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The IHO Geospatial Information Registry

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Structures and applications for hydrographic information beyond ECDIS

An article by *Mathias Jonas*

As a result of lessons learned with ECDIS over a decade, the IHO launched S-100 project in 2005 aiming not only to enhance ENCs for future type approved ECDISes but for extended provision of hydrographic information beyond ships navigation. S-100, the »Universal Hydrographic Data Model (UHDM)«, is not specific for the application of ECDIS. Instead, this data model includes all the components needed to build product specifications to handle a variety of different geospatial applications for hydrographic data, including product specifications for ENC data. However, the core element of S-100 is the IHO Geospatial Information Registry in conformance with the ISO 19100 series of Geographic Information Standards. A Registry contains by definition a number of discrete registers, each owned and managed by the relevant competent authority.

S-100 | S-57 | ECDIS | ENC | IHO | Geospatial Information Registry | Standardisation

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As a result of lessons learned with ECDIS over a decade, the IHO launched its ambitious S-100 project in 2005 aiming not only to enhance ENCs for future type approved ECDISes but for extended provision of hydrographic information beyond ships navigation. In order to facilitate data exchange in new fields of application such as survey, offshore exploration, spatial resource planning, marine environmental information, logistic management, ships security, long range tracking and others, S-57 »The IHO Transfer Standard for Digital Hydrographic Data« is now promoted to become the »Universal Hydrographic Data Model (UHDM)«, called the S-100 series. S-100 is not specific for the application of ECDIS. Instead, this data model includes all the components needed to build product specifications to handle a variety of different geospatial applications for hydrographic data, including product specifications for ENC data. However, the core element of S-100 is the IHO Geospatial Information Registry in conformance with the ISO 19100 series of Geographic Information Standards. A Registry contains by definition a number of discrete registers, each owned and managed by the relevant competent authority. The IHO GI Registry serving for the provision of S-100 elements contains the following principal registers:

- Feature Concept Dictionary (FCD) registers,
- Portrayal registers,
- Metadata registers.

These registers accommodate building blocks for data product specifications for both core hydrographic content and other chart-related content, such as nautical publications, Inland ENCs and marine information overlays. As part of the overall registry, the resulting product specifications are hold in a separate subordinated register as well as producer codes designated to data producers:

- Product Specifications registers,
- Data Producer Code register.

The article describes the implementation status of the elements of the IHO Geospatial Information Registry and gives a synopsis about the introduction of the S-100 based next generation ENC (S-101 ENC Product Specification).

1 Electronic charts are here to stay

The decision to renew the IHO data transfer standard S-57 radically to become the Universal Hydrographic Data Model and to re-launch as S-100 was made during the 17th meeting of the IHO-Committee on Hydrographic Requirements and Information Standards CHRIS in September 2005 in Rostock. At this stage, it was not entirely clear if Electronic Navigational Charts (ENCs) based on S-57 – the standard in place – would finally be accepted on global scale. At that time hydrographic offices but even navigation equipment suppliers dealing with digital chart information faced enormous challenges: The transformation of chart production from analogue into digital routines went slow, the small range of production software on offer did not work fully effective and the issues of data encryption and data dissemination were disputed internationally. As a result, the global ENC coverage grew only slow, ENCs were relatively expensive, end user devices did not work really stable and raster charts were much more accepted and widespread then vector data contained in ENCs. Proponents of carriage requirements for ECDIS (Electronic Chart Display and Information System) working with ENCs argued therefore with a restrained attitude.

2010 shows a much different situation: practically all developed countries who have navigable waters under their jurisdiction are producing ENCs on a regular base and more and more emerging nations join. The British Admiralty – the UK Hydrographic Service – is producing ENCs on behalf of a number of nations who lacking own capacities in this field. At the annual meeting of the Safety of Navigation Committee of the IMO in July 2010 the IHO reported that the global ENC coverage is now equivalent with the coverage of paper charts

in terms of charted details and provision of update service.

The sales figures for ENCs are rising continuously – for the German sea area they were equal with paper charts sales the first time in 2008. This enormous progress and the obvious contribution of electronic sea charts to the safety and efficiency of navigation led the adoption of ECDIS carriage requirements by IMO in 2008. The mandatory use of ECDIS onboard starts in 2012 for new build tankers and passenger vessels and will be enhanced to a significant ships classes from 300 Gross Tonnage upwards until 2018.

2 IHO S-57: Global standardisation for a global shipping

Seen from today it might be surprising that the original intentions for the development of S-57 did not target to a data product for ships navigation. Originally designated as transfer standard for the mutual exchange of hydrographic data between databases, S-57 was designed on (still) modern GIS-concepts who were applied to land based applications a full decade later:

- Vector data, composed from geometric primitives: points, lines and areas.
- Digitisation as geometric objects with specific sets of attributes assigned to.
- Definition of object and attribute catalogues and designation of permitted combinations collected in product specifications.
- ISO compliant coding without specific symbolisation.

For the production of S-57 based data however, there is only less than a handful of software houses who offer their solutions. The scope of their packages range from the object oriented digitisation of paper charts up to the complete workflow for the full variety of nautical publications by means of a hydrographic production database. Indeed, the choice of tools on production side is rather limited but the application side shows a different picture: more than fifty suppliers of soft- and hardware solutions support the import of S-57 based products; there are converters and freeware available and the use of ENCs is not limited to navigation any-more. Research, administrative tasks and the explorers of the maritime environments belong to the user group of ENCs today.

There is no doubt that the IHO Data transfer Standard S-57 and the only data product derived from yet – the ENC – mark a success in global standardisation in the rapidly evolving digital world of geoinformation. But the experiences now gained over more than a decade show substantial deficiencies of S-57 based ENCs as well:

- In comparison to the mainstream of GIS-standardisation S-57 is a proprietary solution. This results in costly software development for data production and use and make their application costly as well.
- The data structure and the data encapsulation (ISO 8211) of ENCs have strong interdependencies which make the definition of data products based on S-57 other than ENCs difficult.
- As binary coded vector data, ENCs are compact by nature, however a clever compression could again reduce the data volume to be transferred and support the attraction for wireless transmission onboard.
- ENCs are by concept a vectorised replica of the traditional paper chart. Contemporary data structures and technologies like gridded data, time variant data and visualisation technology as known from internet technology cannot be applied with.
- The scope of items to be depicted in navigational charts is not static. Mostly initiated by IMO, there is an ongoing request for modifications and amendments of the nautical information to be forwarded to the shipping sector. Unfortunately whose modifications can be applied to ENCs with considerable delay only: Each adaptation requires an upgrade of the data production software ashore and the application onboard. The second is the more severe problem – vessels on international voyages are in very loose access for the OEMs. An example for the resulting difficulties gives the introduction of the charting of Archipelagic Sea Lanes on IMO's request: It took almost four years from the date of adoption until the upgrade of the ENC product specification and the adaptation of the on-board visualisation by means of new editions of the applying IHO standards.
- One added value of the navigation by means electronic sea charts is the combination of spatial information and operative information like radar, AIS, weather, sea state and tides. The ECDIS technology in place is able to superimpose such information layers but true integration on functional level can hardly be reached with the S-57 structures.

3 What should IHO S-100 be able to do better?

The primary goal for S-100 is to be able to support a greater variety of hydrographic-related digital data sources, products, and customers. Much alike as S-57 delivers the building blocks for the current ENC Product Specification, S-100 serves as an umbrella standard named »IHO Universal Hydrographic Data Model« for a full suite of derived product specifications. The first of such specifications are currently undergo a drafting process:

- S-101 – product specification for the next generation ENC,

- S-102 – high resolution bathymetric grid,
- S-103 – text oriented nautical publications (digital sailing directions).

But more S-100 based products are announced to come: Image data, gridded data, 3D and time variant data products will be provided to feed applications beyond the classic scope of sea surface cartography for ships navigation. Among other topics, S-100 will support marine spatial planning, military applications and offshore exploration software.

3.1 ISO Standards for hydrographic information

In order to maintain all of those diverse purposes effectively on a common technical platform, S-100 is in strict conformance with the generic ISO 19100-Standards suite for geoinformation. This suite contains all elements for the handling of spatial related information independent from the thematic designation and opens the door for enhanced use of hydrographic data outside the classic range of their application today.

ISO 19100 provides the following elements:

- Data management (including definition and description);
- Acquiring, processing, analysing, accessing, and presenting data;
- Transfer of data between 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.

Currently, there are over 40 standards in the ISO 19100 series. These include both formally adopted and draft International Standards for spatial and temporal schema, metadata, imagery and gridded data, profiles, portrayal, encoding, and so forth (Fig. 1).

The alignment with the ISO 19100 series offers the following advantages:

- Use of cost effective »of the shelf« software for data production and the applications in the field.
- 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 future product specifications will be a subset of S-100, including separate feature catalogues. This will allow the core standard to evolve (through extension) without the need to introduce new versions of product specifications.
- »Plug and Play« updates of data format, symbolisation rules and software modifications through extension of the core standard without the need to new versions of the product specification. If modifications of the embedded data model are required, the adapted elements together with the matching visualisation routines will be delivered in machine readable form as part of the data set. The application software will then be adapted »on the fly«.
- An ISO-conforming registry on the IHO Web site containing registers for Feature data dictionaries, portrayal and metadata. The registers will accommodate both core hydrographic content and other chart related con-

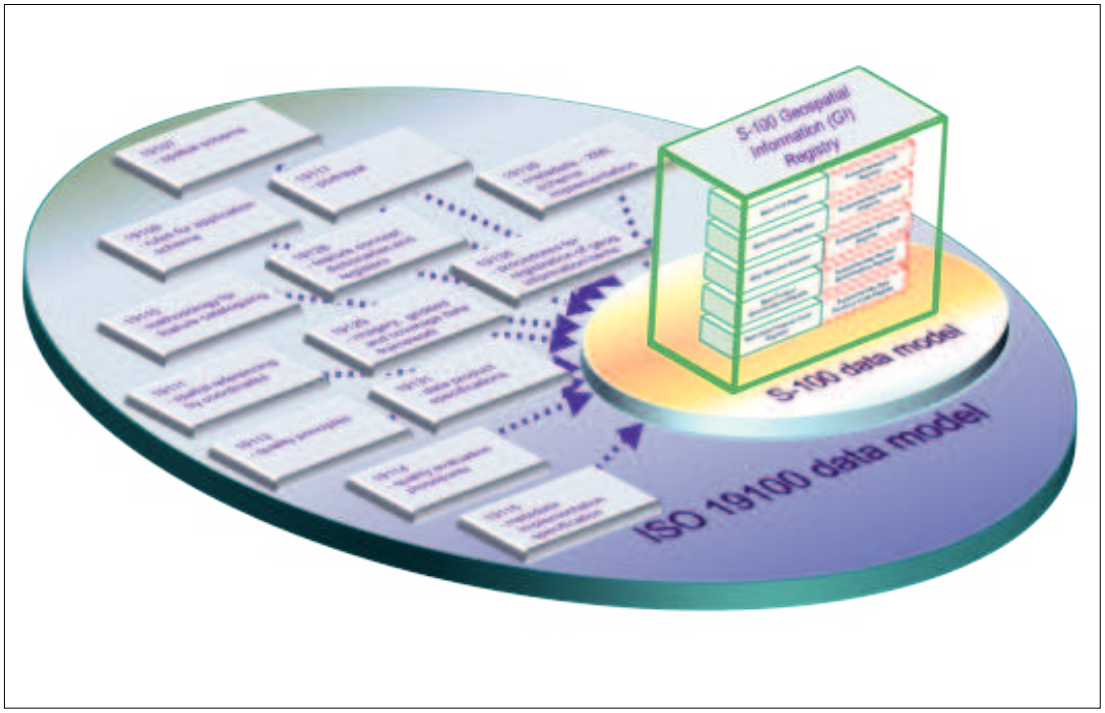

Fig. 1: IHO S-100 Components and their associated ISO-Standards ▸

tent, such as, Nautical Publications, Inland ENC and Marine Information Overlays.

3.2 New terminology and new basic elements

The binding of S-100 to the ISO 19100-Series requires the redefinition of some core elements of S-57. Table 1 contains the comparison of the most important terms in both standards:

IHO S-100	IHO S-57
Registry Register	No equivalence The only equivalency is the voluntary object/attribute registration of additional combinations which are not included in the S-57 Edition 3.0/3.1 hosted by the Open-ECDIS-Forum (OEF)
Feature	Object
Feature attribute	Attribute
Feature concept dictionary	Object catalogue
Curve	Edge
Point	Node
Surface	Face
Application schema	Application Profile

4 The »Registry« and the register

The most important element of S-100 with regard to ISO compliance is the »Registry«. The registry is a web based library of registers in a manageable hierarchic structure. Registers are thematic collections of data types, metadata and feature data dictionaries belonging to a specific domain. Each dictionary hosts the standardised »vocabulary« to describe the entities of the domain in a digital way. The »IHO Geospatial Information (GI) Registry« –accessible via the IHO web site (www.iho.org) will consist of the following register types:

- Feature Concept Dictionary (FCD) Registers – dictionaries containing object and attribute collections.
- Portrayal Registers – thematic collections of presentation rules.
- Metadata Registers – thematic collections of metadata structures.
- Data Producer Code Register – collection of ENC-Producer Codes.
- Product Specifications Registers – collection of product specifications.

All registers exist twofold for each domain – one main register for themes which are under the auspices of IHO, e. g. sea cartography, text related nautical publications and tides; another supplementary register for marine related topics beyond IHO core responsibilities, e. g. for ice coverage and inland waterways.

The particular novelties of the registry concept compared to the static definitions of S-57 are:

Expandable Feature Concept Dictionaries (FCDs):
Feature concept dictionaries consist of extensible lists of objects, attributes and – as a new element – enumerations. The unlimited combination of those basic elements allow the description of all spatial referenced items belonging to the »wet domain«. Specific feature catalogues as part of a product specification are composed from such combinations of these basic elements. The useful expansion of the dictionaries is in principle open to everybody, however the management of the entries is supervised by a group of experts or a skilled organisation.

Enhanced Feature Catalogues:

- Feature catalogues for individual product specifications can be constructed using either items referenced from the Data Dictionary Registers or new items defined in the catalogue itself.
- Decisions about the binding between Features and Feature Attributes will be defined in the individual catalogue along with the unit of measure for numeric attributes.
- A new Information Type is introduced which does not have any spatial attribution and will provide 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 is introduced. This is an extension of the ISO concept of an Attribute of an Attribute.

Flexible version control:
Flexibility is an essential benefit of the register concept. Multiple versions of similar entries in a data dictionary can be maintained using unique identification and classification. For instance, an entry can be 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 always remain valid 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, new versions of existing product specifications are not required. Non valid items remain visible in the Registers to ensure that any future proposals for similar items have not been previously suspended.

Spatial component:
The one and two-dimensional geometry of S-57 is being updated in S-100 to accommodate the use of a wider range of database and encoding

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applications. For example, the use of a composite curve to consolidate the individual curve components of a feature simplifies operations on such a feature in the software environment. Surfaces are introduced to solve issues of area features truncated by data boundaries. This accommodates 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.

Gridded data and imagery component:
This component defines specific grid organisations to be used for hydrographic data and images associated with hydrographic data. Both simple grids and complex multi-dimensional grids are 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«.

Presentation rules:
Similar to the FCD registers, the portrayal registers consists of lists of symbolisations such as dots, lines and areas but even complex symbolisation rules. Specific sets of symbolisations collected in portrayal catalogues are referenced by the features as contained in feature cata-logues as part of a product specification.

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 similar structure. A product specification consists of the following basic parts:

- product identification,
- data content and structure,
- co-ordinate reference system,
- data quality,
- data capture,
- data maintenance,
- portrayal,
- encoding,
- product delivery.

Product Specifications belonging to the IHO-Registry may also refer to other registers as long as they are in ISO 19100 conformity.

Variable coding:
S-100 itself does not mandate particular encoding formats. This means that the developers of product specifications can decide on the suitable encoding standard for their particular applications Fort the time being S-100 provides an updated schema for ISO 8211. This will eventually be extended to include other formats as and when required. The catalogues for features and portrayal belonging to a product specification will be distributed by means of XML.

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 hydro-graphic data is crucial in 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 will need to record quality information about their data. This will be at least one part of a metadata requirement. 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 data sets, clearinghouse activities, and the full description of geographic and non-geographic resources. Although it is primarily intended to describe digital geographic data, it may also be used to describe other resources such as charts, maps, textual documents and non-geographic resources.

Continuos maintenance:
S-100 will never be »frozen« although the frequency of new versions will be strictly controlled by the IHO as the Registry Owner. There will be three types of change proposal in S-100: clarification, correction and extension. Any change proposal must be one of these types. The maintenance regime has been changed considerably in comparison to that in S-57. The concept of a change being both a clarification and a correction has been removed. The new version control mechanism will be as follows:

- Clarifications denoted as 0.0.x.
- Corrections denoted as 0.x.0.
- Extensions denoted as x.0.0.

5 The Registry/Register Management

S-100 is supported by an organisational and governance framework that involves all the stakeholder groups. The IHO is the principal sponsor and has overall control of the standard in its role as the owner of the Registry. It is the authority that decides if Registers can be established in its Registry and what policies will apply. A Registry Manager appointed

by the Registry Owner is responsible for monitoring and maintaining the day-to-day operation of the Registry. The responsibilities and obligations of the IHO as Registry Owner will be under-taken by a Registry Control Board: the IHO Hydrographic Services and Standards Committee (HSSC).

However, the development and extension of the specific registers to meet particular user group requirements is placed under the control of those user groups. This is achieved through different instances for the various Registers that form part of the IHO Geospatial information Registry:

- Register Owner,
- Register Manager,
- Register Control Bodies,
- Submitting Organisations.

Register Owner:
Each established Register has a Register Owner. A Register Owner may be an organisation that:

- establishes one or more Registers,
- has primary responsibility for the management, dissemination, and intellectual content of its Registers,
- may appoint another organisation to serve as the Register Manager,
- shall establish a procedure to process proposals and appeals made by Submitting Organisations.

In the IHO, a number of existing technical Working Groups (WG) will be Register Owners.

Register Manager:
Register Owners will appoint a Register Manager for their Registers. A Register Manager is responsible for the administration of a Register. This includes:

- co-ordinating with other Register Managers, Submitting Organisations, the related Control Body, Register Owner and the Registry Manager to ensure entries are being compiled in the appropriate Register;
- maintaining items within the Register;
- maintaining and publishing a list of Submitting Organisations;
- distributing an information package containing a description of the Register and how to submit proposals;
- providing periodic reports to the Register Owner and/or the Control Body. Each report will describe the proposals received and the decisions taken since the last report. The interval between those reports would normally not exceed 12 months.

A Register Manager may manage multiple Registers. A key element in the management and maintenance of a coherent Registry is co-ordination between the Register Managers to ensure that there is consistency between Registers.

Register Control Body:
A Control Body is a group of technical experts appointed by a Register Owner to decide on the acceptability of proposals for changes to the content of a Register. The Control Body must comprise of experts in the related field that makes up the contents of the Register that they control. For IHO owned and managed registers those expert are typically members of the technical working group under the umbrella of HSSC.

Submitting Organisations:
Submitting Organisation to develop submissions of proposals for registration according to their respective communities or organisations. However, proposed changes to an IHO Register must then meet the submission procedures established by the Register Owner. Register Managers will consider whether a proposed item is suitable for the Register in which it is pro-posed to reside.

6 Migrating from S-57 to S-100 and introduction of S-101

S-100 – the »IHO Universal Hydrographic Data Model (UHDM)« as the new framework standard for the registration, maintenance and capture of hydrographic geospatial data and product specifications was formally adopted by the IHO Member States and was set in force by 1. January 2010. Feature Concept Dictionary registers in a tentative arrangement are already accessible at the IHO homepage. The launch of the full IHO Registry is scheduled for the third quarter of 2010.

For the introduction of product specification for next generation ENC becoming S-101 ENC a phased approach for the development, testing and release is envisioned. This process is designed as an iterative development, there each iteration step is usable and testable. It is expected that this strategy also enables a test of the change control process to both S-101 and S-100 and, consequently, a smooth migration from S-57 to S-101 driven ECDIS for the OEMs and even type approval authorities.

Phase 1	S-57 ENC Content Equivalent
Phase 2	Enhanced Packaging and Data Loading
Phase 3	Extending the S-101 Model
Phase 4	Scalability

Phase 1: *S-57 ENC Content Equivalent*

- The Feature Catalogue coded in XML includes only those features and attributes that are currently in S-57, Version 3.1.2.
- The portrayal component continues to use the existing mechanisms as contained in S-52 Presentation Library, Edition 3.4.
- The new general feature model of S-100 including new geometry, i. e. Compound

References:
IMO-MSC86/26: Report of the Maritime Safety Committee on its eighty-sixth Session, London, 12 June 2009
IHO S-100 Standard, Edition 1.0.0 – January 2010
Ward, R.; Alexander, L.; Greenslade, B.: IHO S-100: The New IHO Hydrographic Geospatial Standard for Marine Data and Information, IHB, Monaco, April 2009
Minutes of the 20th meeting of the Transfer Standard Maintenance and Application Development Working Group (TSMAD), Rostock, May 2010

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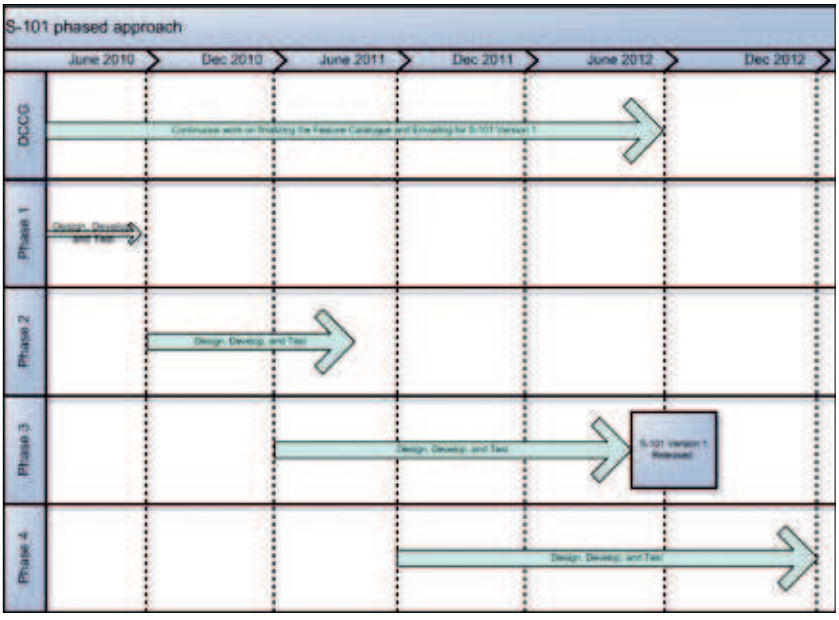
curves is implemented and encapsulated with the new ISO8211 encoding.
- Deliverable: S-101 .000 file and updates (no catalogue file).

Benefits:
- Proof of the concept and validation of S-100.
- Feature Catalogue is exchanged as data set.
- Utilisation of the new 8211 encoding.
- Creation of an S-100 compliant product specification.
- Template for other S-100 product specifications.
- Prove that an S-57 based product can be built using S-100.

Phase 2: *Enhanced Packaging and Data Loading*
- New support file formats and management (XHTML, JPEG, etc.).
- New file naming conventions.
- Populating exchange sets including Metadata and improved display scales for ECDIS loading.
- Updating Scenarios which includes text file updating.
- The XML-coded Portrayal Catalogue is introduced.
- Deliverable: Complete Exchange Set including updates.

Benefits:
- Demonstrate improved functionality of S-100.
- Prove that this process is supportable.
- Improved data delivery.
- Improved data discovery.
- Easily Accessible Metadata.
- Support File Improvements (XHTML, JPEG).
- Continuous dialogue between IHO and stakeholders.
- Opportunity to test potential deficiencies.
- Platform to demonstrate new capabilities.

Fig. 2: Time line of S-101 introduction



Phase 3: *Extending the S-101 Model*
- Utilisation of extended model capabilities by means of an extended feature catalogue.
  - Introduce Complex attributes.
  - Introduce Information Types.
  - Multiple language support.
- Explore the use of cartographic attributes for enhanced display.
- Continue to update the Data Capture and Classification Guide to support enriched content.
- Issue of a new version of the Feature Catalogue and Portrayal Catalogue with content change mechanisms.
- Deliverable: Complete Exchange Set, updated Feature and Portrayal Catalogues, Data Capture and Classification Guide.

Benefits:
- Prove maintainability.
  - Feature Catalogue updating.
  - Portrayal Catalogue updating.
- Enhanced language support.
- Improved Update process.
- Prove that the catalogues are machine usable data.
- Data Quality and Usability improvements.
- Complex attributes will clean underlying data.

Phase 4: *Scalability*
- Introduce the concept of Scale Independent and Scale Dependent Data Sets.
  - Create an information object data set that contains all the information objects for every data set associated with it.
- Finalise Version 1 of the feature catalogue and portrayal catalogue.
  - Additional complex attributes.
  - Additional information types.
- Deliverable: Version 1.0 of S-101 Test Data Set and Test Data Sets containing scale independent and scale dependent data.

Benefits:
- Test the continued maintenance of the standard.
- Improves the ability of data producers to reflect the real world.

At the moment, the Phase 1 of the S-101 introduction is about to finish. Preparations for a testbed to cover Phase 2 targets have started already. The time line for completion of the S-101 ENC product specification introduction including Phase 4 is December 2012 (Fig. 2).

The actual status of development to be presented at the annual meeting of the Hydrographic Standards and Services Committee in October 2010 in Rostock will be included in the presentation to be given by the author at HYDRO 2010. □