Application of Universal Hydrographic Data Model S-100 Standards for Marine Spatial Data Management, Coastal Zone Management and Ocean Studies

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Abstract

Marine cartography is science and art of making navigational charts and electronic navigational charts for the safety of mariner at sea. The approach available for supporting navigation are paper charts, Raster Navigational Charts or Electronic Navigational charts (ENC). The current ENCs are used worldwide and are based on International Hydrographic Organization (IHO) S-57 data model which is exclusively for the maritime navigation and is in use since last three decades. Keeping blue economy in spectrum, IHO has developed S-100 Standard, a Universal Hydrographic Data Model (UHDM) expanded from ISO 19100 Geographic Information standards, with an objective of bringing the stakeholders other than hydrography into one platform with data interoperability and integrating future maritime navigation with other coastal and oceanographic studies. The S-100 data model supports multiple arrangements of data formats which can be interlinked and can provide platform for analysis of gridded data, imagery, 3-D and time-varying data and this model go beyond the scope of traditional hydrographic data management and representation. It will also enable the use of Web-based services for acquiring, processing, analyzing, accessing and presenting data for navigation. Several sub groups have been created based on S-100 data model for managing and monitoring the marine spatial data by developing different product specification, for example, S-101 for ENC, S-102 for bathymetry, S-122 for Marine Protected Areas and many more. These product specifications can be further extended for planning and monitoring the thematic data resource management and coastal zone management. The aim of the study is to bring out the benefits of S-100 data model for e-navigation and monitoring of ocean data which can help in coastal zone and oceanographic data management e.g., surface current, water level etc. This will be a helpful tool for the administration for framing the Coastal Zone Regulations and its implementation for the sustainable coastal development.

Keywords IHO, Universal Hydrographic Data Model, S-100, S-57, marine spatial data management, Coastal zone management, Marine Information Overlay, Electronic Chart Display Information System

Introduction

Marine cartography is science and art of making navigational charts and electronic navigational charts for the safety of mariner at sea. The extensive approach available for supporting navigation are paper charts, raster navigational charts or Electronic Navigational charts (ENC) for the mariners. The current ENCs are used worldwide and are based on

International Hydrographic Organization (IHO) S-57 data model which is exclusively for the maritime navigation and is in use since last three decades. Keeping blue economy in spectrum, IHO has developed S-100 Standard, a Universal Hydrographic Data Model (UHDM) expanded from ISO 19100 Geographic Information standards, with an objective of bringing the stakeholders other than hydrography into one platform with data interoperability and integrating future maritime navigation with other coastal and oceanographic studies. International Standards 19100 series developed by the ISO/TC211, a group of which supports data management, acquiring, processing, analyzing, accessing, presenting and transferring data between different users, systems and locations for geographic information. This standard enables easier integration of hydrographic data and several applications into geospatial solutions. S-100 is fundamentally more flexible and attributed than S-57 and provides provision for use of imagery and gridded data types, enhanced metadata and multiple encoding formats. Several sub groups have been created for managing and monitoring the marine spatial data by developing product specification, for example, S-101 for ENC, S-102 for bathymetry S-104 for water level, S-111 for currents, S-122 for Marine Protected Areas, S-412 for weather overlay and many more based on S-100 data model. These product specifications can be further extended for planning and monitoring the thematic data resource management and coastal zone management. It provides a framework of components that enables the building of standardized Product Specifications for the modeling of hydrographic data and thus providing true interoperability between different data standards and systems. The primary goal of S-100 is to support a greater variety of hydrographic-related digital data sources, products, related users and customers.

The paper presents the study about the benefits of application of S-100 data model for e-navigation and providing support which can help in coastal zone and oceanographic data management e.g., high density bathymetry surface, surface current, water level etc. This will be an accommodating structure for the administration for framing the Coastal Zone Regulations and its implementation for the sustainable coastal development.

Objectives:

1) Application of S-100 Data model for coastal zone management and ocean studies.
2) Marine spatial data management using S-100 data model.

These objectives set an outline for the marine community to manage data and utilize at its best extent and carry out safe navigation and research studies.

IHO S-100 Universal Hydrographic Data Model

What is IHO S-100 Universal Hydrographic Data Model?

The S-100 Standard is a framework document that is intended for the development of digital products and services for hydrographic, maritime and GIS communities. It comprises multiple parts that are based on the geospatial standards developed by the International Organization for Standardization, Technical Committee 211 (ISO/TC211). It is a hydrographic geospatial data standard that can support a wide variety of hydrographic-related digital data sources, and aligns with mainstream international geospatial standards – in particular the

ISO 19000 series of geographic standards. This alignment enables easier integration of hydrographic data and applications into geospatial solutions.

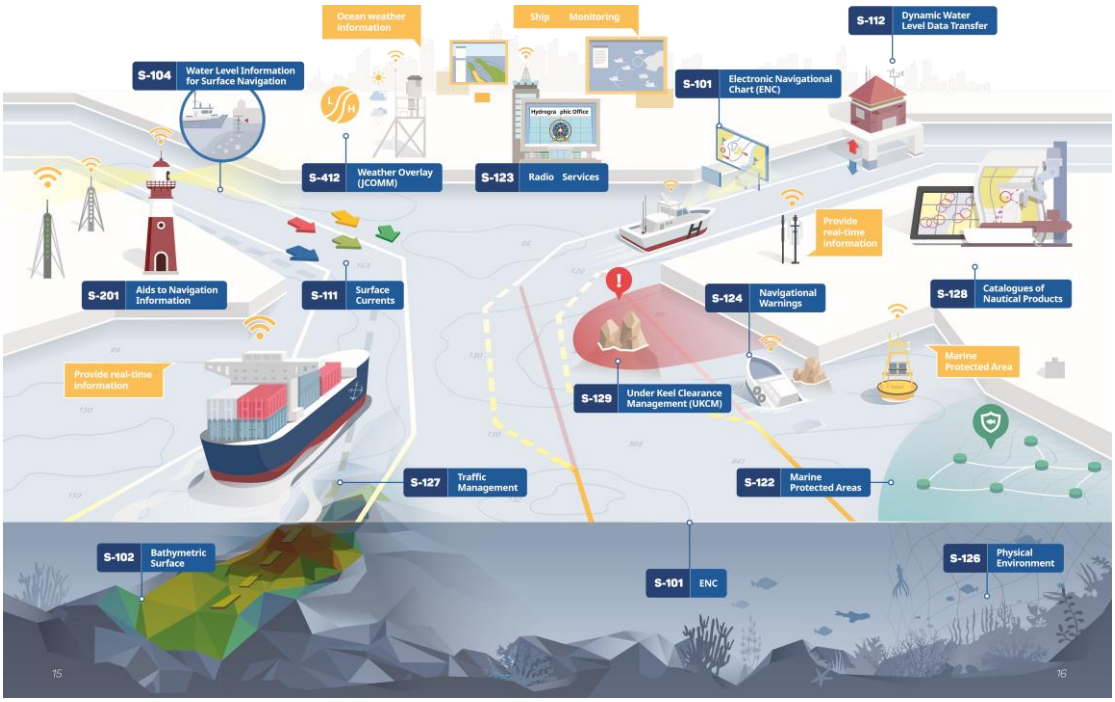

Fig. 1 Image showing present IHO S-1xx concept (Source: IHO_S-100 brochure).

History of requirement for development of IHO S-100:

"S-57 ENC has served nautical charting for about three decades; however, it suffers from an inflexible regime, inability to support gridded bathymetry or time-varying information, and the sole purpose for the production and exchange of ENC data (Alexander et al., 2007)". After decades of using S-57 data for navigation, a new generation of digital products and services enters to empower hydrographic, maritime and GIS communities with data that pushes traditional hydrography boundaries.

Due to the limited possibilities in ENC product specification S-57 data model, in 2000, the IHO approved a major revision to S-57 that led to the development of a new framework for hydrographic geospatial data standards, the S-100 Universal Hydrographic Data Model. It was decided that the S-57 Edition 4.0 that was currently under development would henceforth be designated as S-100 (IHO Geospatial Standard for Hydrographic Data). Any product specifications developed using S-100 would follow in an S-lOx series as they are produced. Thus, at some future date when an ENC Product Specification based on S-100 is developed, it will be designated as S-101. S-100 can be used by other data providers for their maritime-related (non-hydrographic) data and information. For instance, S-100 has been adopted by the United Nations' International Maritime Organization (IMO) to be the basis of IMO's Common Maritime Data Structure of e-navigation (Hahn et al., 2016). E-navigation aims to improve the sharing of marine information through the use of modern technology and includes marine data such as ENCs, bathymetric, tidal, meteorology, radar-image, and Automatic Identification System (AIS) data (Contarinis et al., 2020).

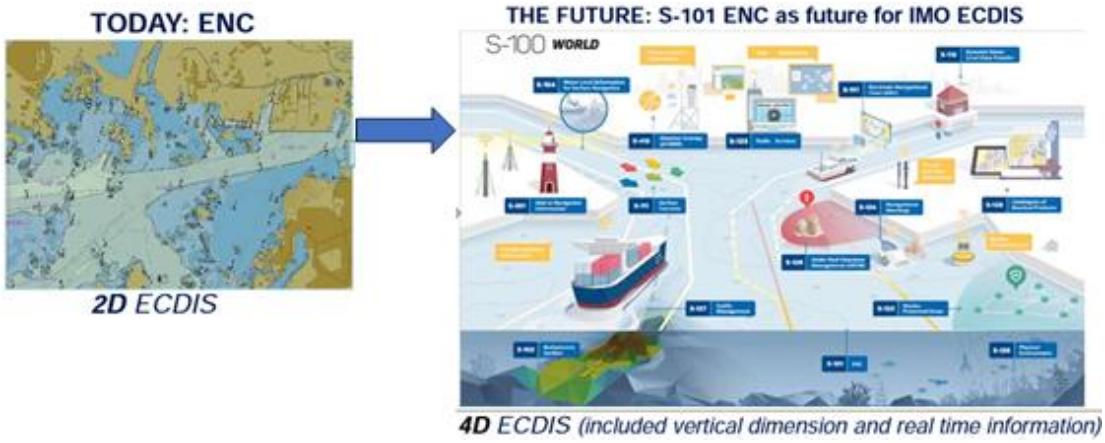

Fig. 2 Present ENC display and projected S-1xx concept (Source: TS04A_sinapi_11663_ppt).

IHO S-100 Dependent Product Specification:

The list of S-100 products is available on IHO website. There are a number of Product Specifications that are either in final stage or under development so far. The Hydrographic Services and Standards Programme (HSSC) of IHO allocates S-1XX numbers to be used for the development of S-100 dependent products developed by the IHO. In support of IHO There are other agencies involved in development of products. A range of S-100 product numbers are provided below with the concerned agencies responsible for development:

Fig. 3 Organization involved in S-1xx development (Source: IHO_S-100 brochure).

Way ahead for the S-100 Implementation by IHO in Decade (2020 – 2030):

IHO is in final stage of implementing the S-100 data model and incorporating production of S-1xx products. The roadmap defines the current implementation process of the S-100 data model and its product to the marine community. Among the list of S-1xx products IHO has special focus on implementation of products involved in the route monitoring. Further the phase vise implementation will take place for the other associated product.

The S-101 will gradually replace the S-57 while it is expected that in 2030, S-57 will be discontinued. S-101 ENCs will serve as the base layer within an S-100 enabled ECDIS and other additional products will interact with S-101, such as the S-102, S-104, and S-111 S-122,

S-129 etc. as an overlay. The product specifications and data sets are available for the trials. The approach of implementation of S-100 data model is shown in below image.

Table 1 S-100 dependent products and allocated Product Specification numbers for the different organizations. (Source: https://iho.int/en/s-100-based-product-specifications).

International Hydrographic Organization (IHO) (S-101 to S-199)	
S-101 Electronic Navigational Chart (ENC)	S-124 Navigational Warnings
S-102 Bathymetric Surface	S-125 Marine Aids to Navigation (AtoN)
S-103 Sub-surface Navigation	S-126 Marine Physical Environment
S-104 Water Level Information for Surface Navigation	S-127 Marine Traffic Management
S-111 Surface Currents	S-128 Catalogue of Nautical Products
S-112 Open - (see Decision HssC9/38)	S-129 Under Keel Clearance Management
S-121 Maritime Limits and Boundaries	S-130 Polygonal Demarcations of Global Sea Areas
S-122 Marine Protected Areas	S-131 Marine Harbour Infrastructure
S-123 Marine Radio Services	S-164 IHO Test Data Sets for S-100 ECDIS
International Association of Marine Aids to Navigation and lighthouse (IALA) (S-201 to S-299)	
S-201 Aids to Navigation Information	S-240 DGNSS Station Almanac
S-210 Inter-VTS Exchange Format	S-245 eLoran ASF Data
S-211 Port Call Message Format	S-246 eLoran Station Almanac
S-212 VTS Digital Service	S-247 Differential eLoran Reference Station Almanac
S-230 Application Specific Messages	
Intergovernmental Oceanographic Commission (IOC) (S-301 to S-399)	
None proposed yet	
Inland ENC Harmonization Group (IEHG) (S-401 to S-402)	
S-401 IEHG Inland ENC	S-402 IEHG Bathymetric Inland ENC
WMO Service Commission (SERCOM) (S-411 to S-414)	
S-411 Ice Information	S-413 Weather and Wave Conditions
S-412 Weather Overlay	S-414 Weather and Wave Observations
International Electrotechnical Commission - TC 80 (IEC-TC80) Numbers (S-421 - S-430)	
S-421 Route Plan	
NATO Geospatial Maritime Working Group (GMWG) for Additional Military Layers (AML) (S-501 to S-525)	
None proposed yet	

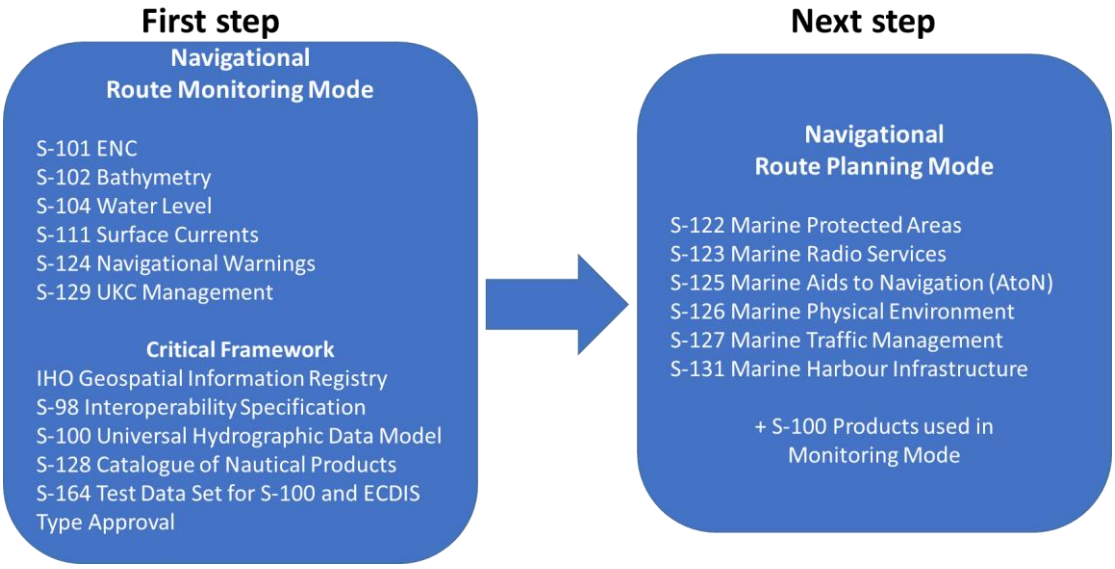

Fig. 4 Image showing phase vise implementation of S-1xx product. (Source: https://iho.int/en/s-100-implementation-strategy).

Application of S-100 Data Model for coastal zone management and ocean studies

The coastal zone is a region where land, ocean and atmosphere interact and hence it is dynamic in nature. Coastal Zone areas support different coastal activities, comprises various type of coastal habitats and plays significant role in terms of economy and ecology.

"Coastal Zone Management (CZM) involves public policies and processes for managing coastal areas to balance environmental, economic, human health, and human activities, aiming to preserve, protect, develop, enhance, and restore where possible, the coastal resources (NOAA 2021)".

The main importance of CZM is protection of ecologically sensitive areas likes coral reefs and mangroves, conserve and protect coastal stretches, and to promote development in a sustainable manner. Coastal zone management depends on the information available on varied aspects of coastal habitats, coastal processes, natural hazards and their impacts, water quality, and living resources. The effective management practices depend on such knowledge and suitable response by concerned government agencies.

Coastal nations, through their dedicated Hydrographic Offices (HOs), have the obligation to provide nautical charts for the waters of national jurisdiction in support of safe maritime navigation. The basic studies of any sea, ocean or water body are prepared based upon the initial bathymetric survey or hydrographic survey. National agencies e.g., National Hydrographic Offices, carry out Hydrographic survey as part of the source data collection, which further transforms the acquired data in form of Electronic Navigational Charts or Paper Charts for the marine community. Other govt agencies or private parties uses these ENCs or nautical paper charts for safe navigation and further studies about environment management and ocean research.

The data provided so far is based on the S-57 data model for the ENC which will be outdated and unable to accommodate requirements of the digital transformation of the maritime industry. The future surveys will be oriented based on the attributes required for the S-100 data model and its products e.g. high-density bathymetry, marine protected areas,

surface currents, real time weather information integration, real time water level information etc. The products of this data model will be encoded accordingly and will be used by concern administrative authorities to provide adequate information to the mariner or the community involved in the marine research as an overlay on top on the ENCs. Below picture represents the pyramid of products and few layer e.g. S-101, S-102, S-104, S-111, S-412 and S-122 etc. which will be used in ECDIS for the coastal zone management and ocean studies.

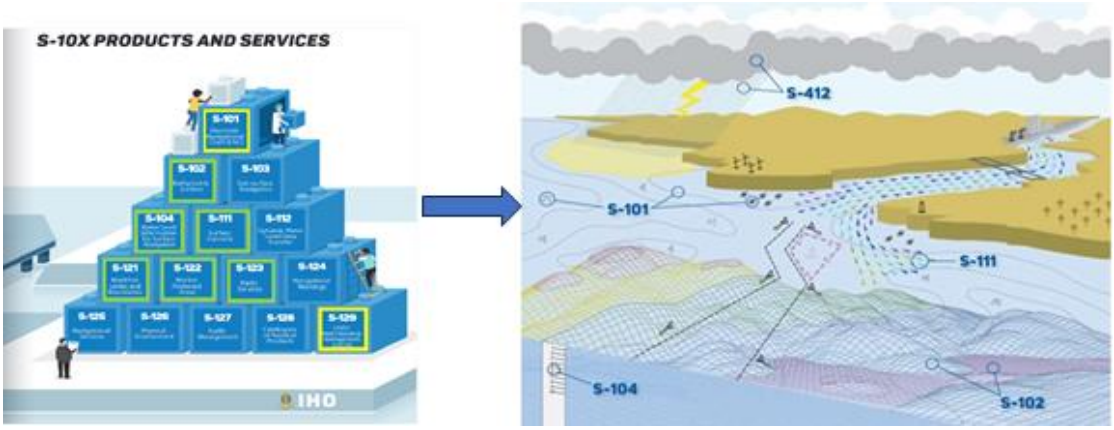

Fig. 5. Image showing S-1xx product layer (Source: IHO_S-100 brochure).

Application of S-100 in Marine Spatial Data Infrastructure:

A Marine Spatial Data Infrastructure (MSDI) is the element of a Spatial Data Infrastructure (SDI) that focuses on the marine input in terms of data content, governance, standards, and technologies. SDI is usually defined as "the relevant base collection of technologies, policies, and institutional arrangements that facilitate the availability of and access to spatial data" MSDI encompasses marine and coastal geographic and business information. A MSDI typically includes information on seabed bathymetry (elevation), geology, infrastructure (e.g., offshore installations, pipelines, cables), administrative and legal boundaries, areas of conservation of marine habitats and oceanography. (IHO, 2017)

Typically, hydrographic information has been used primarily for navigation. However, it has gained wider applications in other areas, including: maritime trade, environmental protection, sustainable fishing, resource development, infrastructure construction, defense, search and rescue, and scientific research. The combination of hydrographic data with other marine spatial data for efficient analysis can also support some of the major challenges: blue economy, e-navigation, emergency planning and response, climate change and sea level rise, and marine spatial planning (MSP). MSDIs grow in capability and capacity, enhancements to data storage and optimization would be required, whether it is stored on-premise or in clouds. Especially with increased demand for 3D data and (near) real-time data, there will be an increase in the footprint of data by several magnitudes compared to 2D data. A systematic understanding of the marine areas requires the integration of different spatial and nonspatial data. The objectives of marine area management will be achieved by using an appropriate method of collecting data from different sources, which could include 3D data. 3D data collected and processed could come from various sources such as satellite-based sensors, UAVs, LIDAR, photogrammetry, bathymetry, sounding and radar. The raw 3D data can be very large (up to petabyte size), hence MSDIs should be prepared to cater for

appropriate data infrastructure that can handle big 3D data. In the case of 3D data, HDF5 is one of the possible optimized data formats that MSDIs can consider. It has been in use for scientific visualization of 3D data and is part of the S-100 Framework encoding. Original 3D data stored in HDF5 format can create an abstraction of it for display.

S-100 has been designed to address the limitations of its predecessor S-57. S-100 provides the universal data model for holding a wide range of data in a widely recognized format. It is adopted by the United Nations' International Maritime Organization (IMO) to be the basis of IMO's Common Maritime Data Structure (CMDS) of e-navigation (Hahn, 2016). E-navigation aims to improving the sharing of marine information through the use of modern technology and includes marine data such as electronic navigational charts, bathymetric data, tidal data, meteorology data, radar-image data, and the radio-based AIS data.

The S-100 standard of the International Hydrographic Organization (IHO) has the potential to become the de facto marine data model for future MSDI implementations.

Conclusions

IHO S-100 Data Model is a revolution for the maritime international community. It will provide complete 4d picture of the marine environment, using data and information which will be useful for the mariners and help in sustainable development of marine community. It will improve the respect for the marine environment and will facilitate the ability of hydrographic offices and other marine GIS domain agencies to use other sources of geospatial data, for example combining topography and hydrography for coastal zone management and oceanographic studies. The primary goal of S-100 is to support a greater variety of marine-related digital data sources and products to provide more safety to the mariners. This includes the use of imagery and gridded data, enhanced metadata specifications, unlimited encoding formats and a more flexible maintenance regime.

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List of S-100 Product specification (https://iho.int/en/s-100-based-product-specifications)

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