(e-Navigation, Marine Navigation, Safety at Sea, Hydrography, Data Model, IMO, IHO

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DEVELOPMENT OF THE IHO UNIVERSAL HYDROGRAPHIC DATA MODEL AS PART OF THE DEVELOPMENT OF E-NAVIGATION STRATEGY

e-Navigation is the future, digital concept for the maritime sector, being developed under the auspices of the United Nations International Maritime Organization (IMO) to bring about increased safety and security in commercial shipping through better organisation of data on ships and onshore, and better data exchange and communication between the two. The International Hydrographic Organization (IHO) is involved in the development of the e-Navigation concept to ensure that any underpinning hydrographic standards, products or services are in place from the beginning. In the paper the Author, a member of the IMO Expert Group on e-Navigation, established in 2006, presents recent issues related to the development of e-Navigation - the concept of the IHO Universal Hydrographic Data Model.

TWORZENIE UNIWERSALNEGO MODELU DANYCH HYDROGRAFICZNYCH W RAMACH ROZWOJU STRATEGII E-NAVIGATION

e-Navigation to przyszła cyfrowa koncepcja dla sektora morskiego, rozwijana pod auspicjami Międzynarodowej Organizacji Morskiej (IMO), agendy Organizacji Narodów Zjednoczonych, w celu zwiększenia bezpieczeństwa i ochrony żeglugi handlowej poprzez lepszą organizację danych na statkach i na lądzie, oraz lepszą wymianę danych i komunikację w relacji w relacji statek - statek, statek - stacja brzegowa, stacja brzegowa - statek, oraz stacja brzegowa – stacja brzegowa. Międzynarodowa Organizacja Hydrograficzna (IHO) od samego początku uczestniczy w rozwoju koncepcji e-Navigation by zapewnić, żeby jakiekolwiek tworzone hydrograficzne standardy, produkty oraz usługi były zgodne z tą koncepcja. W opracowaniu Autor, członek grupy ekspertów IMO ds. e-Navigation założonej w 2006, przedstawia najnowsze uzgodnienia dotyczące koncepcji e-Navigation – pojęcie uniwersalnego model danych hydrograficznych.

1. INTRODUCTION

The advantage of the latest technical development in the field of automation, electronics, telecommunications, informatics, telematics, geomatics and global position fixing techniques, achievement in data storing, processing, analysing, transferring and visualisation should be taken into account and applied to the maritime technology. In the

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paper the author tries to discuss a strategic vision of development e-navigation concept using those new technologies and the main tasks of the maritime community for the near future in that new field.

e-Navigation is an International Maritime Organization (IMO) led concept based on the harmonisation of marine navigation systems and supporting shore services driven by user needs. It is currently defined as:
e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment.

The vision for e-Navigation is to enhance the best practices of traditional navigation, by better integrating humans and machines to take advantage of both their unique skills [3]. Electronics have proven excellent at continually monitoring and checking mundane routines such as comparing various sources of navigation inputs, a task that most mariners can't accomplish as quickly and eventually find tedious. Humans excel in intuitive skills and addressing abstract challenges such as ship handling and resource management. The enhancements brought in by e-Navigation are to optimise the support technical systems give to the human decision making process for the safe operation of shipping.

With the advent of electronic navigation (not to be confused with e-Navigation) such as electronic charts and positioning systems, the role of the mariner has changed without the change being holistically addressed by the maritime community. These conditions also exist with shore-side operations. e-Navigation is a process that seeks to reassess these roles and ensure that mariners and shore operators are actively engaged in the process of navigation and not just monitoring it. This will enable mariners and operators ashore to make better decisions, supported by robust electronic technology and information management systems that reduce existing distractions.

2. THE USER NEEDS

e-Navigation, as agreed by the IMO, is a 'User Led' initiative, and the users include those who navigate vessels of all sizes and types, and a broad section of shore based authorised users. At the IMO Safety of Navigation Sub-committee (NAV55), it was agreed that the preliminary shipboard needs included:

- improved ergonomics;
- greater standardisation of interfaces;
- better familiarisation training;
- more effective display of NAVTEX and other MSI;
- alert/alarm management;
- improved reliability and better indication of reliability;
- more standardised and automated reporting facilities;
- improved target detection;
- more effective guard zones;
- reduction of administrative burden; and
- more automated updating of essential information.

Shore based needs are currently being developed with the assistance of IALA and are anticipated to fall into the categories of:

- better data collection for marine domain awareness;

- more effective information management;
- better provision of information to vessels;
- greater quality assurance;
- more effective sharing of information between authorised shore users to reduce the burden on seafarers and improve logistic management; and
- To support Search and Rescue (SAR) operations by improving access to relevant information and ensuring effective communication.

It is understood that improvements in all these areas will not solely rely on technology, but will require attention to training and procedures as well.

3. FURTHER PROGRESS IN THE DEVELOPMENT OF E-NAVIGATION STRATEGY IMPLEMENTATION PLAN

The IMO Sub-Committee on Safety of Navigation (NAV), at 57th session held in June 2011 made further progress in the development of the e-navigation strategy implementation plan, which aims to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing transparent, user-friendly, cost-effective and compatible system that will contribute to enhanced navigational safety (with all the positive repercussions this will have on maritime safety overall and environmental protection) while simultaneously reducing the burden on the navigator. The e-navigation concept is being developed in cooperation with the IMO Sub-Committees on Radiocommunications, Search and Rescue (COMSAR) and Standards of Training and Watchkeeping (STW)).

The NAV Sub-Committee agreed the current overarching e-navigation architecture (Fig. 1), which is intended to be kept under review. It provides the shipboard and the shore-based parts connected through different links. It also identifies the concept of Maritime Service Portfolio (MSP) which defines and describes the set of operational and technical services and their level of service provided by a stakeholder in a given sea area, waterway, or port, as appropriate.

The architecture also includes the Common Maritime Data Structure (CMDS) that spans the whole of the horizontal axis (indicated by the shaded oval in the background), which serves an important function as it is a key to harmonization between the technical systems of stakeholders both shipboard and shore-based.

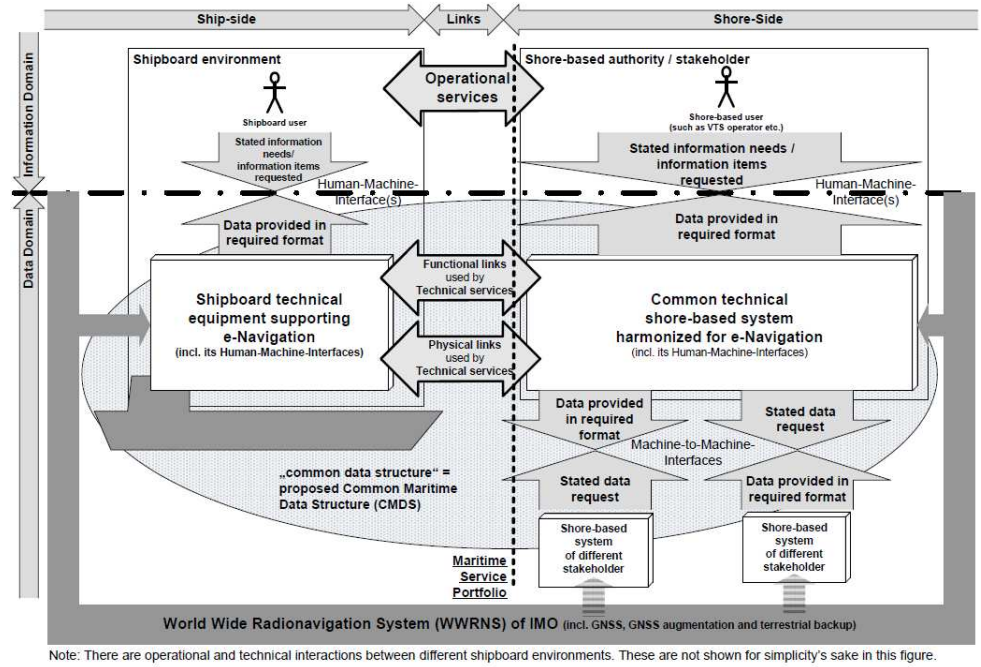
The NAV Sub-Committee also agreed to use the International Hydrographic Organization (IHO)'s S-100 Geospatial Standard for Hydrographic Data as the baseline for creating a framework for data access and services under the scope of SOLAS. S-100 can support a variety of hydrographic-related digital data sources, products and customers, including the use of imagery and gridded data, enhanced metadata specifications, unlimited encoding formats and a more flexible maintenance regime.

The Maritime Safety Committee MSC was invited to approve the establishment of an IMO/IHO Harmonization Group on Data modelling, and relevant terms of reference, to consider matters related to the framework for data access and information services under the scope of SOLAS, using as a baseline IHO's S-100 standard [1].

4. OVERARCHING E-NAVIGATION ARCHITECTURE

The overarching e-Navigation architecture described in figure 1 included, in the horizontal direction, the shipboard and the shore-based parts connected through different links put into a hierarchical perspective (operational services and functional and physical

links used by technical services), stressing the harmonization requirement which was the essence of the e-Navigation definition and highlighting the information/data flow in the e-Navigation architecture. In the vertical direction, a distinction between the information and data domains were represented, including the human/machine Interfaces that interconnect the two domains and provide information and data items to the human users in the required format [4].



Note: There are operational and technical interactions between different shipboard environments. These are not shown for simplicity's sake in this figure.

Fig.1. Overarching e-Navigation architecture [2]

Figure 1 shows the principle of an information/data flow in the e-Navigation architecture while the structural details of both the technical shipboard and shore-based e-Navigation system architectures are not yet shown. This brings into focus the "operational service" level and the "Functional links used by Technical services" and the "Physical links used by Technical services". This is a further development as it highlights the fundamental distinction between information and data domains; explaining the relationship between the user requested information items; putting the concepts of Operational Services, Technical Services as well as Functional and Physical Links into a hierarchical perspective; identifying the place of the concept of "Maritime Service Portfolio"; and unfolding the relationship of shore-to-shore data exchange.

The above architecture also identified the concept of Maritime Service Portfolio (MSP) which defines and describes the set of operational and technical services and their level of service provided by a stakeholder in a given sea area, waterway, or port, as appropriate. This concept would be further developed in the future.

5. DEVELOPMENT OF A COMMON MARITIME DATA STRUCTURE (CMDS)

The figure 1 shows the complete overarching e-Navigation structure, explains the relationship of shore-to-shore data exchange and defines two additional important features:

1. the Common Maritime Data Structure (CMDS) that spans the whole of the horizontal axis (indicated by the shaded oval in the background), which serves an important function as it is a key to harmonization between the technical systems of stakeholders both shipboard and shore-based; and
2. the World Wide Radio Navigation System (WWRNS), which delivers in particular the position and time data to virtually all technical systems in e-Navigation. The degree of this dependency might differ for several shore-based systems (indicated by different arrow shading).

For simplicity of representation, the ship-to-ship interactions are not shown, although they are an integral part of the e-Navigation. The structural details of both the technical shipboard and common shore-based e-Navigation system architectures are not yet shown at this stage. Different figures would be required to be developed in the future in this respect.

The Common Maritime Data Structure (CMDS):

- should be based on user requirements;
- could represent any maritime entity and should be extended by the addition of new entities;
- should be accessible to any stakeholder or implementer;
- should be an abstract representation of parts of the maritime domain (i.e. it should represent the entities and its relationships but it should not represent processes);
- should not contain details on the physical representation of its entities; however, it could be used to guide the development of the necessary databases and interfaces; and
- should be flexible and extendable for meeting future requirements (i.e. new entities could be added by any stakeholder through a process known as registration).

Figure 2 illustrates how the proposed CMDS would influence the components of the e-Navigation architecture when creating hardware and software used for e-Navigation purposes.

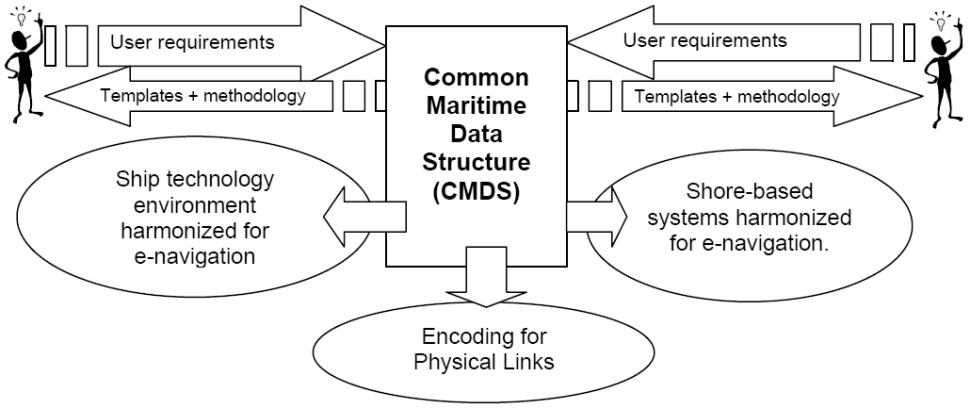


Fig.2. Scope and impact of the CMDS [2]

6. DEVELOPMENT OF THE UNIVERSAL HYDROGRAPHIC DATA MODEL

Development of S-100 – the *IHO Universal Hydrographic Data Model* was included in the IHO Work Programme in 2001. S-100 has been developed by the IHO Transfer Standards Maintenance and Applications Development (TSMAD) Working Group with active participation from hydrographic offices, industry and academia.

S-100 provides a contemporary hydrographic geospatial data standard that can support a wide variety of hydrographic-related digital data sources, and is fully aligned with mainstream international geospatial standards, in particular the ISO 19100 series of geographic standards, thereby enabling the easier integration of hydrographic data and applications into geospatial solutions.

The primary goal for S-100 is to support a greater variety of hydrographic-related digital data sources, products, and customers. This includes the use of imagery and gridded data, enhanced metadata specifications, unlimited encoding formats and a more flexible maintenance regime. This enables the development of new applications that go beyond the scope of traditional hydrography - for example, high-density bathymetry, seafloor classification, marine GIS, et cetera. S-100 is designed to be extensible and future requirements such as 3-D, time-varying data (x, y, z, and time) and Web-based services for acquiring, processing, analysing, accessing, and presenting hydrographic data can be easily added when required.

The S-100 development and maintenance process is specifically aimed at allowing direct input from non-IHO stakeholders, thereby increasing the likelihood that these potential users will maximise their use of hydrographic data for their particular purposes.

S-100 will eventually replace S-57 – the established *IHO Transfer Standard for Digital Hydrographic Data*. Although S-57 has many good aspects, it has some limitations:

- S-57 has been used almost exclusively for encoding Electronic Navigational Charts (ENCs) for use in Electronic Chart Display and Information Systems (ECDIS);
- S-57 is not a contemporary standard that is widely accepted in the GIS domain;
- It has an inflexible maintenance regime. Freezing standards for lengthy periods is counter-productive;
- As presently structured, it cannot support future requirements (e.g., gridded bathymetry, or time-varying information);
- Embedding the data model within the encapsulation (i.e., file format) restricts the flexibility and capability of using a wider range of transfer mechanisms;
- It is regarded by some as a limited standard focused exclusively for the production and exchange of ENC data.

The transition from S-57 to S-100 will be carefully monitored by the IHO to ensure that existing S-57 users, particularly ENC stakeholders are not adversely affected. S-57 will continue to exist as the designated format for ENC data for the foreseeable future.

In the meantime, all existing and potential users of hydrographic information and data are encouraged to use S-100 as the basis for new applications, seeking input to the further development of the standard if their particular requirements are not yet catered for.

S-100 is not limited to hydrographic data or hydrographic applications. It has been developed specifically to enable the widest possible range of users to use hydrographic data in conjunction with data from other maritime and marine domains. As well as traditional applications such as nautical charts and publications, applications based on S-100 already under development by non-IHO stakeholder groups include sea ice forecast reporting,

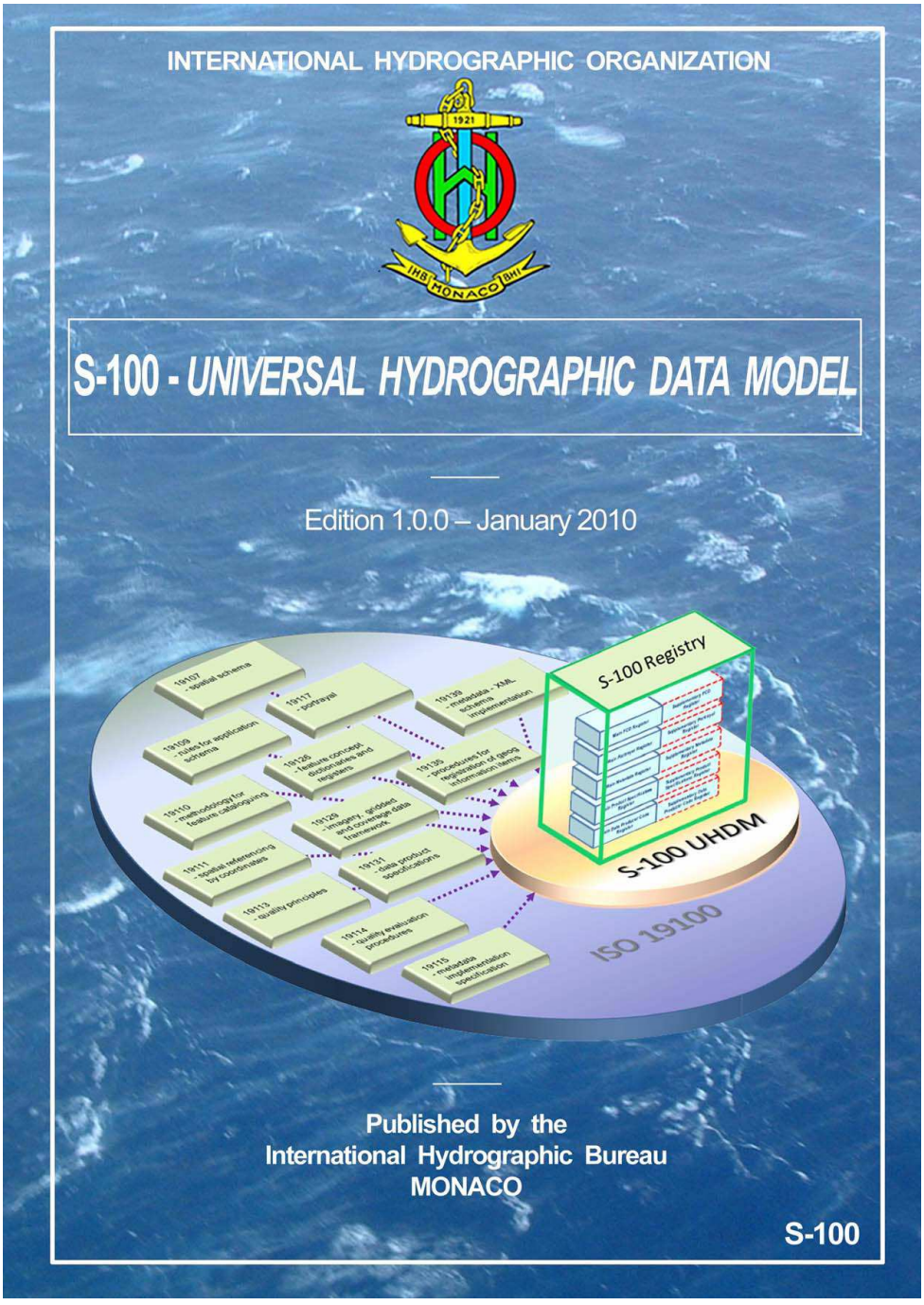


Fig.3. IHO S-100 - Universal Hydrographic Data Model [1]

recording UNCLOS boundaries, and marine information overlays. These are applications that obviously encompass various hydrographic, meteorological and oceanographic parameters that go well beyond the traditional navigation and hydrographic products provided by HO's. S-100 is intended to be a fundamental enabler for hydrographic input to Marine Spatial Data Infrastructures (MSDI) as well other developing marine information infrastructures such as e-Navigation.

7. THE S-100 STANDARD

Standards should encapsulate the use of best practice methods and procedures. They should include guidance on how to implement efficient production methods and optimize the quality of an organizations products and services, and should also enable interoperability between disparate technologies through the use of common interfaces. The S-100 standard attempts to achieve all of these objectives. Furthermore it provides a framework of components that can be used by interested communities to develop their own maritime geospatial products and services.

The S-100 standard has been developed with the advantage of hindsight based on experience gained through the development and use of the existing IHO Transfer Standard for Digital Hydrographic Data (known as S-57). S-100 has been documented using an object-oriented notation known as the Unified Modelling Language (UML). Although UML defines nine types of diagrams, only class, object and package diagrams have been used in S-100 [1].

The S-100 standard provides a theoretical framework of components that are based on the ISO 19100 series of standards and specifications. These standards and specifications are also used as the basis for most contemporary geospatial standards development activities and are closely aligned with other standards development initiatives such as the Open Geospatial Consortium (OGC). The IHO has also developed an associated Registry which can be used in conjunction with the S-100 standard. The IHO Registry contains the following additional components: Feature Concept Dictionary (FCD) Registers, Portrayal Registers, Registers of IHO producer codes. The IHO Registry provides the infrastructure and mechanisms required to manage and maintain the resources listed above, and to extend them as required. S-100 provides a schema and overarching management procedures for a registry and registers and the IHO registry is implemented using these concepts.

S-100 – IHO Hydrographic Geospatial Standard for Marine Data and Information comprises twelve related parts that give the user the appropriate tools and framework to develop and maintain hydrographic related data, products and registers. These standards specify, for hydrographic and related information, methods and tools for data management, processing, analysing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. By following this set of geospatial hydrographic standards users will be able to build constituent parts of an S-100 compliant product specification.

The S-100 conforms as far as is reasonably possible to the ISO TC 211 series of geographical information standards, and where necessary has been tailored to suit hydrographic requirements. S-100 details the standard to be used for the exchange of hydrographic and related geospatial data between national hydrographic offices as well as between other organizations and for its distribution to manufactures, mariners and other data users.

S-100 comprises multiple parts that profile standards developed by the ISO Technical Committee 211. ISO TC 211 is responsible for the ISO series of standards for geographic information. The objective is that, together, the standards will form a framework for the development of sector specific applications that use geographic information. S-100 is an example of such an application.

This standard specifies the procedures to be followed for:

1) establishing and maintaining registers of hydrographic and related information;
2) creating product specifications, feature catalogues and a definition of the general feature model;
3) using spatial, imagery and gridded data, and metadata specifically aimed at fulfilling hydrographic requirements.

8. THE CONCEPT OF A COMMON DATA STRUCTURE

IMO, IHO and IALA have raised the issue that some form of common data structure, representing the maritime domain (and including both ship and shore aspects), will be essential for e-Navigation [5].

IALA is currently developing a proposed Universal Maritime Data Model (UMDM) for e-Navigation to meet requirements arising from the future implementation of e-Navigation. It is therefore important to harmonize efforts in data modelling, with the aim of creating and maintaining a robust and extendable maritime data structure. The common maritime information and data structure will require some form of overarching coordination to ensure the ongoing management and maintenance of the structure. There may be several management roles to be performed by such a coordinating body, (for example, the maintenance of a register). This management role may be able to be shared between relevant organisations.

The common data structure should contain data models like IALA's UMDM, IHO's UHDM and data models of other international stakeholders. The structure is a highly important element by which e-Navigation can modernize the operational environment of the maritime industry. Reporting should be standardized and in a format that supports the effective use ashore, such as a global voluntary single window network. Construction of the UMDM will be a collaborative effort among many parties involved in the maritime environments. By having each party bring their particular expertise, the UMDM will become the accepted standard model.

Implementation of IMO's e-Navigation strategy leads to a larger variety and higher volume of information and increased information exchange due to globalization. Consequently there is a need to handle information more effectively in a standardized way. The first step towards a common data structure is to define the meaning of each and every item in the data structure and the relationships among the items. This is done so that implementers of the data structure have common understanding of items. The means to do this is with a data model. At this stage, the data model, like the system architecture needs only to be described in the most general of terms. An example of how a UMDM could be implemented has been provided by the IHO with its S-100 model.

9. CONCLUSIONS

A significant challenge for e-Navigation is how to efficiently capture and subsequently transfer the many forms of non-hydrographic data and information in the e-Navigation

domain in a relatively seamless, standardised and efficient way. At present, most maritime-related information is little more than textual-based messaging or verbal communication.

The IHO has already developed standardised methods of codifying, encapsulating, and subsequently transferring and distributing hydrographic and charting data using its well-established S-57 data exchange standard which is also the base standard for electronic navigational charts (ENCs). But most other maritime data and information is neither digital nor standardised as yet. Following on from S-57, the IHO has recently developed a contemporary digital data transfer standard that will support its 'next-generation' ENCs, digital nautical publications and supporting symbology, all of which will be part of e-Navigation in the future.

Most significantly and by design, the new standard, known as S-100, is compatible with the ISO 19100 series of geographic data standards. Because of this, increasing levels of interest have been shown by various would-be e-Navigation data providers to use S-100 and its supporting geospatial information (GI) registry as one mechanism for standardising the digital data capture of maritime information, especially where there are no other recognised underpinning data standards.

The implementation of a data structure usually requires writing a set of procedures that create and manipulate instances of that structure. The efficiency of a data structure cannot be analyzed separately from those operations. This observation motivates the theoretical concept of an abstract data type, a data structure that is defined indirectly by the operations that may be performed on it, and the mathematical properties of those operations (including their space and time cost).

It is envisioned that e-Navigation will be a 'living' concept that will evolve and adapt over a long time scale to support this objective. During this time information will change, technologies will change, political and commercial objectives will change, and tasks will change. However it is unlikely that the need for safe and efficient seaborne transport will change significantly.

It is very important especially for safety reason to establish common maritime data structure. The IHO S-100 standard should be considered as the baseline data structure for maritime information in e-Navigation.

10. REFERENCES

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