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Towards a Universal Hydrographic Data Model

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ABSTRACT: The International Hydrographic Organization's (IHO) [1] Transfer Standard for Digital Hydrographic Data S-57 [2] standard has been in force for more than a decade, and has successfully been used for official ENCs adopted by Hydrographic Offices around the world and by navigation equipment manufacturers. Additionally S-57 has been used for many additional purposes. However S-57, and especially the administration of the standard, has also experienced limitations. In 2010, IHO released the next generation hydrographic standard called S-100 Universal Hydrographic Data Model [3]. A move that will open up the door to new possibilities to existing S-57 users and potentially broaden the use of IHO standards in the hydrographic community.
This paper will try to explain why an S-57 replacement was needed and give examples on some possibilities with S-100 and its derived product specifications such as S-101.

1 INTRODUCTION

In the 1980s, computer software for geospatial data (better known as GIS software) had been on the market for more than a decade, but hardware, especially "high-resolution" graphic screens were very expensive and most software very specialized. It was still early days in the marine geospatial world, and much would happen before geospatial data would become mainstream.

Around the mid 1980s several national hydrographic offices acquired geospatial software for chart production and internationally there was talk about geospatial standards. Under IHO was a working group responsible for defining new feature classes based on data found on navigational charts. In 1987 was the first work released as "DX-87" (Digital eXchange 87). It didn't get much attention around the world, but the development was (very slowly) rolling.

Electronic navigational charts was coming, but many would argue that it would have taken forever if it wasn't for one special "event": On March 24, 1989, the oil tanker Exxon Valdez ran aground on the Bligh Reef, Prince William Sound, Alaska, USA, resulting in an oil spill estimated to have been around 40,000 tons [4]. There is probably not a person today involved in electronic charts that haven't heard this story.

Whether (oil) accidents acted as a catalyst for the development of electronic charts and chart systems or not is maybe less important! Many people in the industry and government organizations agreed that electronic charts and electronic navigational systems were the future. In 1990 DX-87 had become DX-90 and included in a new IHO standard named S-57 'IHO Transfer Standard for Digital Hydrographic Data'. At this time some argued that electronic charts would replace paper navigational charts within 5 years. More than 20 years later that has still not happened, but it's certainly closer than ever.

2 S-57 TAKING OFF

With the introduction of the IHO S-57 standard in 1990 the world had probably received its first truly international recognised data exchange standard. There were two major purposes with the standard:

1 1 Exchange of digital paper chart between national hydrographic offices
2 2 Exchange of electronic charts from national hydrographic offices to mariners' navigational systems on board ships.

The first purpose never took off. The major reason for this is probably that paper charts are graphical products and a geospatial standard focusing on feature encoding of "real world features" like S-57 did, was not suitable for this purpose. Converting graphical data from all the various systems used by hydrographic office around the world is far more complex than most people expected at that time. In fact paper charts today mostly, if not entirely, are still exchanged as raster data and not as vector or feature data.

The second purpose using S-57 for electronic chart exchange had more progress! There was much to be learned and during the first years after the release, the IHO DataBase Working Group that maintained the standard met multiple times per year, and the standard was constantly under revision. However in the mid 1990s the standard had matured, and by 1996 edition 3.0 was released. It was decided this edition would remain frozen for 4 years to ensure stability, intended to help hydrographic offices and, maybe especially, navigational equipment manufactures to finalize and release date plus equipment for the market.

Only one year earlier, in 1995, had the International Maritime Organization (IMO [5]) adopted the so-called ECDIS Performance Standard [6], meaning that Electronic Chart Display & Information Systems (ECDIS) now was allowed to be used for navigation, instead of paper charts. Here also were many lessons to be learned, and amendments were frequent in the early years. Work on this standard had taken place internationally for about as long as the data exchange standard and the two have close ties. The ECDIS standard required that charts for ECDIS systems must be Electronic Navigational Charts (ENCs) according to the S-57 standard.

In 2000 edition 3.1 of the S-57 standard was released and this time the standard was frozen "forever". The production of ENCs still lacking behind for many parts of the world, and it was also expensive for the ECDIS manufactures to keep updating their systems. Freezing the standard was intended to help that. Additional it was believed that once an ECDIS was delivered to a vessel there was no guarantee that such system would be updated, e.g. to support new versions of the standard. Neither the ECDIS standard, nor the ENC standard, had means to update ECDIS systems to accept new feature classification or new symbology etc. This worked relatively well for about half a decade, but by mid 2000s there were new requirements from IMO to include new (environmental) features on navigation charts. In January 2007 the so-called 'Supplement 1' to S-57 was released, and it was followed by another supplement two years later. The evidence was clear: A frozen standard would not be able to support future needs.

It was not really a problem with the S-57 standard, which originally included (technical) possibilities to define and encode new feature types. It even included a way to encode class definitions of new features so that navigational systems could "learn" about such new features and present these features to the mariner. However this part of the standard was never utilised.

Additionally S-57 was intended to be used for multiple product types, and had room for various product definitions to be defined. The ENC standard is actually "just" an appendix to the S-57 standard. However that possibility wasn't used; partly because of the frozen state of the standard. At least not under IHO and officially not part of the standard, but more about that below! The S-57 standard and the ENC product specification had become almost inseparable and somewhat synonymous!

3 MULTIPLE PURPOSES

The frozen and somewhat limited S-57 and ENC specification did not stop other S-57 based implementations. One of the earlier ideas for S-57 was for bathymetric survey data exchange, and even though this has been done to some degree, there was much more use of the standard for other purposes. However none of these purposes are developed under IHO, but some of them started using S-57 as early as the mid 1990s.

Some of the other uses of S-57 are:

– Inland ENCs [7]
  Electronic Charts for Inland ECDIS, which are used on rivers.
  In 2001 the Economic Commission for Europe of the United Nations (UN ECE) adopted the Inland ECDIS Standard as a recommendation for the European inland waterway system; using Inland Electronic Navigational Chart (IENC) data. Outside Europe, other countries also looked at Inland ECDIS and the U.S. Army Corps of Engineers [8] developed the Inland Electronic Navigation Charts. While the European Inland ENC standard extended the original S-57 standard with new features, symbology and rules, the US Inland ENC standard used S-57 more or less as it was. To align the standards the International Inland ENC Harmonization Group (IEHG) formed in 2003 and the standards are now maintained as one standard. Other countries adopted this standard and Inland ENCs covering thousands of river kilometres exists today. Countries using this standard include: Austria, Belgium, Brazil, Bulgaria, China, Croatia, Czech Republic, France, Germany, Hungary, Italy, Netherlands, Peru, Poland, Russia, Serbia, Slovakia, Switzerland,

Ukraine, South Korea, USA, Venezuela (plus others).
Note that IENCs are not overlays; they will not be used at the same time as ENCs. They cover different geographic areas and are made for different vessels.
- Ice ENCs [9]
Using S-57 for encoding of Ice features started in the mid 1990s. These datasets are overlays with additional dynamic (ice) information supplementing ENC data.. Countries around the North Pole, followed by countries around the Baltic Sea are among the players.
- Additional Military Layers (AMLs) [10]
Situation awareness layers of data supporting military operations, which as the name indicates are overlay of additional data displayed on a warship ECDIS (called WECDIS). Date layers include bathymetric contours, routes, areas & limits for danger and exercise areas, full wreck and major bottom object information, detailed beach and seabed environmental data, etc.

There are more types like Bathymetric Charts and specialised Pilot Charts. Many more possibilities using S-57 for various purposes exist [11] and are often generically referred to as Marine Information Overlays (MIOs). Each typically has their own feature definitions, encoding rules, etc. However the fact that they are all based on S-57 makes it relatively easy to support more of them. For instance a widely used ENC production tool, CARIS S-57 Composer [12], not only allows users to create IHO ENCs but also the other S-57 product types mentioned above. Users can even define their own S-57 product types.

4 WHAT'S NEXT?

There is no question S-57 will be used for many years to come. There is simply too much data and so many systems using S-57 preventing it from dying anytime soon. ECDIS systems will be using S-57 ENCs for many years to come.

However the geospatial world has been evolving. In the 1980s and even in the 1990s electronic geospatial data was not mainstream, but today almost every mobile phone has not only electronic maps, but also navigation. Imagining a world without Google Maps in 2013 is very hard!

The S-57 standard was one of the first geospatial standards, but it focused entirely on marine information, and (at least) two other major initiatives are now more known than S-57 (at least in the non-marine domain):

- GML [13]
Geography Markup Language (GML) is the flavour of XML defined by the Open Geospatial Consortium (OGC) to encode geospatial information. It is very general and can be used for many purposes. For instance can data types vary a lot between two different data sets both encoded in GML. Meaning there is no guarantee that two systems both supporting GML can exchange data. Google's KML format is often compared to GML, and can loosely be described as a GML specific flavour.
GML has with the latest major version moved to ISO conformity.
- ISO/TC 211 [14]
The International Standards Organization's Standards Committee 2011 (ICO/TC 211) is responsible for ISO's standards on geospatial information and many other organizations have been engaged in this work too. OGC and DGIWG (Defence Geospatial Working Group) are among these, and IHO have also been in close contact with ISO in this area for decades. In 2012 a Memorandum of Understanding (MoU) to increase their cooperation was signed by ISO and IHO.
ISO/TC 211 has released a set of standards know as the ISO 191xx series, each covering different scopes. For instance is 19136 the standard for GML and 19115, which maybe is the best known of these standards, is the standard for metadata.

5 NOT THE NEW S-57

To resolve the issue described above (among other things) IHO has developed the S-100 standard! However it will not immediately replace S-57 and it would be a mistake to call it a new S-57.

The work on S-100 was started by the IHO Transfer Standard and Maintenance Working Group (TSMAD), which previously was known as the DBWG, and this was the group that maintained the S-57 standard. The initial version of S-100 was indeed called S-57 Edition 4.0! However since this new version should resolve some of the issues/limitations with S-57 (both technically and administrative) and it is based on ISO/TC 211 with new terms and models it was decided to give it a new name. Hence S-100 which is following IHO's naming convention for its standards.

With S-100 product specifications are kept completely separate, meaning that feature classes, encoding, etc. are not a part of S-100. S-100 doesn't even dictate what file format to use for the encoding. In line with ISO/TC 211 is GML for instance not mandatory format, but an option depending on what needs to be encoded. It will be the product specifications, which are separately maintained standards, named S-101, S-102, etc. that will contain the encoding and other product implementation rules.

Product specifications are developed under a set of rules defined by S-100, saying for instance that a product specification must consist of (thus define) the following parts:
- product identification
- data content and structure
- coordinate reference system
- data quality
- data capture
- data maintenance
- portrayal
- encoding
- product delivery

S-100 introduces some new data types and structures for modeling and disseminating the data.

One of the new abilities in S-100 is the ability to handle more complex attribute situations. A feature can now have multiple values of a given attribute type and a hierarchy of attribute information can be modeled. Also a new concept called Information Types allow common information to be shared or referenced by multiple objects. As part of the development of S-101 a richer encoding of the real world should become available that will enable systems and users to make better use of the information. The hope is that this will be realized by the end user systems in order to provide improved decision support mechanisms.

Characteristic	Value					
Name	Light sector					
Definition						
Remarks	n/a					
CamelCase	lightSector					
AlphaCode	LITSEC					
DataType	Complex					
	CamelCode	cardinality	c1	c2	ordered	unique
SubAttribute	sectorLimit1	number	1	n/a	n/a	n/a
SubAttribute	sectorLimit2	number	1	n/a	n/a	n/a
SubAttribute	colour	number	1	n/a	n/a	n/a
SubAttribute	valueOfNominalRange	range	0	1	n/a	n/a
	CamelCode	cardinality	c1	c2	ordered	unique
SubAttribute	sectorLimit1	number	1	n/a	n/a	n/a
SubAttribute	sectorLimit2	number	1	n/a	n/a	n/a
SubAttribute	colour	number	1	n/a	n/a	n/a
SubAttribute	valueOfNominalRange	range	0	1	n/a	n/a

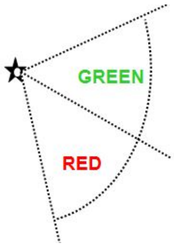

Figure 1. S-101 example of complex attribute encoding in one feature something that in S-57 requires multiple features.

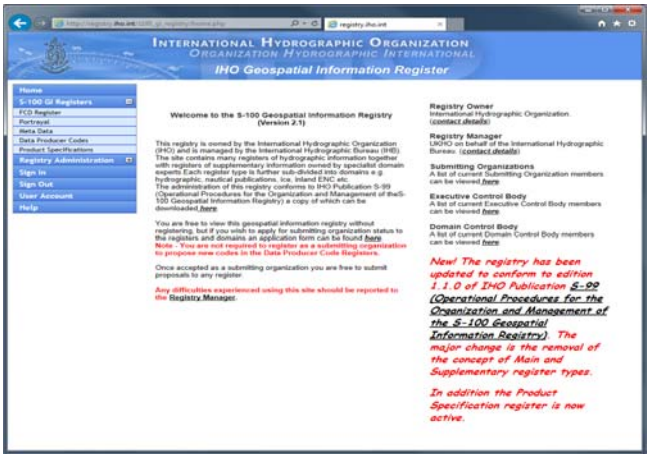

Figure 2. IHO Geospatial Information Register

A major component under S-100 is the IHO Geospatial Information Register [15] where feature catalogues, defining the features to be used in the product specifications, are registered. By registering the feature catalogues (and the features defined in these) in the IHO register it is hoped that feature classes will be shared (and possibly extended), instead of having conflicting feature classes between product specification. It is also hoped that feature classes can be shared between IHO standards and other standards. To help ensure this the IHO registry is open to other non-IHO standard for maintaining their feature catalogues. Today both IENC and Ice IENC features can be found in the registry too.

6 THE FRUITS OF S-100

The first number in the new line of product specifications defined by the IHO is S-101, which is the "Next Generation ENC Product Specification". S-101 is under development and the first draft version is planned for late 2013. ECDIS systems utilising S-101 ENCs are expected operational in 2018 after shore and sea trials. However even at that time will S-100/S-101 not replace S-57 ENCs, but supplement them. S-57 ENCs are not expected to retire before sometime between 2020 and 2030.

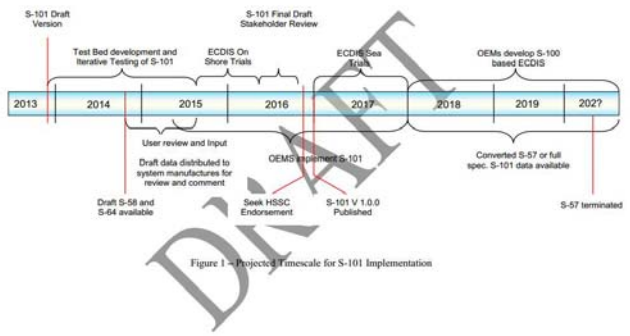

Figure 3. IHO TSMAD S-101 Draft implementation plan (January 2013)

The next IHO product specification in the line of numbers is S-102 [16], which is the Bathymetric Surface Product Specification. This product specification is actually already released (in April 2012). The data/coverage type is a quadrilateral grid coverage together with attributes known as a Bathymetric Attributed Grid (BAG). S-102 is intended for navigational purposes using a digital signature, or for non-navigational purpose (without a digital signature).

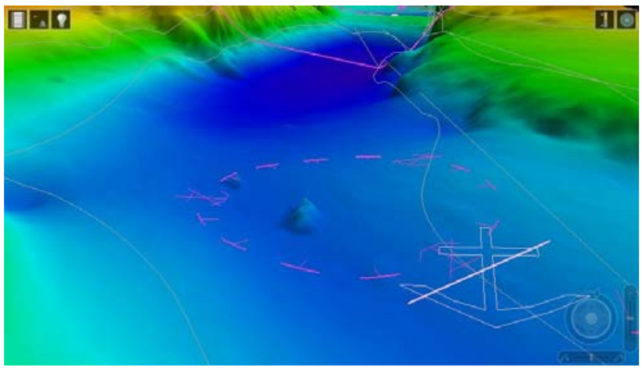

Figure 4. Navigational surface with ENC features.

Using gridded bathymetry in BAG format has for some time been considered; for instance with Port ENCs as described in the 2009 TransNav paper

"Enhance Berth to Berth Navigation Requires High Quality ENC's – The Port ENC – a Proposal for a New Port Related ENC Standard" [17] by D. Seefeldt, former Head of the Geographic and Hydrographic Department at Hamburg Port Authority.

S-102 gridded bathymetry is also very suitable for web viewing and download, as early work with S-102 has been shown by the Canadian Hydrographic Service [18].

Besides S-101 and S-102 is IHO also working towards other S-1xx product specifications! Marine Protected Areas is expected to become a new S-100 product specification called named S-103 Geospatial standard for Marine Protected Areas and there are more being mentioned as possible new product specifications e.g.:

- Routes
- Boundaries
- Ice
- Currents and tides
- Etc.

The IMO Sub-Committee on Safety of Navigation (NAV) is looking at e-Navigation as an important topic for the future of nautical navigation. The Sub-Committee on e-Navigation agreed to use S-100 as the baseline for creating a framework for data access and services under the scope of SOLAS (IMO's Safety Of Life At Sea). Plus the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Council has approved registration of IALA [19] at IHO as a Submitting Organization under the IHO GI Registry and as a domain owner (i.e. the IALA domains within the Registry).

7 FLEXIBILITY

As mentioned earlier, S-57 was intended to be a framework for multiple products but IHO only ended up with one product spec. One of the unfortunate results of this and the frozen specifications is that some implementations were designed to be static. When IHO needed to add some new objects to the catalogue it became clear that this would mean software and system upgrades to make it work. With S-100 the intention is to prevent this situation.

S-100 is under a new maintenance regime that should allow new editions to be created as needed. The concept is that S-100 product specifications would be based on a particular edition of S-100, which would mean that new S-100 editions could be released, while product specifications based on earlier editions still would be valid. This will allow S-100 to be updated to support new product specifications requiring new elements not present in the older edition of S-100.

A concept with S-100 is that the more common/expected changes should be treated as just data updates and not require physical changes (software, hardware) to the end systems. To this end S-100 is defining the means to manage Feature Catalogues and Portrayal Catalogues as data that can be distributed and updated. If there is a need to add a new object to the Feature Catalogue an update to the Feature Catalogue would be released along with corresponding updates to the Portrayal Catalogue and when the system encounters the new object in a dataset or update it would recognize the new object and be able to display it.

Only if a product specification needs to include more significant changes such as file encoding or data structures, then a brand new edition of that product specification would be required and only in such cases would it be expected that systems would require corresponding software updates in order to support the new specification.

8 CONCLUSION

The expectation is that S-100 will provide solutions needed by the growing market of Hydrographic products and will allow for the flexibility to grow as new needs are identified. This will not happen without significant effort and involvement by all aspects of the Hydrographic community. It has been evident with the developments of S-100 so far that input and involvement from producing agencies, system manufacturers, governing bodies and end users are necessary for success. Having been involved in S-57 and related technologies, plus in S-100 since its inception, CARIS is excited about the possibilities that S-100 can bring to the world.

REFERENCES

[1] www.iho.int
[2] http://www.iho.int/iho_pubs/IHO_Download.htm#S-57
[3] http://www.iho.int/iho_pubs/standard/S-100/S-100_Info.htm
[4] http://en.wikipedia.org/wiki/Exxon_Valdez
[5] http://www.imo.org
[6] http://www.imo.org/OurWork/Safety/Navigation/Pages/Charts.aspx
[7] http://en.wikipedia.org/wiki/Inland_Electronic_Navigational_Charts
[8] http://www.tec.army.mil/echarts/
[9] http://hgmio.org/information.html
[10] http://www.ukho.gov.uk/Defence/AML/Pages/Home.aspx
[11] http://www.hgmio.org/specifications.html
[12] http://www.caris.com/products/s57-composer/
[13] http://www.opengeospatial.org/standards/gml
[14] http://www.isotc211.org/
[15] http://registry.iho.int/s100_gi_registry/home.php
[16] http://www.iho.int/iho_pubs/IHO_Download.htm#S-102
[17] http://www.transnav.eu/Article_Enhance_Berth_to_Berth_Navigation_Seefeldt,18,280.html
[18] http://www.caris.com/downloads/brochures/The-New-IHO-S-102-Standard.pdf
[19] http://www.iala-aism.org