

## THE CONCEPT OF A UNIVERSAL MARITIME DATA MODEL (UMDM) ESSENTIAL FOR E-NAVIGATION

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### Abstract

*In the paper the Author describes the general concept of a Universal Maritime Data Model (UMDM) a common representation of all data objects and relationships occurring in the maritime domain. 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. In January 2010, IHO introduced a new data model known as S-100 - the Universal Hydrographic Data Model (UHDM). This international standard has been developed by the IHO over the last ten years in consultation with a wide range of stakeholders, including key ECDIS and navigation equipment manufactures. The purpose of S-100 is to provide framework architecture for a contemporary standard for the exchange of hydrographic and related maritime data. As the UHDM is aligned with ISO 19100 it will enable the exchange of hydrographic, chart and other maritime data and information together with geospatial data from other domains. The use of ISO 19100-based data standards enables interoperability between geospatial data sets from different domains and could therefore be appropriate for many of the datasets envisaged for data exchange in e-Navigation.*

**Keywords:** maritime transport, e-Navigation, ECDIS, Data Model, UMDM, UHDM, IMO, IALA, IHO, ISO

### 1. Introduction. The vision for e-Navigation

The vision for e-Navigation<sup>1</sup> is to enhance the best practices of traditional navigation, by better integrating humans and machines to take advantage of both their unique skills. 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.

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<sup>1</sup> The Author is a member of IMO Correspondence Group on e-Navigation, established in 2006

## 2. Introduction to the IALA Universal Maritime Data Model

### 2.1. Introduction

This paper introduces the technical concept of describing maritime information in a user-friendly, simple and consistent manner using the IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities) Universal Maritime Data Model (UMDM), a consequence of the IMO e-Navigation strategy.

The audience for this paper is Maritime and Inland Waterways Communities, such as, Contracting Governments of the IMO (International Maritime Organization), Coast Guards, Port and Harbour Authorities, Waterway Authorities, Manufacturers and Suppliers of ship and shore equipment and software, Service Providers, Specifiers of Equipment and Services, and other interested parties.

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. IALA realized that a common data model that expressly includes ship and shore data is essential. IALA designed a data model that meets these characteristics but is also extendable so that it can grow as more end user requirements are identified and captured. This data model is named the IALA Universal Maritime Data Model (IALA UMDM).

### 2.2. Universal Maritime Data Model

The IMO has defined e-Navigation as follows: e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of marine information on board 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.

Specifically for integration and exchange of maritime information the IMO has stated in the same report: Mariners require information pertaining to the planning and execution of voyages, the assessment of navigation risk and compliance with regulation. This information should be accessible from a single integrated system. Shore users require information pertaining to their maritime domain, including static and dynamic information on vessels and their voyages. This information should be provided in an internationally agreed common data structure. Such a data structure is essential for the sharing of information amongst shore authorities on a regional and international basis [3]:

- 1) Information – knowledge concerning objects, such as facts, events, things, processes or ideas, including concepts, that within a certain context has a particular meaning or, data made useful by interpretation or analysis.
- 2) Data – representation of facts, concepts or instructions in a formalized manner, suitable or communication, interpretation or processing by humans or by automatic means.

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. A data model is an inventory of item definitions and blueprints for item relationships, and as such is a tool used to define data structures. The IALA UMDM is a data model specifically designed for maritime data.

The UMDM is an abstract representation of the maritime domain. Specifically, it represents the entities and relationships among the entities that exist in this domain but does not represent processes. The purpose of a data model is to give users a common understanding of the entities and relationships.

### **2.3. The description of the IALA UMDM**

The UMDM is neither a database nor an interface. The model contains no details about physical representation of the entities within it. However, the UMDM can be used to guide the development of databases and interfaces, which are the physical representations of entities.

By defining a common reference, all implementers can be assured that their understanding of the entities required agrees with the understanding of others.

The UMDM is flexible and extendable for meeting future requirements. New entities can be added to the model by any e-Navigation stakeholder through a process known as registration. Once registered, an entity is available to all stakeholders; there is open, public access. The UMDM also has provisions for proprietary entities that do not require registration. The model is modular and an appropriate subset is easily referenced.

The UMDM can represent any maritime entity, can be extended by the addition of new entities, and is accessible to any e-Navigation stakeholder or implementer, thus it is considered to be universal in the maritime domain. As such, the UMDM should be unique. A parallel can be made between the UMDM and the Internet. Although it is possible to have multiple global networks, the true benefits of such a network would only be achieved if there is only one global network.

The parallel extends even further as the Internet provides a series of standardized network services from which the client can choose only the ones which he or she requires, e.g., e-mail, ftp, www, etc. Hence, e-Navigation shore-based stakeholders can choose to implement only the UMDM objects that they require, as long as the objects implemented are compliant with the UMDM. The UMDM will require a governing body to fulfil the role required for the management of the model. The UMDM management role is addressed further in the document.

### **2.4. IALA and e-Navigation**

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) was formed in 1957 as a non-government, non-profit making, technical association that provides a framework for aids to navigation authorities, manufacturers and consultants from all parts of the world to work with a common effort to:

- harmonize standards for aids to navigation systems worldwide;
- facilitate the safe and efficient movement of shipping; and
- further the protection of the maritime environment.

The main function of IALA is to provide specialist advice and assistance on aids to navigation issues (including technical, organizational and training matters). IALA does this by publishing recommendations and guidelines and organizing workshops and symposia.

IMO considers IALA to be a competent body because of its natural role and experience in shoreside matters [4]. Furthermore, IALA previously assisted IMO in developing the e-Navigation strategy [5]. IALA is participating in the implementation plan of the e-Navigation strategy, by capturing user requirements, developing shoreside architecture and performing gap and cost/risk analyses [4]. IALA formed the e-Navigation committee for the purpose of developing recommendations and guidelines on shore-based e-Navigation systems and services.

The IALA e-Navigation Committee's work includes a suite of recommendations on the shoreside architecture [1], that is being used by IALA members (and other interested parties) to implement e-Navigation systems and services. One aspect of the IALA e-Navigation architecture is the need for a consistent and unique data model, realized by the IALA Universal Maritime Data Model.

As stated above, the IALA UMDM is universal in nature and can easily be extended to encompass the complete maritime domain. IALA invites the Maritime and Inland Waterways Communities at large to consider using and contributing to the IALA Universal Maritime Data Model.

## 2.5. IALA's UMDM

The IALA Universal Data Model concept is composed of these central elements:

- UMDM – this is the structure of the data model itself and the data objects it contains, together with a data object definition rule base. In the terminology of UMDM, maritime entities are represented by data objects.
- UDOI – Universal Maritime Data Object Identifier – Entities are represented in the UMDM by objects. In order to use objects unambiguously, they must be uniquely identified. Identification of objects is accomplished using the Universal Maritime Data Object Identifier (UDOI) system where each object is given a unique UDOI. The UDOI:
  - Expedites access of objects,
  - Facilitates interchange and sharing of objects,
  - Is used as an index into the Universal Maritime Data Object Registry.
- UMOR – Universal Maritime Data Object Register – this is the mechanism for extending and maintaining the UMDM. The Register will require some place to be hosted which is the Registry. The organisation fulfilling the role of managing the UMDM is named the Registrar. Initially, IALA could host the Register, and act as the Registrar. By providing for organization of objects and their UDOIs, the Registry:
  - Eases maintenance of the UMDM,
  - Facilitates finding and retrieving objects,
  - Prevents redundancies within the UMDM,
  - Facilitates global implementation and exchange of objects through standardization.
- Rules for management of the UMDM – provided by relevant standards.

As previously mentioned, the UMDM requires a governing body to ensure proper management of the model. There may be several management roles to be performed by the governing body, one of which is the Registrar. The different management roles may be delegated at the discretion of the governing body. Hence, the Registrar may not be the same organization as the governing body. The tasks of the governing body always comprise supervision for the Registrar, however.

Initially, IALA will operate as the governing body and Registrar for the IALA UMDM. Once brought to a certain degree of maturity, the IALA UMDM would be offered to IMO as a contribution to the implementation of IMO's e-Navigation strategy. Then IMO would assume the role as the governing body for the UMDM, thereby guaranteeing the uniqueness of the UMDM within e-Navigation. IALA is prepared to continue as the Registrar for the IMO UMDM. There is precedent for this within IMO, e.g., the registrar for a ship's IMO number is Lloyd's Register. IALA invites the Maritime Waterways Community at large to consider using IALA as the Registrar for the entire Universal Maritime Data Model.

## 3. The concept of a Universal Maritime Data Model (UMDM)

When considering the e-Navigation architecture, one should think in terms of information/ data flow, application interactions, and user interfaces, as follows: User requirements can be described in terms of the information needed to perform each task. The required information items are delivered at the Human Machine Interfaces of the user applications by the shore-based e-Navigation system as fulfilment of the user requirements. These information items are transmitted, stored, and processed as so-called data objects by the shore-based e-Navigation system. The UMDM is therefore a common representation of all data objects and relationships occurring in the maritime domain. 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.

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 [2].

On 1 January 2010, the IHO introduced a new data model known as S-100 - the Universal Hydrographic Data Model (UHDM) [9]. This international standard has been developed by the IHO over the last ten years in consultation with a wide range of stakeholders, including key ECDIS and navigation equipment manufactures. The purpose of S-100 is to provide framework architecture for a contemporary standard for the exchange of hydrographic and related maritime data. S-100 is based on the ISO 19100 series of geographic standards and is fully compatible and interoperable with those standards.

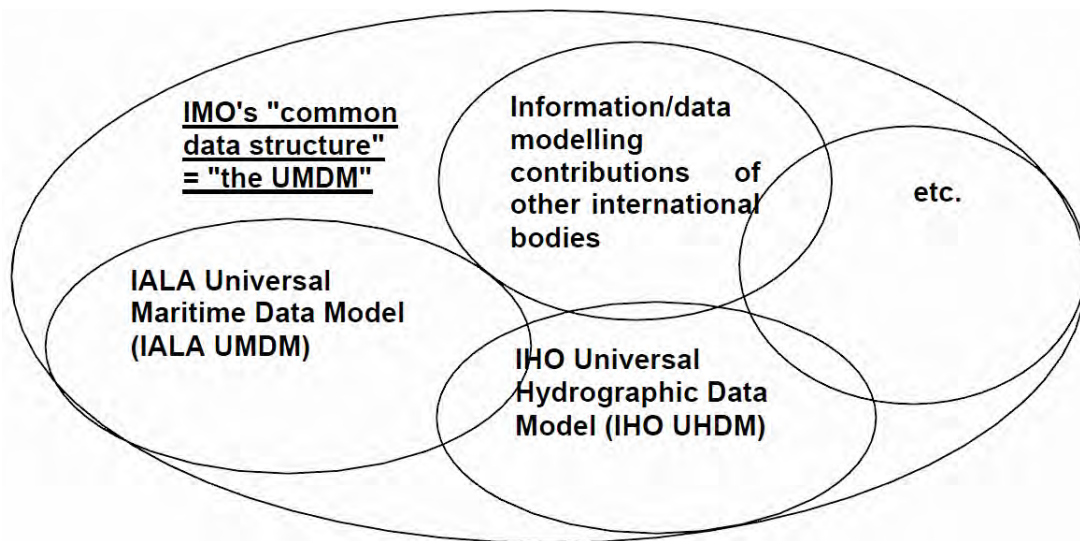


Fig. 1. Composition of proposed IMO's UMDM and the relationship of contributions of different international bodies, such as IALA and IHO (IALA UMDM and IHO UHDM) [8]

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, 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. Subject to further investigation and discussions with IHO, S-100 may meet all the requirements for a UMDM.

#### 4. IMO's UMDM

As announced in document [6] IALA have progressed the development of the IALA Universal Maritime Data Model (IALA UMDM), in accordance with the following statement made in the IMO submission: The high-level needs noted in the report of IMO NAV 54 include a common maritime information/data structure and IALA is progressing towards an IALA Maritime Data Model and Data Object Identifiers.

As explained in the annex, the proposed Universal Maritime Data Model (UMDM), could be governed by IMO [3], henceforth called IMO's UMDM. This and the IALA UMDM are and will

be different entities: The IALA UMDM should be construed as a subset of the IMO UMDM, as could be the individual data modelling contributions of other international bodies, such as the IHO's Universal Hydrographic Data Model (UHDM). Each respective data model defines and describes data objects and associated data properties in those fields which are particular relevant to that respective international body. The Figure overleaf illustrates this concept.

The apparent duplicate definitions within the UMDM, indicated by the overlap areas in Fig. 2, result from commonly used data objects and data property definitions, for example geographical position related data objects and property definitions. Duplicate definitions, and hence ambiguity, should be avoided by harmonization between the different contributing international bodies.

As a first step for a harmonization as described above, IALA wishes to liaise with IHO as a sister organization. As a result of this harmonization process there could be an IALA-UMDM and IHO-UHDM based core of IMO's UMDM, which would also be in conformity with ISO standardization, as amended due to any recognized harmonization need within ISO standard framework itself. Similarly, liaison with IEC would be essential on aspects such as interfacing.

IALA will continue to inform IMO on progress regarding the development of the IALA UMDM and the above harmonization process with the data modelling activities of other international bodies.

## 5. Initial technical e-Navigation architecture

### 5.1. Introduction

The IMO document „Initial technical e-Navigation Architecture“ [1] is the first contribution to the IMO e-Navigation Correspondence group, prepared by the IALA e-Navigation Committee for information of and approval by the IALA Council. It is an initial description of:

- the overarching e-Navigation architecture;
- its dependency on external systems and on infrastructure;
- the concept of the Universal Maritime Data Model (UMDM);
- central elements of the UMDM i.e. Universal Data Object Identifier, Universal Maritime Data Object Register and the importance of a Registrar.

The e-NAV committee continues its work on the shore based technical e-navigation system Architecture at its next meeting and at inter-sessional meetings, with the intention to provide further input to the IMO Correspondence Group.

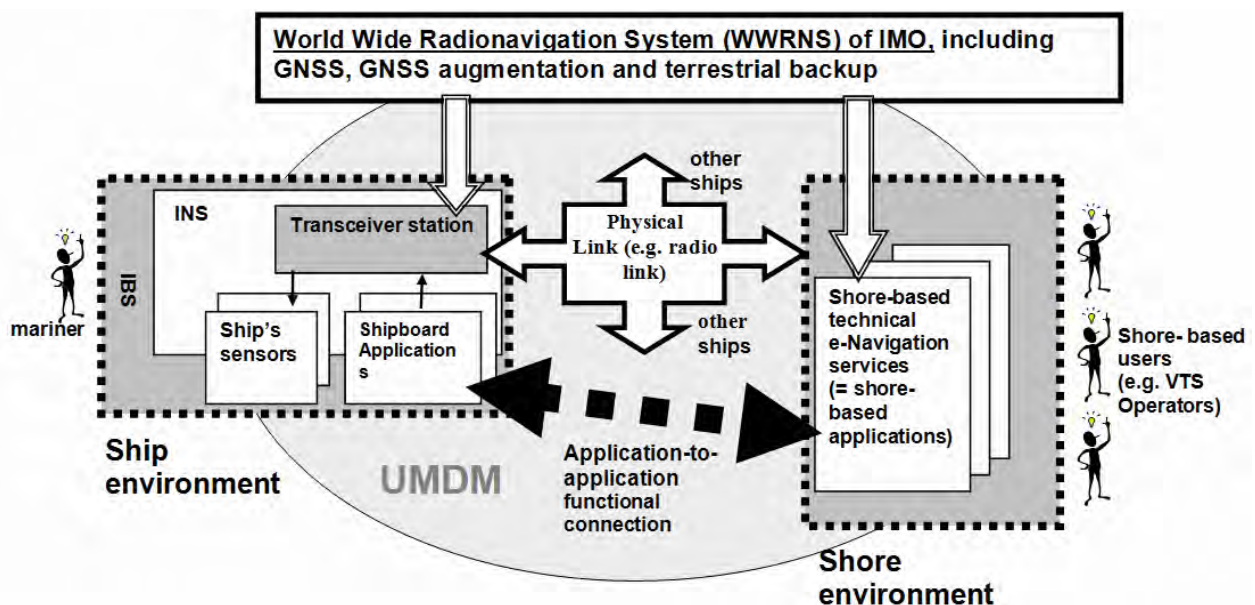


Fig. 2. e-Navigation architecture [1, 7]

IALA has started the “Initial technical e-Navigation architecture work” based on the following understanding of IMO’s e-Navigation concept in general, and the e-Navigation architecture specifically using the following quotations taken from IMO documents:

- In order to have the e-Navigation concept implemented, the architecture is a required step [4]: In order to prepare the strategy implementation plan several steps are required, such as capturing evolving user needs, developing an architecture and undertaking a gap analysis, a cost-benefit analysis and a risk analysis. These elements should provide a common and informed foundation for the creation of a detailed strategy implementation plan.
- The IMO is also specific regarding the functions and components of any technical e-Navigation architecture [4]: The overall conceptual, functional and technical e-Navigation architecture will need to be developed and maintained, particularly in terms of process description, data structures, information systems, communications technology and regulations. The architecture should include the hardware, data, information, communications technology and software needed to meet the user needs. The system architecture should be based on a modular and scalable concept. The system hardware and software should be based on open architectures to allow scalability of functions according to the needs of different users and to cater to continued development and enhancement.

## 5.2. Scope of the e-Navigation architecture

Further, IALA has undertaken this work, due to the invitation of IMO as stated in the following IMO documents:

- The above mentioned IMO document “Work programme - coordinated approach to the implementation of the e-Navigation strategy”; [4], as adopted by MSC86, contains several times the invitation to IALA to contribute [5].
- IMO NAV55 identified in particular the contribution of IALA to the “Initial e-Navigation Architecture” [7]: The group also noted that development of system architecture had taken place in the interim period within IALA. Accordingly, the group invited IALA to provide the results of these developments to the correspondence group.

## 5.3. The overarching e-Navigation architecture

The scope of this introduction to the IALA developed “Initial technical e-Navigation architecture” is represented by Fig. 2 below, which shows the shipboard entities, the physical link(s) and the shore-based entities. Figure 2 is an abstract representation of the e-Navigation environment. On the left there is a single “*ship environment*”. From the e-Navigation concept’s perspective the relevant devices within the ship environment are the transceiver station, the sensors and applications connected to the transceiver station, the Integrated Navigation System (INS) and the Integrated Bridge System (IBS). The transceiver station is shown as a single station, although in reality there may be several transceiver stations. The transceiver station interfaces via the physical link(s) with the appropriate technical e-Navigation services ashore.

Within the shore-based services there are particular technical services responsible for interfacing to the ship. All of the shore based technical services encapsulate the technology and, hence, reduce complexity. Functional interfaces of the shore-based technical services are defined in accordance with the requirement for open system architecture.

The operators ashore, e. g. VTS operators, pilot station operators, and lock operators, need the user applications to perform their tasks in co-operation with shipboard applications. From their perspective, it is neither the physical links nor the shore-based technical e-Navigation services that matter – they have been encapsulated for that reason. It is the functional links between the shore-based user applications and the shipboard applications which matter to the users on both sides. A similar setup of interactions applies for ship-to-ship and shore-to-shore applications.

Figure 2 also shows a dependency on the IMO World Wide Radio Navigation System (WWRNS), which provides position and timing information. The UMDM is an abstract and common data representation of the entities and relationships within the maritime domain. The bold arrow in Fig. 2 is the representation of the functional connections for data exchange between the shore-based applications and the “ship’s environment”, and vice versa. The physical path of the data exchange uses the physical links and the various physical interfaces between the shore-based applications and the “ship’s environment”. The functional connection is the abstract statement in regard to requirement analysis for the application-to-application data exchange. Physical links between (fixed) shore and (mobile) shipboard equipment each employ one or more appropriate mediums such as radio waves or light.

## Conclusions

This paper introduced the technical concept of describing maritime information in a user-friendly, simple and consistent manner using the IALA Universal Maritime Data Model (UMDM), a consequence of the IMO e-Navigation strategy. But IMO’s approach to UMDM should be much wider than preliminary description of the IALA UMDM and/or IHO S-100 and should refer to use in the future three interacting parts of e-Navigation architecture:

- shipboard integration of data processing devices,
- solution to application data/information exchange in relation ship-shore, shore-shore, ship-ship,
- shore based integration of a variety of different systems.

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