data model
- General rules for encoding data into the ISO 8211 encapsulation

In addition to its main part, there are two appendices to S-57:

- Appendix A is the Object Catalogue. It provides the official, IHO-approved data

¹ IHO Information Paper - *S-100: The New IHO Geospatial Standard for Hydrographic Data*, Ward, Alexander, Greenslade and Pharaoh, March 2008 and revisions 2009

schema that can be used within an exchange set to describe real-world entities.

- Appendix B contains Product Specifications adopted by the IHO. Product specifications contain additional sets of rules for specific applications. Currently, the only IHO product specification in S-57 that is in widespread use is for an Electronic Navigational Chart (ENC). A product specification for an IHO Object Catalogue Data Dictionary was also included but for all practical purposes has never been implemented.

S-57 Edition 3.0 was released in November 1996. Edition 3.1 containing minor revisions and some additional attribute values were issued in November 2000. Currently, S-57 edition 3.1 is “frozen”. S-57 will remain valid until no longer required.

Supplements to S-57. In order to avoid the need to release a new edition of S-57 together with the consequential effects on both data producers and equipment manufacturers, the IHO introduced the concept of supplements to S-57. Supplements are primarily intended to enable new features specified by the IMO that affect safety of navigation and which cannot adequately be encoded by an existing S-57 object class. Two supplements to S-57 have been published. Supplement 1 (January 2007) and Supplement 2 (June 2009). Supplement 2 (which also incorporates Supplement 1) covers:

- new features and attributes required to enable the encoding of Archipelagic Sea Lanes (ASL) and Particularly Sensitive Sea Areas (PSSA). These newly designated sea areas were designated by the International Maritime Organization for use by mariners when navigating in certain areas.
- a new feature and attributes which enables the inclusion of any new feature specified by the IMO and that affects safety of navigation which cannot adequately be encoded by any existing object class for use in an S-57 data set.
- inclusion of temporal attributes on certain features in order to meet the requirements of a new version of IEC 61174 type approval standard.

Current Limitations of S-57 Edition 3.1

Although S-57 Edition 3.1 has many good aspects, it does have limitations:

- It was primarily developed to meet the ENC requirement called for in an IMO-compliant Electronic Chart display and Information System (ECDIS).
- It has an inflexible maintenance regime. Freezing standards for lengthy periods is counter-productive.
- As presently structured, S-57 cannot support future requirements (such as gridded bathymetry, or time-varying information).
- Embedding the data model within the encapsulation (file format) restricts the flexibility and capability of using a wider range of transfer mechanisms.
- S-57 is regarded by some as a limited standard focused exclusively on the production and exchange of ENC data.

In order to address these and other limitations, the IHO Committee on Hydrographic Requirements for Information Systems (CHRIS) first considered a major revision of S-57 in November 2000. Subsequent work has resulted in the development and introduction of S-100 which includes both additional content and a new data exchange format.

New Name: S-100

During the years that S-57 has been in use, many people have come to regard the S-57 standard and the ENC product specification as the same thing. In reality, the ENC product specification is, in effect, a specific implementation of S-57 for the purpose of producing an ENC for use in ECDIS. This misconception resulted in a conclusion by many within the ECDIS and ENC community that the work on a new or revised edition of S-57 would radically change the current ENC, thus affecting existing ENC production and ECDIS implementation. This was never the intention.

In order to avoid a direct connection between S-57 edition 3.1 ENCs and any subsequent new IHO data transfer standard, the IHO decided in 2005 that the development of an Edition 4.0 of S-57 would henceforth be designated as S-100: *Universal Hydrographic Data Model*. Any product specifications developed using S-100 would then follow in an S-10n series. Under this schema, when a next-generation ENC Product Specification based on S-100 was developed at some future date, it would be logically designated S-101.

Key Features of S-100

S-100 supports a wider variety of hydrographic-related digital data sources, products, and customers (see Figure 1). This includes new spatial models to support imagery and gridded data, 3-D and time-varying data (x, y, z, and time), and new applications that go beyond the scope of traditional hydrography (for example, high-density bathymetry, seafloor classification, marine GIS, etc.).

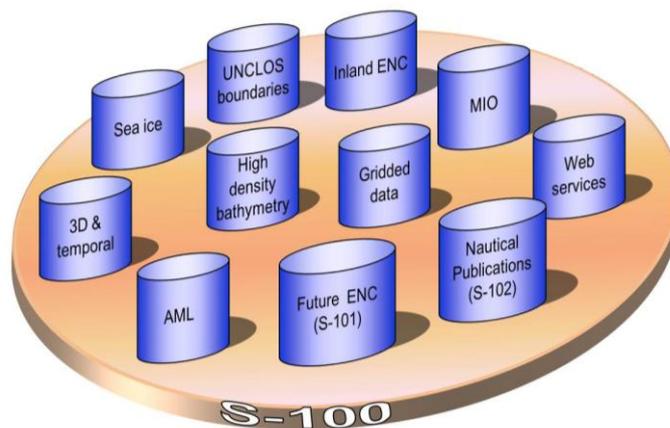


Figure 1 - S-100 will support a far greater variety of data sources, products and services

Other features include:

- Separating the data content from the carrier (file format). In this way, data can be manipulated and encoded without being permanently tied to a single exchange mechanism.
- Manageable flexibility that can accommodate change. The content of product specifications will be a subset of S-100, including separate feature catalogues. This allows the core standard to evolve (through extension) without the need to introduce new versions of product specifications.
- An ISO-conforming registry on the IHO web site containing registers for feature data dictionaries, portrayal and metadata. The registers accommodate both core

hydrographic content and other chart related content, such as, nautical publications information, Inland ENC, Sea Ice, Additional Military Layers (AMLs) and Marine Information Overlays (MIOs).

Benefits

S-100 introduces a number of new benefits:

- Using ISO-developed components and terminology helps ensure that S-100 and future extensions are in the mainstream of the geospatial information industry. This will help to encourage greater use and lower costs in implementing S-100 for both hydrographic and other types of geospatial applications (for example, marine GIS).
- Conformance with the ISO/TC211 standards will maximize the use of commercial-off-the-shelf (COTS) software applications and development and promote better interoperability.
- There will be greater compatibility with web-based services for acquiring, processing, analysing, accessing, and presenting data.
- New components of S-100 will not be developed in isolation from the rest of the geospatial information technology community.
- Any new requirements can be incorporated within the established framework of ISO/TC211 based standards.
- Rather than being regarded as simply a standard for hydrography, S-100 will be interoperable with other ISO/TC211 standards and profiles such as NATO DIGEST.
- National standards bodies can take full advantage of S-100 being aligned with ISO/TC211 standards.
- Compatible hydrographic data will be available to more than just hydrographic offices and ECDIS equipment.
- S-100 will enable hydrographic offices to use compatible sources of other geospatial data, for example combining topography and hydrography to create a coastal zone map.

ISO Standards for Geographic Information

The International Organization for Standardization (ISO) is a non-governmental international standards organization comprising a worldwide federation of national standards bodies from over 130 countries. In response to a growing demand for geographic information standards, ISO established Technical Committee 211 (ISO/TC211) in 1994. The aim of ISO/TC211 is to establish a structured set of standards for information concerning geographic objects or phenomena. IHO, together with many other geographic standards development organizations, is a Class-A liaison organization to ISO/TC211. Currently, there are 31 liaison organizations including:

- Digital Geographic Information Working Group (DGIWG),
- Global Spatial Data Infrastructure (GSDI),
- Open Geospatial Consortium (OGC),

- Organization for the Advancement of Structured Information Systems (OASIS),
- United Nations Geographic Information Working Group (UNGIWG)
- World Meteorological Organization (WMO).

Alignment with ISO/TC211

Given the prominence of ISO standards and their worldwide recognition and use, it made sense for IHO to follow the ISO/TC211 suite of standards for the compilation and maintenance of S-100.

In 1999, ISO/TC211 invited the IHO and the NATO Digital Geographic Information Working Group (DGIWG) to enter into a cooperative agreement for future standards development. Rather than work at cross-purposes, it was considered prudent to harmonize the data content contained in IHO S-57 (that is - the Object Catalogue) with that of NATO DIGEST (the DGIWG Feature Data Dictionary – formerly called Feature Attribute Coding Catalogue or FACC). Further, the intention was to develop hydrographic standards that were compatible with a broad range of other ISO geospatial standards. This was endorsed at the 12th meeting of the IHO CHRIS in October 2000. Currently members of both organizations attend each other’s meetings and have played important roles in the harmonization process.

ISO 19100 Standards

The standards developed by ISO/TC211 are contained in the ISO 19100 series of geographic information standards. For all forms of geographic data, these standards specify the methods, tools, and services for:

- Data management (including definition and description)
- Acquiring, processing, analysing, accessing, and presenting data
- Transferring data in digital electronic form between different users, systems and locations

In the most general sense, these standards fall into one of the following categories:

- Framework and Reference Model
- Profiles and Functional Standards
- Data Models and Operators
- Data Administration
- Geographic Information Services

As of January 2011, there are over 50 standards in the ISO 19100 series together with another 20 supplementary or additional standards under development. These include standards for spatial and temporal schema, metadata, imagery and gridded data, profiles, portrayal, encoding, and so forth. A number of these standards are referenced by S-100 and will be used in conjunction with S-100 based products and applications. The relationship between S-100 work packages and the associated ISO 19100 series of standards is shown in Figure 2.

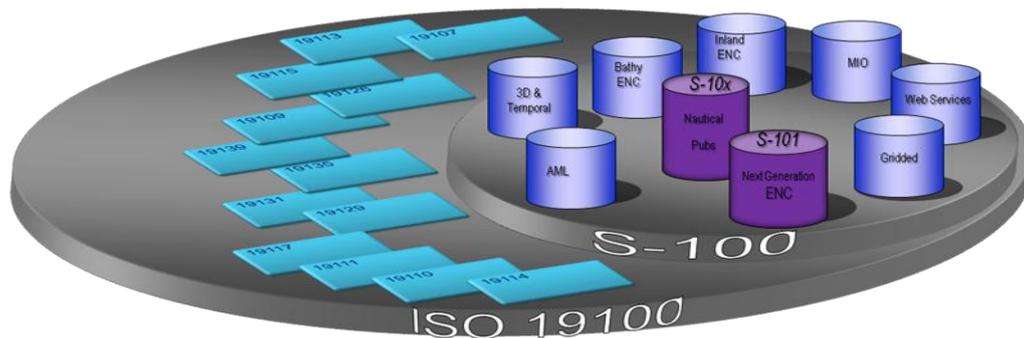


Figure 2 - IHO S-100 Components and their associated ISO 19100 series of standards.

S-100 Framework

S-100 comprises multiple components that are aligned with the ISO 19100 series of geospatial standards. Developing S-100 in this way has enabled hydrographic data to be included in many more general geospatial applications than has been the case before.

Alignment with the ISO 19100 series of geographic standards has required that S-100 is organized and defined in a different way when compared to S-57. More specifically, it requires a new framework or structure, and a revised set of terms to describe the components of S-100. The remainder of this paper describes how this will be achieved.

New Terminology (IHO S-57 → IHO S-100)

Some of the terms and definitions used in S-57 Ed. 3.1 are not used in S-100. They have been re-defined or modified to conform to the terms used in the ISO TC/211 series of standards.

Some examples of changes in terminology include:

<u>IHO S-100</u>	<u>S-57</u>
<i>registry</i> <i>register</i>	no terms used [The closest thing to a registry/registers that exists in S-57 is the object/attribute registration arrangement on the Open ECDIS Forum (OEF). During the past six years, it has served as a useful mechanism/database for registering additional objects/attributes that were not contained in S-57 Edition 3.0/3.1]
<i>feature</i>	<i>Object</i>
<i>feature attribute</i>	<i>Attribute</i>
<i>enumerated values</i>	<i>attribute values</i>
<i>feature concept dictionary</i>	<i>object catalogue</i>
<i>curve</i>	<i>Edge</i>
<i>point</i>	<i>Node</i>
<i>surface</i>	<i>Face</i>
<i>application schema</i>	<i>application profile</i>

The Registry and Registers

One of the most significant aspects in terms of alignment with the ISO TC/211 19100 series of standards is the employment of a *registry* and *registers*. A registry is the entire information system (or location) in which a collection of registers is located. A register is a collection of tables in a database containing identifiers assigned to items with descriptions of the associated items. Descriptions may consist of many types of information, including names, definitions and codes.

In the case of S-100, the IHO is hosting an on-line registry engine² that provides the facility to access and maintain the various S-100 registers.

The S-100 geospatial information registry contains the following principal subordinate registers:

- Feature Concept Dictionary (FCD) registers
- Portrayal registers
- Metadata registers
- Data Producer Code register
- Product Specifications registers

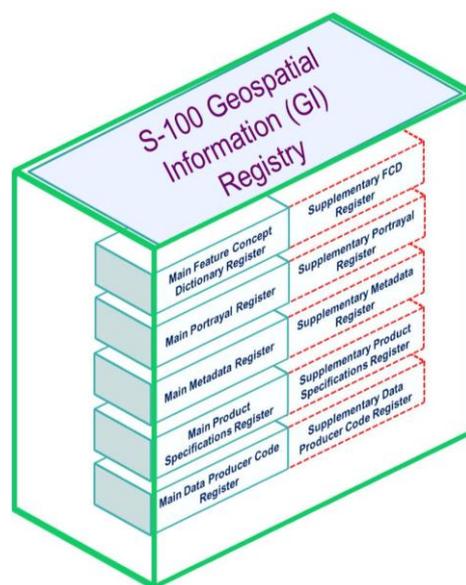


Figure 3 - IHO Geospatial Information Infrastructure Registry

A detailed description of the S-100 GI Registry and the operational procedures for its use are available in IHO publication S-99 - *Operational Procedures for the Organization and Management of the S-100 Geospatial Information Registry*, which can be downloaded from the IHO website.

New Possibilities with S-100

The S-100 geospatial information registers support a number of features not available with the S-57 standard, including:

² <http://registry.iho.int>

Unbound Feature Concept Dictionaries. Unlike S-57 feature catalogues, feature concept dictionaries only consist of the definitions for features, feature attributes and enumerations. Binding between these definitions, units of measure, format and so on, is included in a feature catalogue which is specific to each product specification. As of January 2011 there are registers for hydrographic information (based on the existing S-57 feature and attribute catalogues), dynamic ice coverage, nautical publications and Inland ENC's.

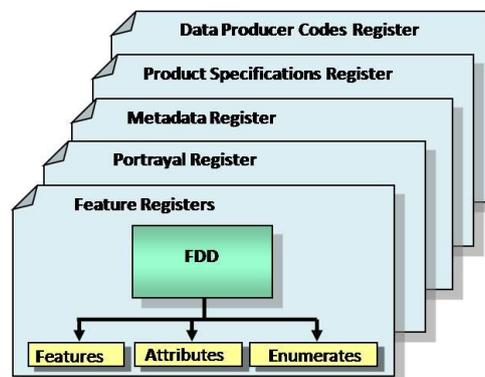


Figure 4 – Features, Attributes and Enumerates not bound in the S-100 Registers

Feature Catalogues. S-100 provides improved flexibility including:

- Feature catalogues for individual product specifications can be constructed using either items referenced from the Feature Concept Dictionary registers or new items defined in the catalogue itself.
- Decisions about the binding between Features and Feature Attributes are defined in the individual catalogue along with the unit of measure for numeric attributes.
- A new Information Type has been included that does not have any spatial attribution provides information about a feature by association. This could be a note associated with a pipeline or a buoy, for example.
- A new complex attribute type has been included. This is an extension of the ISO concept of an *attribute of an attribute*.

Flexible Version Control. A major benefit of the registry and register concept is its flexibility. Multiple versions of similar entries in a Feature Concept dictionary can be maintained using unique identification and classification. An entry is classified as being either:

- *valid* (latest version)
- *superseded* (previous version/s)
- *retired* (no longer recommended for use)
- *non valid* (proposed but not accepted or no longer acceptable)

In this way Product Feature Catalogues reference items that will always be legitimate even if a newer version of the referenced item is registered at a later date. This means that if a new item is registered or an existing item is upgraded, newer versions of the existing product specifications are not automatically required as a consequence. The category of *Non valid* items is listed in the registers specifically to help identify the inappropriate reintroduction of previously rejected proposals.

Metadata. Increasingly, hydrographic offices are collecting, storing and archiving large quantities of digital data which are becoming an important national asset. Knowledge of the quality of hydrographic data is crucial to ensuring that the data is used appropriately; different users and different applications often have different data quality requirements. In order to provide relevant details, data custodians need to record quality information about their data.

The S-100 metadata component makes provision for the creation of metadata records that provide information about the identification, spatial and temporal extent, quality, application schema, spatial reference system, and distribution of digital geographic data. It is applicable to the cataloguing of datasets, clearinghouse activities, and the full description of geographic and non-geographic resources. Although the metadata component is primarily intended to describe digital geographic data, it could also be used to describe other related resources such as charts, maps, textual documents and non-geographic resources.

Spatial Geometry. The one and two-dimensional geometry of S-57 has been updated in S-100 to accommodate the use of a wider range of database and encoding applications. For example, the use of a composite curve to consolidate the individual curve components of a feature will simplify operations on such a feature in the software environment. Surfaces are being introduced to solve issues of area features truncated by data boundaries. This will accommodate the encoding of one area feature with one set of geometry, unlike in S-57 where several features using individual geometries are required to model what is actually a single feature.

Imagery and Gridded Data. This component defines specific grid organizations to be used for hydrographic data and images associated with hydrographic data. Both simple grids and complex multi-dimensional grids have been defined.

Hydrographic soundings are by their nature a set of measured data points. These data points can be represented in a grid structure in several different ways, including elevation models, using a regular grid spacing, and irregular grids with variable size cells or picture elements (pixels) that closely correspond to the handling of soundings as point sets.

Images are also of great importance for hydrographic data. This includes images from sensors such as aerial photography or LIDAR, photographs that can be associated with vector based feature oriented data and scanned paper chart products, commonly known as “raster charts”. All of these applications of imagery and gridded data can be catered for in S-100.

Multiple Encoding. S-100 itself does not mandate particular encoding formats. This means that the developers of product specifications can decide on the most suitable encoding standard for their particular application.

Initially (January 2011) S-100 only provides an updated schema for ISO 8211 and schemas for GML including a version for *simple features* for use in web feature services. This will eventually be extended to include other formats as and when required.

Standardised Product Specifications. A product specification is a description of all the features, attributes and relationships of a given application and their mapping to a dataset. It is a complete description of all the elements required to define a particular geographic data product. This component ensures that any data product specification will maintain a consistent structure.

A product specification consists of the following basic parts:

- product identification
- data content and structure
- coordinate reference system
- data quality
- data capture
- data maintenance
- portrayal
- encoding
- product delivery

Continuous Maintenance. S-100 (as well as the contents of the S-100 GI Registry) will never need to be “frozen”, although the frequency of new versions of S-100 will still be carefully controlled by the IHO as the ultimate register owner. There are three classes of change under S-100: *clarification*, *revision* and *new edition*.

The maintenance regime is therefore considerably different to that of S-57. The concept of a change being both a clarification and a revision has been removed. The version control arrangements under s-100 can be summarised as follows:

- Clarifications denoted as version 0.0.*n*.
- Revisions denoted as version 0.*n*.0.
- New Editions denoted as version *n*.0.0.

where *n* is the cumulative change number.

Future Developments

Migrating from S-57 Edition 3.1 to S-100

ENC data conforming to S-57 Edition 3.1 will continue to be a requirement for type-approved, IMO-compliant ECDIS for the foreseeable future. As a consequence, hydrographic offices will continue, as at present, to produce S-57 Edition 3.1 ENC data to support this. However, work is already underway to develop an S-100 based ENC product specification, to be known as S-101.

S-101 ENC Product Specification

S-101 will enable such things as “plug and play” updating of data, symbology and software enhancements as well as the more efficient use of additional data captured according to the S-100 framework model and other ISO geographic data structures.

The development, implementation and transition into force of S-101 will follow the IHO governance model for technical standards as illustrated in Figure 6.

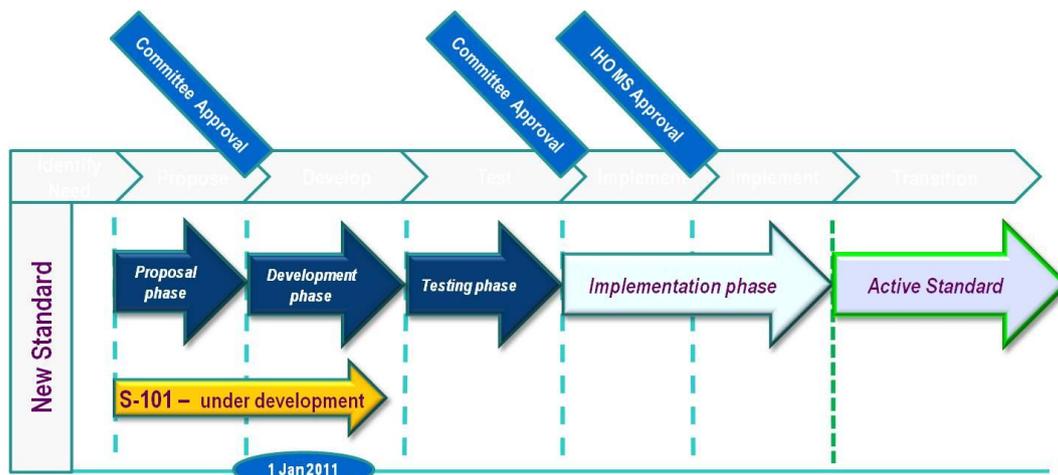


Figure 5 - Development Progress of the S-101 ENC Standard

Development of S-101 is being undertaken over several years, and will involve the active participation of all stakeholders, including hydrographic offices, ENC software producers, ECDIS manufacturers, mariners, and other maritime users. As a consequence of the extensive development process, S-101 could not come into force before 2012 or later, depending on general progress and the testbed requirements, and even then, the standard will sit alongside the existing S-57 Edition 3.1 product specification for some time. It is expected that any ECDIS equipment software that is upgraded or reconfigured to use S-101 ENCs will continue to be able to use S-57 edition 3.1 ENCs until such time as S-57 ENCs are no longer being produced.

S-100 and e-Navigation

The International maritime Organization (IMO) is developing the e-Navigation concept. Under this concept, e-Navigation is defined as:

The harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.

The aim of the IMO is to develop a strategic vision for e-navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety while simultaneously reducing the burden on the navigator. The IMO set up a Correspondence Group (CG) to advise its various Committees on the development of such a concept. Included in the work of the CG was an examination of suitable data structures.

The S-100 GI Registry was purposely created to be extendable so as to encourage the widest possible use of hydrographic data and other related data types. It has now been recognised that S-100 and the GI Registry may be a suitable basis for the data capture requirements of certain other data providers under the e-navigation concept. As a result, the IMO Correspondence Group on e-Navigation, IALA, and other maritime data providing organizations are showing increasing interest in S-100 and in particular the opportunity to use the S-100 GI Registry to provide as common a data structure as possible for e-Navigation.

In early 2011, the IMO Correspondence Group on e-Navigation reported to IMO that S100 should be considered as a baseline, as an important element in the IMO e-navigation concept. The CG went on to comment that if a prospective e-Navigation data provider has not yet

adopted a data structure, then it should consider using an established standard, such as S-100, or ensure that it is compatible with existing standards such as S-100. In this context, it is increasingly obvious that S-100 is destined to play an important role in hydrographic and the wider maritime domains for many years to come.