

IHO S-100 Data Model and Relevant Product Specification

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ABSTRACT: The International Hydrographic Organization (IHO) has established a new hydrographic information standard, the S-100 standard. This standard applies the ISO 19100 series to the legacy hydrographic exchange standard in order to overcome the limitations of existing hydrographic information expression. The first version of the S-100 standard was released in 2010, and the latest version, 5.0.0, was released in 2022. The International Maritime Organization (IMO) officially adopted the IHO's S-100 for hydrographic information exchange. The S-100 standard is the base standard, and each hydrographic information is developed as a document called the product specification. The product specification is being developed and led by various standardization organizations. The product specifications developed by each standardization organization are based on S-100, but they are defined in various ways according to the characteristics of information and expression methods. In this paper, the different product specifications of IHO's S-12x series and IALA's S-2xx series are analyzed in terms of features and classes from the data model point of view. The analysis of the feature, attribute, and feature relationship of each product specification was conducted by reviewing both the Data Classification and Encoding Guide (DCEG) and the entire document of the product specification. This study has identified areas of overlap in S-100 product specifications and has explored potential solutions to address these issues.

1 INTRODUCTION

The International Maritime Organization (IMO) establishes and implements e-Navigation strategies for maritime safety and marine environment protection. Many electronic techniques have been introduced for e-Navigation, and as a result, a lot of information has been converted to computer-based information. In particular, hydrographic information is communicated in a standardized structure called the Common Maritime Data Structure (CMDS). IMO adopted IHO S-100 as the CMDS for hydrographic information exchange [1].

The International Hydrographic Organization (IHO) has used the S-52 and S-57 standards for hydrographic information representation and exchange. The legacy standards have limitations in expressing information, such as seafloor topography and tide, in 3D. In addition, it is difficult to accommodate a request to express additional information in addition to the previously defined information. IHO introduced the concept of the ISO 19100 series, which are geographic information standards used on land, established by the International Organization for Standardization (ISO).

The S-100 standard is the base standard, and each hydrographic information is developed as a

document called the product specification. The product specification is being developed and led by various standardization organizations, such as IHO, the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), and the World Meteorological Organization (WMO). IHO leads the development of product specifications for electronic charts, submarine topography, marine risk areas, and maritime traffic services. IALA defines navigational aid information and port message protocols, such as lighthouses, buoys, and marine facilities, as product specifications. WMO is leading the development of product specifications related to meteorology and is developing electronic chart standards for ice information and inland seas.

Product specifications developed by each standardization organization are based on S-100, but they are defined in various ways according to the characteristics of information and expression methods. Each product specification must ultimately exist for one electronic chart system. Analytical research is being conducted from various perspectives, such as symbol expression and data model, and IHO defines it as the S-98 standard.

In this paper, the different product specifications of IHO's S-12x series and IALA's S-2xx series are analyzed in terms of features and classes from the data model point of view. The analysis of the feature, attribute, and feature relationship of each product specification was conducted by reviewing both the Data Classification and Encoding Guide (DCEG) and the entire document of the product specification. This study has identified areas of overlap in S-100 product specifications and has explored potential solutions to address these issues.

2 CONFIGURATION OF THE S-100 BASED PRODUCT SPECIFICATION

The IHO leads the development of overall electronic charts and ocean data. S-101 is the next-generation electronic chart standard for producing ENC. S-102 is the standard for expressing bathymetric information, and S-104 is a standard for expressing water level information during navigation. The S-111 standard is a standard for expressing current information [1].

Additionally, S-121 is a standard for maritime boundaries, zones, and boundaries. S-122 is a standard for marine protected areas. S-123 is a standard for marine wireless service navigation communication. S-124 is a standard for supplementing navigation warning information of S-101. S-125 is a standard for supplementing navigation function. S-126 is a standard for supplementing environmental information of S-101. S-127 is a standard for supplementing transportation service of S-101. S-128 is a standard for the exchange of catalogues of marine products, and S-129 is developed as a standard for the management of Under Keel Clearance.

IALA leads the development of the production of guides for aid to navigation information and port message formats. They are working standards in the following categories: S-201 aids navigation

information standard, S-210 is an exchange format standard between VTS, S-211 is a port information sharing standard, S-212 is a VTS digital service standard, S-230 is an Application Specific Message Standard, S-240 is a satellite navigation system encoding and exchange standard, S-245 is eLoran ASF Data standard, S-246 is eLoran Station Almanac standard, and S-247 is Differential eLoran Reference Station Almanac standard, among others.

WMO leads the development of weather and ENC. Standard S-401 for Encoding and Metadata of ENC Data, Standard S-402 for Contours of Inland ENC Data, Standard S-411 for Encoding Extents and Characteristics of Glaciers, and Content Structure and Metadata Required for Datasets Standard S-412 for data, etc.

The hydrographic information based on S-100 is developed as a PS document and consists of the main PS document, DCEG, FC, and PC [3].

The Data Classification and Encoding Guide (DCEG) was developed to encode data for S-100-compliant ENC. The purpose of DCEG is to encode data to comply with IMO and IHO standards, in order to properly display electronic charts [4].

The Feature Catalogue (FC) is an Extensible Markup Language (XML)-based document containing information about features. In the S-100 standard, it is recommended to define the waterway information data model of product specifications in the form of an XML document. Create feature data using FC structure and data values.

In order to represent a feature on an electronic navigation chart, the color or shape of the feature is determined by a set of rules. The Portrayal Catalogue (PC) is an XML-based document that contains information on how features are to be expressed, according to these rules. The PC is used to define a set of drawing commands that determine how future features will be drawn.

This paper is focused on the document of the following PS.

Table 1. S-100 based product specifications and examination target

PS No.	Edition	Publish Date	Examination target (DCEG/PS)
S-121	1.0.0	Oct, 2019	DCEG
S-122	1.0.0	Jan, 2019	DCEG
S-123	1.0.0	Jan, 2019	DCEG
S-124	Draft 2.0.0	Jul, 2019	PS
S-127	1.0.0	Dec, 2018	DCEG
S-128	1.0.0	May, 2022	DCEG
S-129	1.0.0	Jun, 2019	PS
S-211	Draft 1.0.0	Mar, 2019	DCEG
S-212	0.6.3	Nov, 2020	DCEG
S-240	1.0.0	Oct, 2020	PS
S-245	Draft 0.0.1	Sep, 2019	PS
S-246	1.0.0	Sep, 2021	DCEG
S-247	1.0.0	Sep, 2021	DCEG

3 ANALYSIS OF THE DCEG WITH DATA MODEL POINT OF VIEW

In this chapter, the relationship between features of PS was identified through DCEG analysis. The analysis targets are IHO's S-12x series and IALA's S-20x series. In the next section, we will compare and analyze each PS separately.

3.1 Comparison S-122 and S-127

Firstly, the IHO's S-12x series DCEG was examined as follows. Table 1 and 2 present the feature lists for the S-122 and S-127 product specification [5, 6]. The confirmation of a same feature name between the two standards was established through analysis of Table 1 and Table 2. It is possible for features that share the same name to possess distinct attribute values. Upon examination of the DCEG of both standards, it was verified that the acronym used in the S-57 standard, an existing hydrographic information exchange standard, is identical. This indicates that the feature in question is the same.

Table 2. Feature list of S-122 product specification

S-122 product specification	
Feature name	S-57 acronym
Marine Protected Area	-
Restricted Area Navigational	RESARE
Restricted Area Regulatory	RESARE
Vessel Traffic Service Area	-

Table 3. Feature list of S-127 product specification

S-127 product specification	
Feature name	S-57 acronym
Radio Calling in Point	RDOCAL
Caution Area	CTNARE
Signal Station Warning	SISTAW
Signal Station Traffic	SISTAT
Radar Range	RADRNG
Concentration of Shipping Hazard Area	CONSHA
Pilot District	-
Pilot Service	PLTSRV
Underkeel Clearance Allowance Area	UKAARE
Underkeel Clearance Management Area	-
Routeing Measure	-
ISPS Code Security Level	SECLVL
Waterway Area	WATARE
Pilot Boarding Place	PILBOP
Military Practice Area	MIPARE
Restricted Area, Regulatory	RESARE
Restricted Area, Navigational	RESARE
Vessel Traffic Service Area	-
Place of Refuge	-
Piracy Risk Area	PIRARE
Local Port Service Area	-
Ship Reporting Service Area	-

3.2 Comparison S-123 and S-246

The S-100-based product specification can be categorized as a whole, and it is evident that there exists a correlation between the S-12x series and S-20x series. The Radio Station feature of the same name is present in both the S-123 product specification and the S-246 product specification, as demonstrated in Tables 3 and 4 [8, 10]. Upon examination of the DCEG for each product specification, it was verified that the

acronyms for Radio Stations in each standard were identical.

3.3 Comparison S-127 and S-129

The S-127 product specification includes two areas, namely the 'Underkeel Clearance Allowance Area' and 'Underkeel Clearance Management Area', which are equivalent to the Underkeel Clearance Management information addressed in the S-129 product specification [6, 7].

Table 4. Feature list of S-123 product specification

S-123 product specification	
Feature name	S-57 acronym
Radio Station	RDOSTA
Navtex Station Area	NAVTEX
Weather Forecast / Warning Area	WETFCA
Radio Service Area	RDOSVC
Indeterminate Zone	INDZON
Forecast Area Aggregate	-
Radio Service Area Aggregate	-
Landmark	LNDMRK
Building	BUISGL
Coastguard Station	CGUSTA
Navigational Meteorological Area	-
Inmarsat Ocean Region Area	-
GMDSS Area	-

Table 5. Feature list of S-246 product specification

S-246 product specification	
Feature name	S-57 acronym
Radio Station	RDOSTA
- dGNSS station	
- dLoran station	
- eLoran station	
eLoran Station Almanac	-

3.4 Comparison S-240, S-246 and S-247

The S-20x series comprises various standards, among which the S-246 standard pertains to eLoran, while the S-247 standard pertains to dLoran [8, 9]. Furthermore, a standard exists that pertains to Differential Global Navigation Satellite System (DGNSS).

Table 6. Comparing features between S-246 and S-247 product specification

S-240 product specification	S-246 product specification
Feature name	Feature name
Radio Station	Radio Station
<attribute>	<attribute>
:Category of Radio Station	:Category of Radio Station
- radio direction-finding station	- dGNSS station
- Decca	- dLoran station
- Loran C	- eLoran station
- Differential GNSS	
- Toran	
- Omega	
- Chaika (Chayka)	
- radio telephone station	
- AIS base station	
DGNSS Station Almanac	dLoran Station Almanac

Upon examination of Table 3, it is evident that both the S-240 and S-246 product specifications incorporate Radio Station features and almanac features for each station. Additionally, when examining the DCEG of each standard, it was observed that the Radio Station attribute is represented by the S-57 acronym RDOSTA. However, the attribute values are different, which have been verified as a recently established category value in accordance with the pre-existing S-57 standard [10].

Upon examining the feature composition presented in Table 4, it is evident that the S-246 product specification has the Radio Station feature. Notably, the 'Category of Radio Station' attribute comprises dGNSS Station, dLoran Station, and eLoran Station. According to the S-247 product specification, the dLoran Station is represented as a singular feature.

Table 7. Similar features between S-246 and S-247 product specification

S-246 product specification	S-247 product specification
Feature name	Feature name
Radio Station	dLoran Station
- dGNSS station	
- dLoran station	
- eLoran station	
eLoran Station Almanac	dLoran Station Almanac

4 DISCUSSIONS

In this chapter, the identification of duplicate issues was facilitated through a comparative analysis of product specifications presented in chapter 3.

4.1 Case 1 - Sharing the same feature name

The product specifications for IHO's S-122 and S-127 have the same feature names. By examining the S-57 acronym for the features listed in DCEG, it can be seen that they are both referred to as "RESARE" which stands for "Restricted Area." Therefore, it can be concluded that the features of these two product specifications are identical.

Furthermore, there is a feature called "Radio Station" between IHO's S-123 product specification and IALA's S-246 product specification. The S-123 product specification pertains to radio station channel information, whereas the S-246 product specification pertains to eLoran stations. When looking at DCEG, it shares the same S-57 acronym as "RDOSTA".

However, even if a feature is the same, not all encoding values defined in the S-57 standard are necessarily utilized. When comparing the encoding values of "Restrict Area Regulatory" in the two product specifications, the values are as follows. However, in the case of the "Restrict Area Regulatory" in the S-122 product specification, only some of them are utilized. Table 8 shows comparison S-122 and S-127 product specification.

In addition, while the S-123 and S-246 product specifications have the same features and attributes, S-

246 product specification defines new values instead of existing ones.

Table 8. Comparing features between S-122 and S-127 product specification

S-122 product specification	S-127 product specification
Feature name	Feature name
Restricted Area Regulatory <attribute>	Restricted Area Regulatory <attribute>
:Category of Restricted Area	:Category of Restricted Area
- nature reserve	- offshore safety zone
- bird sanctuary	- nature reserve
- game reserve	- bird sanctuary
- seal sanctuary	- game reserve
- historic wreck area	- seal sanctuary
- research area	- degaussing range
- ecological reserve	- military area
- Environmentally Sensitive Sea Area (ESSA)	- historic wreck area
- Particularly Sensitive Sea Area (PSSA)	- navigational aid safety zone
- Coral sanctuary	- minefield
- recreation area	- swimming area
	- waiting area
	- research area
	- dredging area
	- fish sanctuary
	- ecological reserve
	- no wake area
	- swimming area
	- water skiing area
	- Environmentally Sensitive Area (ESSA)
	- Particularly Sensitive Sea Area (PSSA)

Table 9. Comparing features between S-246 and S-247 product specification

S-240 product specification	S-246 product specification
Feature name	Feature name
Radio Station <attribute>	Radio Station <attribute>
:Category of Radio Station	:Category of Radio Station
- circular (non-directional)	- dGNSS station
Marine or aero-marine radiobeacon	
- directional radio beacon	- dGNSS station
- rotating-pattern radiobeacon	- eLoran station
- Consol beacon	
- radio direction-finding station	
- coast radio station providing QTG service	
- aeronautical radiobeacon	
- Decca	
- Loran C	
- Differential GPS	
- Toran	
- Omega	
- Syledis	
- Chaika (Chayka)	

4.2 Case 2 - Features and Product Specifications with the Same Meaning

The S-127 product specification includes a feature related to the clearance under the keel. This feature displays the distance between the ship and the seabed, which is commonly referred to as the underkeel clearance. The "Underkeel Clearance

Management Area" feature displays information about underkeel clearance, either statically or dynamically, depending on the value of the attribute called "dynamicResource". There is also a feature called the "Underkeel Clearance Allowance Area". This feature displays an area as a variable value that can change depending on the fixed value of underkeel clearance and the beam (or draft) of the ship.

The S-129 product specification is for the "Under Keel Clearance Management Product Specification," which calculates the difference between the underwater topography and the underkeel clearance value for each ship. This information is used to display safe areas (go-areas) and unsafe areas (no-go areas). This illustrates the correlation between features and product specifications that are used in a similar context. To resolve the ambiguity shown in this, it is necessary to modify it to clearly understand the meaning.

4.3 Case 3 - Product Specification Structure

The S-240, S-246, and S-247 product specifications are used to manage station information. However, the S-240 product specification includes a "Radio Station" feature, while the S-246 product specification also includes a "Radio Station" feature but with different attribute values. The S-247 product specification includes a dLoran station as a feature, which is not categorized as a "Radio Station".

Each product specification has a different structure. In particular, the S-246 and S-247 product specifications express one side as a feature and the other side as a corresponding attribute. Upon examining the remaining attribute values, it can be confirmed that the attributes for both product specifications are identical. Depending on the category classification of the S-246 product specification, the selection of a dLoran station in the "Radio Station" feature of S-246 can be a singular feature of the dLoran station. It might be resolved such ambiguous issues by naming features with clear meanings, such as the S-247 product specification.

5 SUMMARY AND CONCLUSION

In line with IMO's e-Navigation strategy, IHO's S-100 standard to establish a common standard for expressing hydrographic information.

Various hydrographic information product specifications are being developed based on the S-100 standard to digitize waterway information. In this paper, we analyzed the differences between product specifications based on S-100 by comparing DCEG and PS. We also discussed potential solutions to these issues.

Recently, there has been active research on autonomous ships. The analysis method presented in this paper has the potential to be enhanced and utilized in the field of machine learning within the realm of artificial intelligence in the future.

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