S-100 Master Plan

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1. 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 role is to establish and maintain appropriate standards to assist in proper and efficient use of hydrographic data and information. Digital hydrographic information has become a basic element of all aspects of use and preservation of the maritime domain, including the underpinning of marine spatial data infrastructures. Consequently, a huge variety of stakeholders beyond the community of national hydrographic services is supportive to IHO´s objectives in standardization of hydrographic data: greatest uniformity and interoperability.

The Universal Hydrographic Data Model, designated S-100, was designed as the succeeding standard to current IHO Transfer Standard for Digital Hydrographic Data S-57. The design of S-100, coupled with its alignment with the ISO 19100-series of geographic information standards, enables support of a much wider variety of hydrographic-related digital data sources, products, and customers. This includes new geospatial models to support imagery and gridded data, 3-D and time-varying data, and new applications that go beyond the scope of traditional hydrography. For example, high-density bathymetry, surface currents, water levels and marine GIS. S-100 is realized by the development and implementation of different product specifications. Product specifications describe the elements of S-100 that used to create different types of products or datasets. Products created under the S-100 framework allow the "plug and play" concept to be achieved.

When the International Maritime Organization (IMO), in 2012 at MSC 90, designated S-100 as the baseline standard for creating a framework for e-Navigation data access and services, called the "Common Maritime Data Structure (CMDS), the wide range of applicability of S-100 and its design as a profile of the geoinformation standards of the International Organization for Standardization (ISO 19100 series) were noted as significant features. In addition, the Geospatial Information (GI) Registry, which constitutes the foundation of the S-100 Model, was noted by IMO. Like a digital library, the Registry includes a common concept dictionary that hosts data model entities to design and maintain interoperable data product specifications of nearly unlimited purpose. Originally intended to cover geospatial data only, the S-100 concept is now enhanced to support all aspects of shipping and the maritime domain at large, including the modelling of non-spatial information, such as pilot requests, regulatory information and user requirements.

This plan describes the objectives and the associated timelines in the development and implementation phases of IHO´s core standardization project over the next five years. It expands upon earlier descriptions of the development of S-100, to explain the rationale of what developments are happening and promote the active involvement of both existing and potential stakeholders. Special emphasis is put on the development and implementation of the product specification S-101 - the standard for the next generation ENC.

1.1. Acronyms

IEHG Inland ENC Harmonization Group

IALA International Association of Lighthouse Authorities
IHO International Hydrographic Organization
IEC International Electrotechnical Commission
JCOMM Joint Technical Commission for Oceanography and Marine Meteorology
IMO International Maritime Organization
ISO International Organization for Standardization
ENC Electronic Navigational Chart
GIS Geographic Information System
DCEG Data Classification and Encoding Guide
ECDIS Electronic Chart Display and Information System
FCB Feature Catalogue Builder
PCB Portrayal Catalogue Builder
FCD Feature Concept Dictionary
KHOA Korean Hydrographic and Oceanographic Agency
HSSC Hydrographic Standards and Services Committee
TWCWG Tides, Water level and Current Working Group

2. S-100 A Framework Standard

S-100 enables the development of specifications for the provision of digital products such as electronic navigational charts, nautical publications, marine GIS and other e-Navigation related products and services. It includes multiple data encoding formats that are widely implemented and "fit for purpose". The S-100 extensible GI Registry provides a common repository of feature and attribute concepts that caters for different user communities.

Figure 2-1 S-100 provides a common framework for a great variety of Maritime data products.

S-100 is a profile of ISO 19100 set of Geographic Information Standards, meaning that it restricts or expands where required, on the ISO standards that are implemented as part of the S-100 framework. S-100 consist of components that are used as needed when a product specification is developed.

S-100WG is developing an enhanced guide for product specification development. This guide will provide greater elaboration of each step of product specification development process, including how to use S-100 and the various components of the S-100 infrastructure.
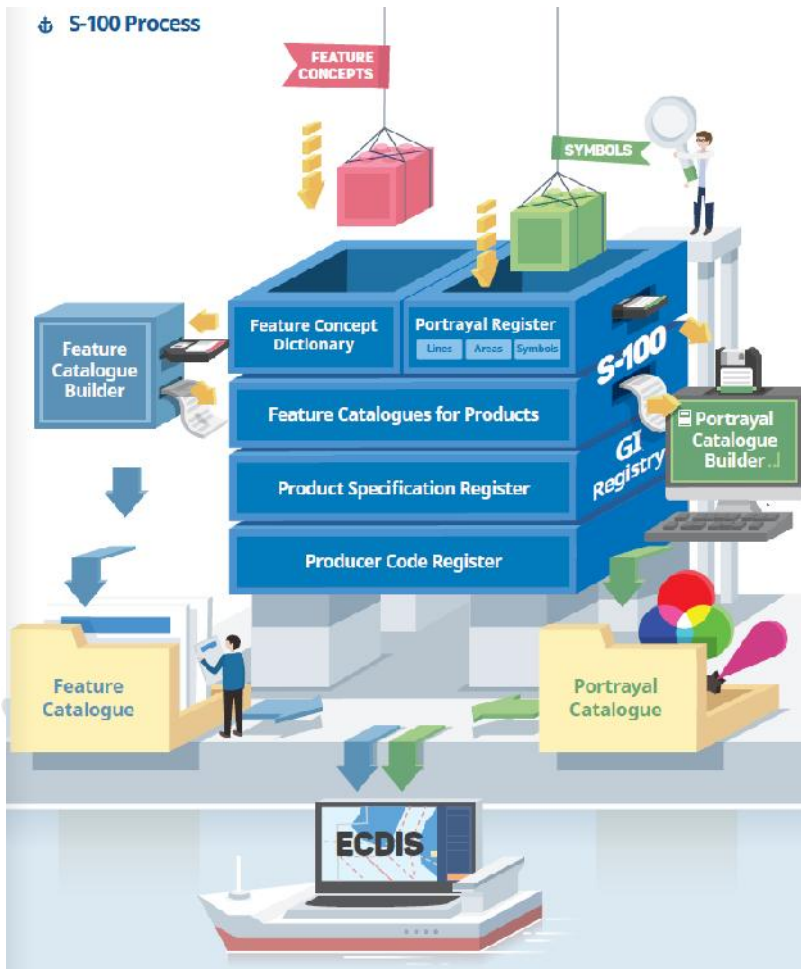
Figure 2-2 The S-100 concept provides the box of building blocks for product specifications.

The key feature of S-100 is that is maintained independently from all the product specifications that are built from it. The S-100 framework utilizes versioning in both S-100 and the derived product specification. This means a product specification is built from a version of S-100 and is not affected as S-100 evolves. Only when the product specification needs maintenance itself should a review be done if aligning with the latest version of S-100 is needed.

3. S-100 Infrastructure

The S-100 infrastructure, whose backbone is the GI Registry, has been operational for a few years. In addition to the various working groups under IHO's remit, a number of organizations have been utilizing the Registry to propose their concepts. The Registry now holds several thousands of concepts that are in various stages of lifecycle. Much valuable experience has been gained through the registration and approval process.

3.1.   S-100 Infrastructure upgrade

Due to lessons learned from testbeds and the development of various product specifications, it become clear that the GI Registry needed improvements. The Republic of Korea is leading the work and a major revision is under way. The current GI Registry consists of a Feature Concept Dictionary Register and a Portrayal Register. The new register will be expanded with Product Specification Register, Producer Code Register and Test Bed Register. Moreover, there will be a separation of the content in the FCD Register into a Concept Register and a Data Dictionary Register.
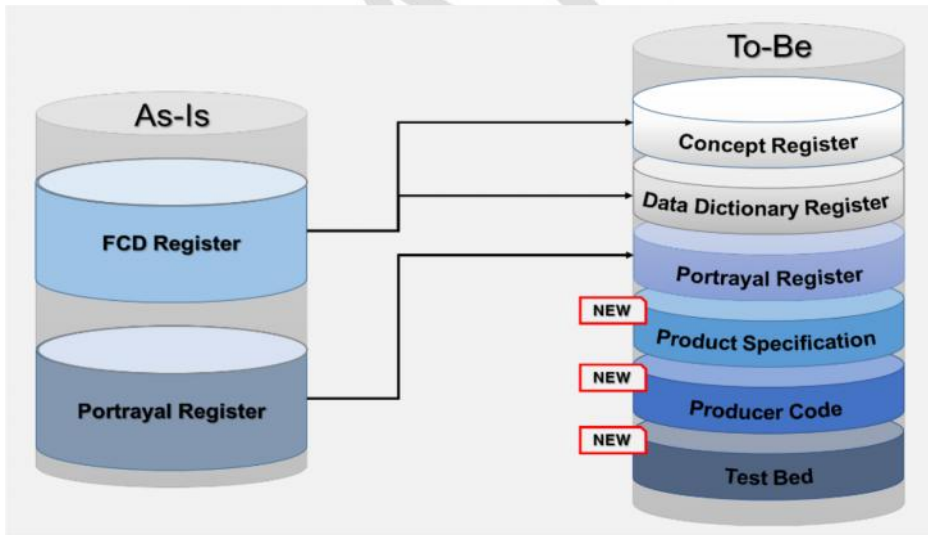

Figure 3-1 GI Registry update

The IHO GI registry is an instance of a Registry that is defined in S-100 Part 2 and is managed by the procedures defined in S-99. With the upgrade the GI Registry, a revision of S-99 will be required. However, the revision should wait till the upgrade of the registry is further along, to ensure that all components can act and interact as intended.

3.2.   Feature Catalogue Builder (FCB)

The purpose of the FCB is to produce S-100 conformant Feature Catalogues that contain all relevant data model elements such as feature types, attribute bindings or associations that are required for a product specification. The FCB interfaces with the GI Registry to allow feature catalogue developers to take advantage of common concept definitions and recommended attribute bindings. Functions for defining local types or draft types are also provided. Through experience, it was decided that also associations and roles should be defined in the FCB, and not be contained in the Registry. This is mainly due to the individual nature of these elements as observed through the development of several product specifications.
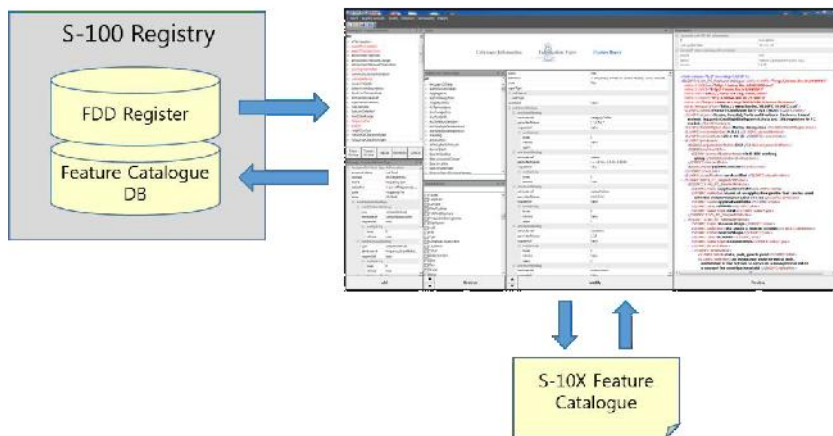

Figure 3-2 FCB production process

3.3.   Portrayal Catalogue Builder (PCB)

The purpose of the PCB is to produce an S-100 Portrayal Catalogue package which contains drawing instructions and symbols for feature types included in a Feature Catalogue. The IHO has stood up a PCB that will undergo operational testing in 2018. The current work focuses on an XSLT based Portrayal Catalogue, and it should be noted that with S-100 will to be extended to include Lua programming language support for S-101 ENC portrayal, a new version of the PCB will be needed to include Lua support when S-100 is updated to include Lua. The Republic of Korea has also offered their development work of a PCB to assist the IHO in facilitating the production of portrayal catalogues for smaller product specifications as the IHO PCB undergoes its operational testing for S-101.

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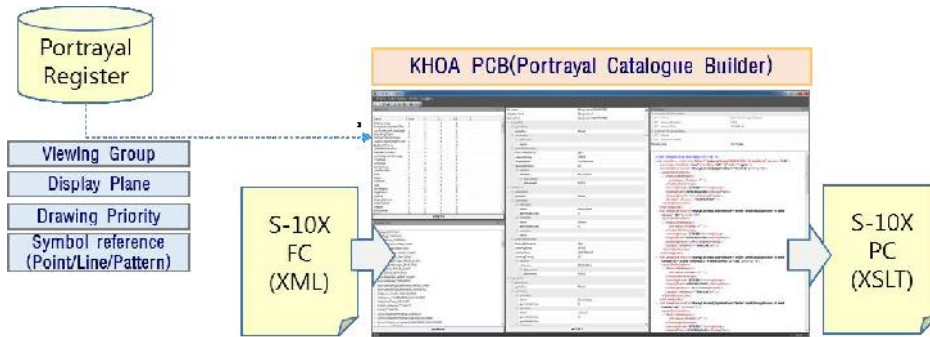
Figure 3-3 PCB production process

3.4.   Data Capture and Encoding Guide (DCEG) builder

A DCEG builder is under development by KHOA in support of the IHO S-100 Infrastructure development. This tool will improve the consistency between a Feature Catalogue (FC) and the associated DCEG. The DCEG is an important component to any product specifications as it provides the human readable rules for data producers to encode the product. Previously, the work with harmonizing a FC and DCEG was a manual operation, which was acceptable if the data model was small, but quickly became a substantial task for larger data models. The DCEG builder will improve on this and reduce much of the manual work required in harmonizing information between the two parts of a product specification.

Figure 3-4 DCEG production process

4. S-100 Maintenance schedule (2018-2022)
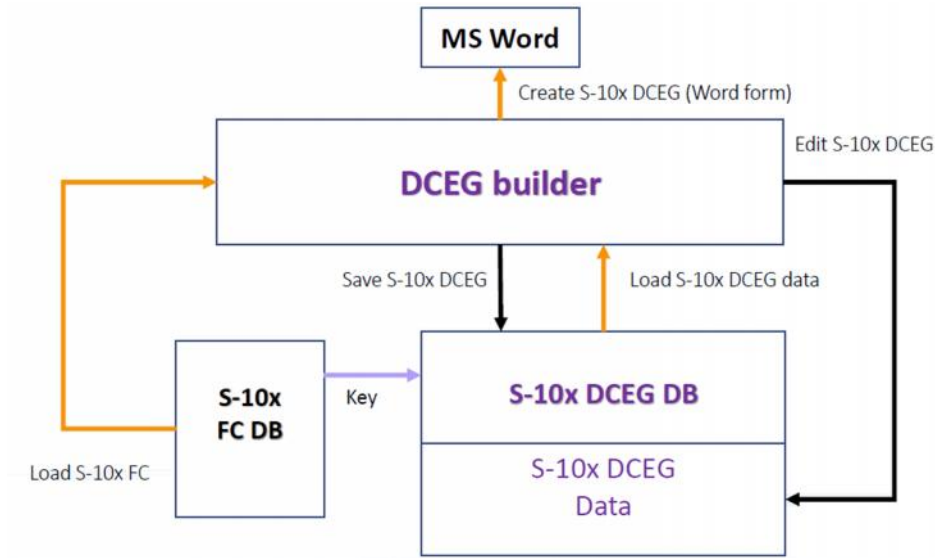
Experience with S-100 has significantly increased over the last few years. This is due to experience gained in in several groups developing product specifications, the S-100 Test Bed and of the development of S-100 graphical (chart-like) viewers, mainly by Republic of Korea and SPAWAR. Industry is also starting to include S-100 in various test projects, such as within the EfficeanSea2, STM Validation and SMART Navigation projects. Also of note is that an S-100 validation test tool that is under development by SevenCs to aid in the quality aspects of the product. .

All this increased activity has resulted in a high number of amendments proposed to S-100, and it is expected that this level of activity will continue for the next few years. Having regularity in the maintenance cycle of S-100 is considered important for stakeholder planning, as it gives predictability to when proposed amendments must be completed and subsequently, when new versions of S-100-based product specifications can be updated to include required amendments in response to changing user needs.

Therefore, S-100WG is expected to release a new version of S-100 ever two years for the foreseeable future. The planning schedule for these releases can be seen in the table below:

Month/Year	Action	Notes
April 2018	Final Consideration of proposals for the next edition of S-100	S100WG3
May 2018	Notification to HSSC10 of a new edition of S-100	
Early 2019	Publication of next edition of S-100	Edition 4.0.0 (have proposals that extend S-100)
March/April 2020	Final Consideration of proposal for next edition	
May 2020	Notification to HSSC12 of a new edition of S-100	
Early 2021	Publication of the next edition of S-100	

Table 4-4-1 S-100 maintenance schedule

5. IHO Product Specifications

The primary purpose of S-100 is to act as a framework from where product specifications can be developed. Several product specifications are under development within IHO d working groups. These have reached various levels of development and this section serves as a snapshot of the status of the various IHO S-100-based product specifications. HSSC acts as the IHO body that gives designation numbers in the S-100 name space to IHO product specifications. Not all proposed S-100 product specifications have received an S-number, and some started product specifications have been discontinued before being completed due to changing use cases or other reasons. The table below provides a snapshot of the current (Spring 2018) development status of the various started and planned IHO S-100-based product specifications, including the 'flag-ship' product specification S-101.

S-Number	Name	Status
S-101	Electronic Navigational Chart (ENC)	Under Development
S-102	Bathymetric Surface	Published as 1.0.0, new version under development
S-103	Sub-surface Navigation	Planned
S-104	Water Level Information for Surface Navigation	Under Development
S-111	Surface Currents	Under Development
S-121	Maritime Limits and Boundaries	Under Development
S-122	Marine Protected Areas	Under Development
S-123	Radio Services	Under Development

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S-124	Navigational Warnings	Under Development
S-125	Navigational Services	Under Development
S-126	Physical Environment	Under Development
S-127	Traffic Management	Under Development
S-128	Catalogues of Nautical Products	Planned
S-129	Under Keel Clearance Management (UKCM)	Under Development
S-1xx	Marine Services	Planned
S-1xx	Digital Mariner Routeing Guide	Planned
S-1xx	Harbour Infrastructure	Planned
S-1xx	(Social/Political)	Planned

Table 5-5-1 IHO S-100-based product specification development

5.1. Timeline of IHO S-100 based product specifications development

As mentioned in the previous section, beyond S-101, there are a number of S-100 based product specifications in active development among IHO working groups. Many of these specifications make up the ECDIS and e-navigation ecosystem and are viewed as primary selling points for the S-100 ECDIS. The development of the product specification are on different timelines, where the time line status as of Fall 2017 can be seen in Figure 5-1 below. It should be noted that the timeline shows 2018/2019 as the peek time frame for releasing the specifications for Member State vote, and subsequent release for implementation.
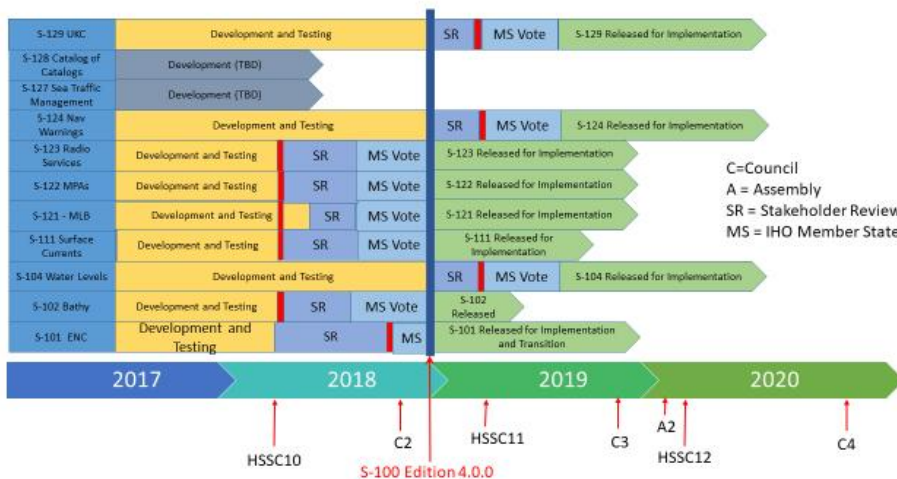

Figure 5-1 S-100 based product specification development timeline

6. S-100 Test Bed

The development of S-100 and derived product specifications by the IHO, including S-101, have increasingly reached the stage where testing and further development is required to complete and mature the specifications for approval. S-100WG has established the S-100 Test Bed, which is built a system engineering approach based on ISO 15288:2008 and reflects a philosophy of standards can only be tested sufficiently as implementations. Moreover, the S-100 Test Bed recognize that a complex system of systems makes up the marine navigational environment and strives to maintain a test environment that reflects this reality.

A continuously updated S-100 Test Bed framework document is maintained by S-100WG to document the status, progress and structure of the S-100 Test Bed. The testbed framework intends to support testing of the wide range of S-100 based product specifications by testing their intended use, such as an overlay product specification with the base data, e.g. ENC with Marine Protected Area information. The S-100 Test Bed can identify the level of testing required for each product specification will vary, depending upon the end use of the data. For example, if the data is intended to be used in an ECDIS to support navigation, then the product specification should utilize all components of the framework. If the end result is for shore-based information systems, then it may not be necessary to test the product specification all the way to full ECDIS capabilities.

The test bed framework has the following objectives:
- *S-100 products display and function as required by users in S-100 ECDIS. Standards and testing must ensure the required level of consistency and reliability.*
- *S-100 products can be distributed and ingested in a proper and reliable manner by S-100 ECDIS.*
- *S-100 products can be collated and packaged into distribution packages with required data integrity etc.*
- *S-100 products can be validated to conform to defining standards and acceptable quality levels.*
- *S-100 products can be created and updated.*
- *S-100 feature and portrayal catalogues can be created and updated. Processes must ensure catalogues are valid and consistent.*

More specifically, this framework will test four major types of products that could be used within an S-100 ECDIS. They are:

- *S-101 ENC Product Specification*
- *S-10X Overlay – where the data would overlay the base ENC to provide additional information*
- *S-10X Partial Replacement – where the data would replace part of the base ENC to provide more detailed information*
- *S -10X wholesale replacement – where the data would replace the entire ENC. For example, a port ENC may replace the existing harbour ENC.*

In order to manage the number of sub systems and complexity involved, this framework has divided the overall S-100 system testing into 9 phases. These phases are shown in Figure 6-1 and follow a logical progression from catalogue creation through to use of data within ECDIS.
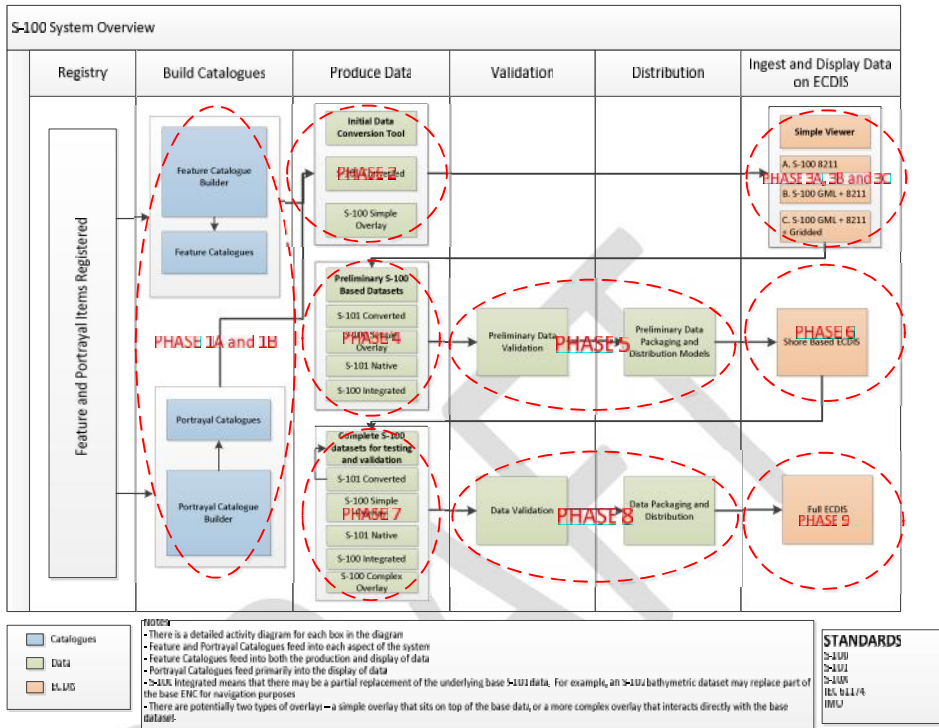
Figure 6-1 S-100 High Level System Overview with Phases

Dividing testing into phases allows for the iterative development of the eco system that includes the future S-100 ECDIS, by gradually increasing requirements and thus building the test bed upwards to its full scope. At a high level, the phases and current status (Spring 2018) are as follows:

Phase 1: Feature and Portrayal Catalogue Generation. This phase is consisting of two parts that concentrates on the feature and portrayal catalogue builders and the generation of catalogues to support the S-101 product specification development and development of other S-100 based product specifications.

Status Spring 2018: Several trials have been made in creating the feature catalogue and portrayal catalogue, which revealed that improvements were required in the construction of the GI Registry. Test versions of the feature catalogue builder has been created, and it is now awaiting the new version of the GI Registry before new improvements are carried out. The portrayal

catalogue builder meanwhile has been delayed due to lack of resources and from a discussion on which technology to choose. As an example, stay with XSLT or switch to LUA, but is now back on track with the assistance of KHOA.

Phase 2:   Initial Data Conversion Tool. This phase deals with creating S-101 ENCs by using the S-57 converter. In addition, it will also look to create S-100 simple overlay datasets for use in testing.

Status Spring 2018: A draft version of the convertor tool has been created, and several stakeholders have trialed the tool and the feedback has been utilized to improve the converter tool. Test data has been created for several overlay product specifications that are in development, e.g. S-111, S-122, S-123.

Phase 3:   Simple Viewer. This phase is split into three parts to create a simple viewer that will ingest feature and portrayal catalogues, along with S-100 based datasets to validate if the datasets displays according to what is defined in the portrayal catalogue. It is split into three phases in order to build capability to view datasets that are utilizing different S-100 encoding formats.

Status Spring 2018: Two simple viewer projects are under development, one by Republic of Korea and another by SPAWAR. Both undergo continuous development to respond to feedback and lessons learned from trialing various test data.

Phase 4:   Preliminary S-100 Based Datasets. This phase deals with multiple datasets and scenarios to provide test data for S-100 testing. At this time, it is expected that test data will not be converted data from S-57, but rather data that can realize the full functionality of S-100.

Status Spring 2018: Test data has been created for various product specifications. It was then realized that rules for how these various types of data interact will be required and a specification for machine readable interoperability rules has been drafted.

Phase 5: Preliminary Data Validation and Distribution. This phase will put in place draft data validation rules and test data packaging and distribution models.

Status Spring 2018: Some of the developed specifications includes validation checks. Tools to test the data still remains to be developed.

Phase 6: Shore-Based ECDIS. This phase deals with the creation and testing of several shore based ECDIS. This version of the S-100 ECDIS is not expected to have the full capabilities of an ECDIS that will undergo type approval but should be able to handle different types of S-100 based data, perform basic navigation functions; such as set the safety contour and have the pick report functionality implemented.

Status Spring 2018: The Republic of Korea has begun preliminary sea trials

Phase 7 – 9: Complete S-100 datasets for testing and validation, Data Validation, Distribution, and Full ECDIS. These final three phases deal with the full system testing and implementation of S-100 and S-101.

Status Spring 2018: Not yet started

7. Interoperability of S-100-based products in S-100 ECDIS

Mariners and other users will receive different S-100-based data products, each providing one or more information layers, and will often need to view some of the information layers simultaneously on a S-100 compatible ECDIS as well as in other ship and shore-based scenarios. Other data layers such as radar overlays are also expected to be present. The smooth interoperation and harmonized user-friendly graphical presentations of these various products is therefore necessary.

S-100WG is developing S-98 Interoperability Specification, as a framework for machine readable interoperability rules, that are intended to be delivered as the IHO Interoperability Catalogue. These rules for interoperation and harmonized graphical presentations of S-100 data products are contained in a proposed interoperability catalogue, which is a kind of meta-product that describes how specified product combinations are to be used and displayed simultaneously. Within the S-98 framework, IHO will issue one global interoperability catalogue for ECDIS. Other systems can have their own interoperability catalogues. ECDIS OEMs may extend the IHO interoperability catalogue, provided the functions of the IHO issued version are not impacted.

Republic of Korea hosted a workshop in August 2017 to test the concept. Figures 7-1 and 7-2 shows examples from testing of interoperability catalogue where the absence of such a catalogue is contrasted with the interoperability catalogue turned on.
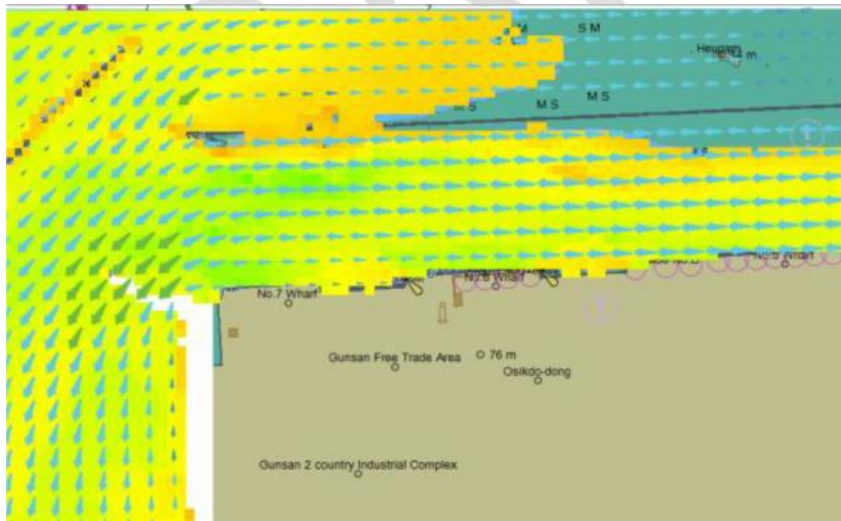

Figure 7-1 Example of S-101, S-102 and S-111 without any interoperability rules applied
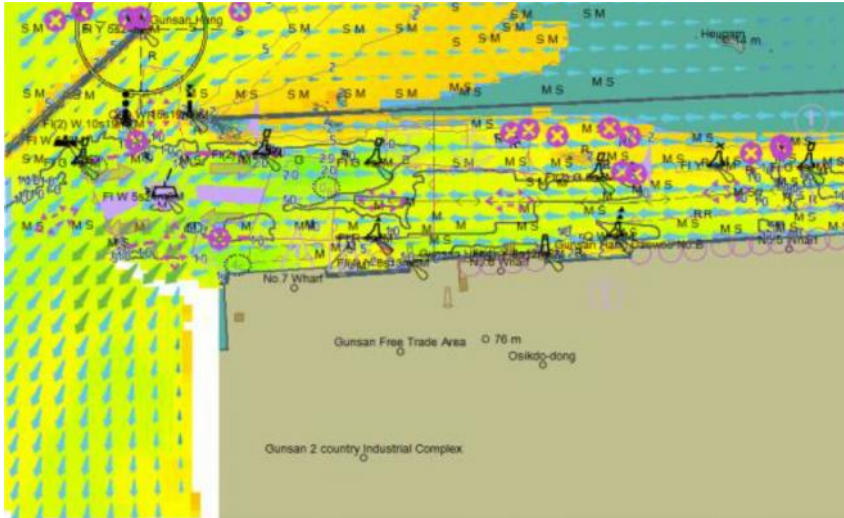
Figure 7-2 Example of S-101, S-102 and S-111 with Interoperability rules applied

Without the interoperability specification each product is treated as a layer and the order of the layers determines what objects are visible versus what objects are covered by other data and therefore not visible. With the interoperability catalogue applied, product interleaving is possible which, for example, allows aids to navigation, soundings and depth contours from ENC to show over gridded bathymetry, which masks out ENC depth areas. The interoperability concept therefore allows for defining important objects that will remain visible when additional data layers are turned on, and which objects are permitted to be overwritten.

8. Interaction with non-IHO stakeholders

With the development of e-Navigation, S-100 is being used by an increasing number of stakeholders. These stakeholders are developing a variety of product specifications for many different uses, including outside of the traditional hydrographic domain. More S-100 based product specifications are planned. The needs of these new stakeholders are varied and, in some parts, there are gaps identified in S-100 which leads to submissions of extensions of the framework, so that the new gaps can be addressed. S-100WG maintains an ongoing dialogue with stakeholders and have invited them to participate at S-100WG meetings. IEHG, IALA, JCOMM and IEC regularly attends.

8.1.   The Inland ENC Harmonization Group (IEHG)

IEHG is currently developing S-401 (Inland ENC) based on S-100 as the next generation Inland ENC standard. They have finished submitting all their features and are awaiting the update of the GI Registry to progress the development of feature and portrayal catalogues, as well as the remaining specification development.

IEHG has also started to plan development of S-402 IEHG Bathymetric Inland ENC for carrying high contour density information in inland waters. This is planned to be a vector specification.

8.2. International Association of Lighthouse Authorities (IALA)

IALA is developing a number of S-100 based specifications that are intended to serve the needs of aids to navigation authorities, such as for sharing information with stakeholders. IALA manages the S-200 name space. The work with developing S-100 specifications has increased the interaction with IHO, and IALA is contributing to the overall improvements of S-100 through such items as MRN identifiers and Online Services definitions for data provision.

S-201	Aids to Navigation Information	Under development
S-210	Inter-VTS Exchange Format	Under development
S-211	Port Call Message Format	Under development
S-230	Application Specific Messages	Planned
S-240	DGNSS Station Almanac	Under development
S-245	eLoran ASF Data	Under development
S-246	eLoran Station Almanac	Planned
S-247	Differential eLoran Reference Station Almanac	Planned
S-2xx	Port Collaborative Decision Making (PortCDM)	Under development

Table 8-1 IALA S-100 based product specifications and their development status

8.3. Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM)

JCOMM has been developing S-100 based product specifications from a WMO point of view. The focus has been on environmental information, like ice and weather. Ice information (S-411) is the first and followed by weather overlay (S-412).

S-411	Ice Information (WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology [JCOMM])	Under Development
S-412	Weather Overlay (JCOMM)	Under Development

8.4. International Electrotechnical Commission (IEC)

IEC is developing S-421 as a new version of the route plan exchange format (RTZ) included in Annex X in IEC 61174, and using S-100 as the framework. The new version is looking to enhance the RTZ format with lessons learned from the first version developed in the Monalisa project and later included in the 4th version of IEC 61174.

It is likely that IEC will develop additional S-100 based specifications is the near future.

9. S-100 and Type approval of ECDIS

Concurrent with the various testbeds and trials of S-100, a review of ECDIS Performance standards and IEC test standards should be conducted. The goal of the review should be to establish any need for revisions to IMO and IEC standards so that S-100 ECDIS can be legally equivalent to current S-52/S-57 ECDIS. It should be noted that the IMO ECDIS Performance Standard (RESOLUTION MSC.232(82)) makes mention of S-57 but not S-100 or S-101 and may therefore need revision before the S-100 ECDIS can materialize.

Also note that the IMO ECDIS Performance Standard mentions IEC 61174 and other IEC standards. A review should be considered if the IEC standards require amendments for S-100 ECDIS, and if amendments are required, is it is possible to make these amendments without negatively affecting S-52/S-57 ECDIS. If there is a negative effect, it may be required to issue new S-100 only standards, and further amendments will be needed to the IMO ECDIS Performance Standard.

A roadmap for any required amendments may have to be developed and executed before it would be possible to type approve any S-100 ECDIS.