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| From: VTS Committee | VTS38-12.1.7 |
| To: ENAV Committee | 10th October 2014 |

Liaison Note

**IALA Recommendation e-NAV-140 On**

**The e-Navigation Architecture - the Shore-based Perspective**

# Introduction

In response to paper VTS38-9.2.8 submitted by the ENAV Committee.

# Action requested

The secretariat is requested to forward the VTS Committee response:

The VTS committee recognizes the work done by the ENAV committee on the e-Navigation Architecture from the Shore-based perspective. However, due to the size of the document, the wide-ranging extent of the material and the potential impact on VTS, the VTS Committee was not able to complete a full review of the document during VTS38. Some minor editorial changes are suggested as reflected in the annex.

**ANNEX**

Document Revisions

**Draft (2.20; 2013-09-25) Revision of**

**IALA Recommendation**

**e-NAV-140**

**On**

**The e-Navigation Architecture -**

**the Shore-based Perspective**

**Edition 2**

**October 2013**

**[December 2013]**

***AISM***Association Internationale de Signalisation Maritime ***IALA***

International Association of Marine Aids to Navigation and Lighthouse Authorities

20ter, rue Schnapper, 78100

Saint Germain en Laye, France

Telephone: +33 1 34 51 70 01 Fax: +33 1 34 51 82 05

e-mail: [iala-aism@wanadoo.fr](mailto:iala-aism@wanadoo.fr) Internet: [www.iala-aism.org](http://www.iala-aism.org)

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

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| --- | --- | --- |
| **Date** | **Page / Section Revised** | **Requirement for Revision** |
| 2010-November + 2011-January + 2013-Septem-ber | All sections | Progress from “initial” stage (Ed. 1) to more mature stage (Ed. 2) |
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IALA Recommendation on The e-Navigation Architecture - the initial Shore-based Perspective

(Recommendation e-NAV-140)

THE COUNCIL:

**RECALLING** that one of the aims of the Association is to foster safe, economic and efficient movement of vessels and the protection of the environment through the improvement and harmonisation of aids to navigation, vessel traffic services and other means world-wide;

**RECOGNISING** that the e-Navigation architecture will assist in the development and maintenance of e-Navigations applications for ship to ship, ship to shore, shore to ship, shore to shore, in particular in the following fields:

* shore-based technical services;
* technical means for communication;
* data modelling and referential data;
* Human Machine Interface presentations;

**RECOGNISING ALSO** that the e-Navigation architecture will:

* assist administrations in the efficient deployment of their operational and technical services to the mariner and to the maritime community;
* require administrations to maintain those operational and technical services to the mariner and to the maritime community with the service level, as published in their service portfolios;

**RECOGNISING FURTHER** that the “IALA e-Navigation stack”, i.e. the internationally harmonized and to some degree unified layer modelling, will assist in the creation of:

* a common comprehensive, persistent, harmonized, and consistent representation of agreed user requirements of IALA stakeholders, which are derived from maritime transportation processes and IMO’s stated user needs;
* commonly agreed, harmonized, and consistent operational procedures;
* unified Human Machine Interface presentations;
* an IMO governed Common Maritime Data Structure (CMDS);
* a framework for data encoding;
* a common shore-based system layout harmonized for e-Navigation as an engineering model to be used by IALA members as a reference;
* generic shore-based technical service engineering model;
* technology-specific shore-based e-Navigation services;
* internationally recognized verification, validation, and certification framework and procedures; and

**RECOGNISING FURTHER** that the “IALA e-Navigation stack” will assist administrations in the efficient deployment of their operational and technical services to the mariner and to the maritime community;

**NOTING**

* that the definition of e-Navigation has been established by the **International Maritime Organisation (IMO);**
* IMO’s “Strategy for the development and implementation of e-Navigation” (MSC85/25, Annexes 20 and 21);
* that IMO also calls this strategy a *“vision”* (MSC85/25; Annex 20, paragrah 4);
* that IMO has expressed an interest in the contribution of IALA to the work on e-Navigation (compare IMO MSC86/23/4, IMO MSC86/26, paragraph 23.26);
* that IMO has established preliminary user needs for both shipboard and shore-based users;
* that IMO has identified eleven core objectives for e-Navigation (IMO MSC85/25, Annex 20, para 5.1), *all of which* are relevant to IALA and its membership, as follows (quote):
* 1. facilitate safe and secure navigation of vessels having regard to hydrographic, meteorological and navigational information and risks;”
* 2. facilitate vessel traffic observation and management from shore/coastal facilities, where appropriate;
* 3. facilitate communications, including data exchange, among ship to ship, ship to shore, shore to ship, shore to shore and other users;
* 4. provide opportunities for improving the efficiency of transport and logistics;
* 5. support the effective operation of contingency response, and search and rescue services;
* 6. demonstrate defined levels of accuracy, integrity and continuity appropriate to a safety-critical system;
* 7. integrate and present information on board and ashore through a human-machine interface which maximizes navigational safety benefits and minimizes any risks of confusion or misinterpretation on the part of the user;
* 8. integrate and present information onboard and ashore to manage the workload of the users, while also motivating and engaging the user and supporting decision-making;
* 9. incorporate training and familiarization requirements for the users throughout the development and implementation process;
* 10. facilitate global coverage, consistent standards and arrangements, and mutual compatibility and interoperability of equipment, systems, symbology and operational procedures, so as to avoid potential conflicts between users; and
* 11. support scalability, to facilitate use by all potential maritime users.
* that IMO has established the initial version of the overarching e-Navigation architecture ( NAV57, WP.6, as incorporated by reference in NAV57 report to MSC);
* that IMO has finalized a gap analysis (NAV58, report to MSC, refers);
* that IMO has recognized the concept of Maritime Service Portfolios (MSPs) as a “key enabler” for e-Navigation (NAV59, WP.8, Annex, Table “examples of fundamental key enablers of e-navigation refers);
* that IMO has decided that the IHO standard S-100 should be the baseline for the IMO envisaged Common Maritime Data Structure (CMDS) and has established an IMO/IHO Harmonisation Group on Data Modelling (HGDM) (MSC90/22, Annex 22, refers);
* that IMO has recognized Coastal states’ VTS services provisions as well as their shore-based infrastructures as “key enablers” of e-navigation and has recognized IALA’s role in this regard (NAV59, WP.8, Annex, Table “examples of fundamental key enablers of e-navigation refers);
* that IMO has started to discuss the concept of a “Maritime Cloud” as another way to describe relevant elements of the overarching e-Navigation architecture, which is compatible and consistent with the above recognized overarching e-Navigation architecture (NAV59, WP.8, paragraph 3.13);
* that IMO has started work on the detailed shipboard architecture for e-Navigation with modular systems like Integrated Navigation Systems (INS) at the core (IMO NAV 58/6 Rev1, Annex 1, refers), and that IEC has finalized a test standard for the shipboard INS;
* that IMO has a Performance Standard in place for Integrated Bridge Systems (IBS);
* that IMO is in the process of finalization of an e-Navigation Strategy Implementation Plan (SIP);
* that IMO has decided that the IMO Member State Audit Scheme shall become mandatory as of 01 January 2015 (IMO Resolution A.1018(26), adopted 25 November 2009 refers), and that this may have an impact on the implementation of the e-Navigation, too;
* an increased usage of service level definitions to describe the quality parameters of those operational and technical services (compare IMO’s core objective No. 6 above);
* expected variations of service portfolios, i.e. possible variations in services and their service levels;

**NOTING ALSO** thatthe **International Hydrographic Organisation (IHO)**

* has entered into a formal agreement with IALA on mutual co-operation („Co-operation agreement between the International Hydrographic Organisation (IHO) and the International Association of Marine Aids-to-Navigation and Lighthouse Authorities (IALA)”, 2001);
* has established a Geo-spatial Information Registry (GI Registry), as defined by their publications S-100 and S-99;
* has introduced the notion of “products” as a internationally unified rule base for the combination of different parts of the GI Registry to “products” of IHO member authorities;

**NOTING ALSO**

* the work of various **IALA** Committees regarding e-Navigation within the scope of IALA;
* an increased need for service portfolio management, both for operational and technical services provided by an IALA National Member to the ship-board and shore-based users;
* that these operational and technical services are also “products” of the business processes of an IALA National Member;
* the need to revise IALA recommendations, guidelines, and manuals for the implementation of IMO’s e-Navigation strategy eventually; and
* that IALA is in the process of becoming a “Submitting Organisation” and a “Domain Owner” under IHO’s S-100/S-99 standards;

**NOTING FURTHER**

* that during a transition period both “e-Navigation compliant” services and systems and legacy services and systems will co-exist, and that that co-existence must not threaten the established level of safety and of efficiency and of the protection of the marine environment;

**NOTING FURTHER** that from the above IMO core objective No. 4 for e-Navigation it can be inferred, that

* there is a need for an international/global framework of measures and services to support all maritime transport processes, including the maritime logistics chain;
* IMO would support this framework by its e-Navigation strategy;
* IMO has developed and published a Concept of a Sustainable Maritime Transportation System (SMTS) (published on the occasion of the World Maritime Day 2013) and that IALA’s work is referenced frequently in this concept in particular regarding the “maritime traffic support and advisory systems”;

**ADOPTS**

* the e-Navigation Architecture – the Shore-based Perspective in the Annex of this recommendation;
* the “IALA e-Navigation Stack” in the Annex of this recommendation;
* an internationally agreed and recognized life cycle management model for IALA’s work regarding the different aspects of the “IALA e-Navigation Stack”;
* the concept of “products”; and
* the view that IMO’s e-Navigation strategy will support maritime transportation processes;

**RECOMMENDS** thatNational Members and other appropriate authorities providing marine aids to navigation services

* adopt the e-Navigation design and implementation principles in accordance with the Annex to this recommendation;
* adopt the “IALA e-Navigation stack” in accordance with the Annex to this recommendation;
* contribute to and support the individual strategic, operational and technical initiatives and projects consequentially answering IMO’s e-Navigation initiative as a result of the considerations regarding the e-Navigation architecture;
* take into account the e-Navigation architecture as described in the Annex when setting up domestic projects or when upgrading existing or implementing new Aids-to-Navigation, VTS, and VTMIS related infrastructure; and
* consider and support the above mentioned “Sustainable Maritime Transportation System” initiative of IMO.

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Annex

**The e-Navigation Architecture –**

**the Shore-based Perspective**

# Overview

This Annex describes the e-Navigation architecture from a shore-based perspective.

This Annex first provides background information on IMO’s e-Navigation concept, the driving forces which lead to its development, and IALA’s role in the e-Navigation concept. Within this context, the dual nature of IALA’s commitment to IMO’s e-Navigation concept is reflected. While there has been a long standing responsibility for architectural considerations of shore-based systems within IALA’s existing mandate, IMO’s e-Navigation concepts adds new dimensions to those architectural considerations. These are reflected in a summary of the overarching e-Navigation architecture.

The Annex goes on to introduce important principles of the e-Navigation architecture, such as the orientation towards information/data instead of technology orientation. The Annex then establishes relevant principles for a shore-based system architecture harmonized for e-Navigation.

A number of principles are introduced and explained, in particular

* the harmonisation of user requirements as derived from maritime transport processes and stated user needs;
* the harmonisation of operational presentation surfaces for users;
* the concept of layered structures, registers and unique identifiers;
* the harmonisation of data structures and models;
* interactions between applications, and
* functional and physical links ship to ship, ship to shore, shore to ship and shore to shore.

The Annex also explains (in details) the concepts of:

* products;
* the maritime service portfolio;
* operational and technical services;
* layered structures, registers and unique identifiers; and
* encapsulation.

This Annex then describes how it is possible to seamlessly derive technical requirements for the modules and components of the shore-based system from stated information needs and formats of the users (top down approach). The result of that top-down analysis is the so-called “IALA e-Navigation stack”, which is introduced this Annex. It also takes into account system engineering requirements and requirements of life-cycle management.

This Annex then discusses certain aspects regarding the place of the IALA e-Navigation stack within IMO’s e-Navigation strategy, in particular

* the relationship of the IALA Harmonized Data Model (IHDM) with the IMO governed Common Maritime Data Structure (CMDS); and
* the potential benefits of a similar layered structure for future shipboard equipment harmonized for e-Navigation.

This Annex continues to discuss the relationship of the e-Navigation architecture with other international and regional initiatives, namely

* the relationship with other shore-based systems which are set-up, operated and maintained by bodies other than IALA members, taking into account the concept of “single window”;
* the relationship with an IMO initiative which addresses the need of an international/global framework of measures and services to support a Sustainable Maritime Transportation System, including the maritime logistics chain.[[1]](#footnote-1)

e-Navigation implementation depends on two external contributions, namely the IMO defined World Wide Radionavigation System (WWRNS) (IMO Resolution A.953(23)), and the on-site infrastructure both onshore and onboard ships. These dependencies are finally addressed.

# Background

## IALA’s general mandate

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:

* harmonise standards for aids to navigation systems worldwide;
* facilitate the safe and efficient movement of shipping; and
* enhance the protection of the maritime environment.

The functions of IALA include, among other things:

* developing international cooperation by promoting close working relationships and assistance between members;
* liaison with relevant inter-governmental, international and other organisations. For example, the International Maritime Organisation (IMO), the International Organization for Standardisation (ISO), the International Hydrographic Organisation (IHO), the International Telecommunications Union (ITU), the International Electrotechnical Commission (IEC), and the International Commission on Illumination (CIE);
* liaison with organisations representing the aids to navigation users;
* addressing emerging navigational technologies, hydrographic matters and vessel traffic management;
* providing specialist advice or assistance on aids to navigation issues (including technical, organisational or training matters);
* encouraging IALA members to develop policies that address the social and environmental issues associated with establishing and operating aids to navigation. This includes issues such as use of aids to navigation as a base for the collection of data or other governmental or commercial services.

## IMO’s e-Navigation concept

IMO (MSC 85) adopted a “Strategy for the development and implementation of e-Navigation” (MSC85-report, Annexes 20 and 21).

Therein, IMO adopted the following definition of e-Navigation:

*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.*

Three mutually interacting parts of the e-Navigation architecture can be identified:

1. shipboard systems of information/data processing devices;
2. application-to-application data exchange via physical links ship to shore and shore to ship;
3. shore-based e-Navigation system architecture that integrates a variety of shore-based technologies and data processing devices.

In the abovementioned documents IMO has expanded this definition of e-Navigation into a *holistic vision*. This vision has influenced this Annex largely. Therefore, relevant paragraphs of the abovementioned IMO documents will be referenced and cited throughout this Annex.

## Consequential driving forces for IALA and IALA members due to IMO’s e-Navigation concept

IMO has stated the driving forces and the consequential goal for e-Navigation as follows:

There is a clear and compelling need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools that are optimized for good decision making in order to make maritime navigation and communications more reliable and user friendly. *The overall goal is to improve safety of navigation and to reduce errors.* However, if current technological advances continue without proper coordination there is a risk that the future development of marine navigation systems will be hampered through a lack of standardization on board and ashore, incompatibility between vessels and an increased and unnecessary level of complexity. (IMO MSC 85, Annex 20, para 2.1).

Consequential driving forces for IALA and IALA members, due to that e-Navigation concept are:

* **Increased demand for improved information/data processing in maritime services:** It is a requirement that more data is collected and stored in order to facilitate data comparison, data exchange and statistical evaluation;
* **Increased degree of automation:** An increased degree of automation is needed to process the increased amount of data and is required to assist shore-based operators and maintenance personnel;
* **Request for simplification of information sharing between information users and information providers;**
* **Increased demand for communication capabilities and capacity:** The maritime community requires user friendly and efficient communication systems that ensure confidentiality where required, integrity and availability of information being transmitted and received ship to ship, ship to shore, shore to ship, and shore to shore. Also, there is an increased demand for communication capacity for Search-and-Rescue and law enforcement aircraft;
* **Advent of digital information technologies:** Most information is now available in digital format both onboard ships and within shore-based systems;
* **Extended area coverage, up to global coverage:** There is a requirement for extended area coverage which can be fulfilled more readily by technologies presently under development;
* **Reduction** in staffing level: A steady reduction in staffing level is a demand by national governments; administrations require:
* an optimum of enhanced technical services to support in terms of both investment and maintenance; and
* an efficient life cycle management of the technical services in place.
* **Demand for improved cost/benefit ratios:** Administrations face an increased public awareness for cost/benefit ratios for the operation and maintenance of their shore-based systems;
* **International standardisation:** International standardisation has been recognised as a state-of-the-art description for technology. Hence, there is an increased need for information and documentation for a common, international and public understanding of system functions;
* **Open architecture:** Modular and open system design principles should be applied striving for “plug-and-play” capabilities. Open system architectures are more scalable and better maintainable. When individual components need to be replaced due to life-cycle management, there is a requirement to maintain the functional requirements of a shore-based system
* **Increased demand for formal quality assurance. Any additional comments?**

## IALA’s role in the e-Navigation concept

**IMO** has asserted the overarching governance of the e-Navigation concept as follows:

*The governance of the e-Navigation concept should reside in a single institution that has the technical, operational and legal competences needed to define and enforce the overarching framework with implementation, operation and enforcement taking place at the appropriate level – global, regional, national or local – within that framework.* This approach does not mean that the governing organisation has to carry out all tasks in-house – it can delegate as appropriate to competent bodies. Being responsible for establishing mandatory standards for enhancing the safety of life at sea, maritime security and protection of the marine environment as well as having a global remit, *IMO is the only organization that is capable of meeting the overall governance requirement.* (MSC 85, Annex 20, para 9.2)

On the other hand, IMO has recognized the need to delegate certain tasks to other international organisations. IMO considers IALA to be such a competent body because of its natural role and experience in shore-side matters (IMO MSC86/23/4). Also, IALA previously assisted IMO in developing the e-Navigation strategy (IMO MSC86/26, para 23.26). IALA is participating in the implementation plan of the e-Navigation strategy, by capturing user requirements, developing a shore-side architecture and performing gap and cost/risk analyses (IMO MSC/86/23/4 and IMO draft report of NAV55, para 11.11). Hence, IMO has invited IALA and other international organisations to participate in its work and provide relevant input. Thus, IALA has been recognized as a *steward to the domain of Vessel Traffic Management and Information Services (VTMIS), Vessel Traffic Services (VTS) as well as Aids-to-Navigation (AtoN) at large.*

Because of its general mandate, **IALA** has a responsibility to the maritime community to support national members providing shore-based services (ship to shore, shore to ship and shore to shore). In order to fulfil this responsibility for its membership IALA produces recommendations, guidelines and manuals. In the recognition that IMO’s e-Navigation concept – due to *IMO’s holistic vision regarding e-Navigation* – will bring about a *paradigm shift* both for IMO’s own work and for IALA and the maritime community at large, IALA formed the e-Navigation (e-NAV) Committee for the purpose of developing recommendations and guidelines on shore-based systems and services for e-Navigation. This work has brought forth the holistic and paradigmatic architectural concepts introduced and explained in this Annex.

Thus, IALA fulfils the task that IMO has stated is essential for the implementation of the e-Navigation strategy, namely coordination and standardization on a global scale, as far as IALA’s membership is concerned. In doing so IALA observes the definition and enforcement of the overarching e-Navigation framework as defined by IMO as the governing body.

## Consequences of IMO’s definition of the e-Navigation concept

From the above IMO definition of e-Navigation, the following points are understood:

* **Operational requirements (user requirements)** will be analyzed and their impact on the e-Navigation architecture will be assessed – thereby fulfilling the demand for a user requirement driven system architecture. Conversely, internationally analysed and consolidated operational requirements need to be represented in a way that is meaningful to the individual parts of the shore-based system architecture. These two tasks need to be continually performed as part of the life-cycle management of the shore-based system architecture.
* The e-Navigation concept is envisaged over a ship’s complete voyage from berth-to-berth. Therefore, the e-Navigation concept leads to a **high degree of commonality** of the shore-based system architectures of different national competent authorities. Also, to exchange relevant data between shore authorities involved in that berth-to-berth voyage of the ship, **interoperability** of the shore-based systems of different national competent authorities is needed. Both require a certain degree of international standardisation for operational requirements, system architecture considerations, and human-machine - as well as machine-to-machine interfacing.

Common service levels and standardised minimum capabilities are implied for all of the three mutually interacting parts of IMO’s e-Navigation concept, namely shipside, shore side, and the links in-between. These aspects are brought together in the IMO defined **“Maritime Service Portfolio”** concept and are intended to fulfil the IMO stated e-Navigation core objective to **demonstrate defined service levels** (MSC85/25, Annex 20, 5.1.6 refers).

## IMO’s instruments to implement the e-Navigation strategy

IMO has also already laid out an implementation path for their e-Navigation strategy, and is presently developing a more detailed **Strategy Implementation Plan (SIP)** for e-Navigation.

So far, IMO, by adoption through MSC,

* has asserted overarching governance of the e-Navigation (above section refers; compare also for even more specific statements of IMO the Annex 1 to Annex 20 of MSC85/25);
* has considered several instruments to implement e-Navigation, namely “relevant international conventions, regulations and guidelines, national legislation and standards” (MSC85/25, Annex 20, para 9.1.3) as well as IMO Performance Standards (MSC85/25, Annex 20, para 9.1.7 and elsewhere);
* has specifically announced its intention to “set performance standards appropriate for e-Navigation” for the shore side.
* IMO is “taking the lead in **setting the performance standards** appropriate for e-navigation covering all the dimensions of the system: shipborne, **ashore** and communications. These standards should be based on user needs and should encourage technology neutrality and interoperability of system components;” (Annex 1, para 1.5, to Annex 20 of MSC85/25)
* intends to set up a gradual transitional introduction plan, culminating in a situation “with mandatory equipage and use of a full e-navigation solution in the longer term” (MSC85/25, Annex 20, para 9.9.3). The relevant quotes of IMO are given below:
* “transition planning, taking into account the **phasing** needed to deliver early benefits and to make the optimum use of existing systems and services in the short term. The implementation plan should be phased such that the **first phase** can be achieved by fully integrating and standardizing existing technology and systems (the reduced architecture identified during the gap analysis) and using a reduced concept of operations. **Subsequent phases** should develop and implement any new technology that is required to deliver the preferred architecture and implement the overall concept of operations;” (MSC85/25, Annex 20, para 9.9.1; emphasis added)
* “Communications technology and information systems will have to be identified to meet user needs. This work may involve the **enhancement of existing systems** or the **development of new systems**. Any **impacts affecting existing systems** will need to be identified and addressed, based on technical standards and protocols for data structure, technology, and bandwidth and frequency allocations.” (MSC85/25, Annex 20, para 9.1.5; emphasis added)
* “implementation itself, in phases, perhaps **based on a voluntary equipage** of (integrated) existing systems to begin with, but **with mandatory equipage and use of a full e-navigation solution in the longer term**.” (MSC85/25, Annex 20, para 9.9.3; emphasis added)

It should be noted, that the **IMO Member State Audit scheme** will become mandatory as of 01 January 2015 (IMO Resolution A.1018(26), adopted 25 November 2009, refers). This would provide IMO the legal instruments to verify and validate the implementation of any e-Navigation related measures, amongst others, by its Member States.

For **IALA members** this means, that the current technical environment will still be relevant as IALA members move towards a shore-based system architecture harmonized for e-Navigation. However, in the usual courses of upgrading, recapitalization, changing user requirements and new regulations, the *IALA member will eventually be “e-Navigation compliant”.* IMO has stated that e-Navigation implementation will take place in phases. The first phase will be to integrate existing technology and systems. *But IMO has also stated that “e-Navigation compliance” is expected at some point.*

## IHO’s work on Geo-Spatial Registry (GI Registry) based on S-100/S-99

The **International Hydrographic Organisation (IHO)** is an inter-governmental organisation. In 2001 IHO and IALA have signed a formal agreement on mutual co-operation.[[2]](#footnote-2) During the recent years, IHO has also established a Geo-spatial Information Registry (GI Registry), as defined by their publications S-100 and S-99. This GI Registry is running on dedicated IHO computer systems, and it is fully operational since the beginning of 2011.

IALA has applied formally, under the above formal agreement with IHO, to be recognized as a “Submitting Organisation”, and IHO has applied to be recognized by IHO as an “Domain Owner” in the GI Registry. IALA thereby has agreed to comply with the rules and regulations of the IHO publications S-100 and S-99, as applicable.

IHO has also introduced the notion of “products” as an internationally unified rule base for the combination of different parts of the GI Registry to “products” of IHO member authorities. IALA has adopted the notion of “products” and is presently working on the first IALA product descriptions.

It should be noted, that the IHO’s notion of “products” is similar to the product notion of state-of-the-art business processes and business use case considerations.

# The overarching e-Navigation architecture

## The most generic architecture of the e-Navigation – “the three sides of the coin”

Taking into account the very definition of e-Navigation a rudimentary but still meaningful overarching e-Navigation architecture can be devised. It is illustrated in Figure 1. This Figure is a *graphical representation of the IMO statement of the “vision of e-Navigation”* (IMO MSC85/25, Annex 20, section 4, refers).



**“harmonized collection, integration, exchange, presentation and analysis of maritime information *onboard*”**

**“harmonized collection, integration, exchange, presentation and analysis of maritime information *ashore*”**

1. Rudimentary representation of overarching e-Navigation architecture: shipboard, shore-based and links in-between

This implies that all parts must be considered together to get the full understanding, i.e. they must be considered *holistically*; While there may be a certain degree of independence for the parts, for the detailed layout of e.g. technical systems onboard and ashore, the parts cannot be separated without missing the goals of IMO’s e-Navigation strategy/vision.

## The information/data flow at the core of e-Navigation and its consequences

IMO stated that e-Navigation should be *user needs* driven. This means that *user requirements* must be derived from user needs, while taking into account the requirements of the maritime transportation processes they contribute to.

*User requirements* can be described in terms of their respective *information needs* for their tasks to perform. The required *information items* are delivered at the *Human Machine Interfaces* of the applications as fulfilment of the user requirements. These information items are transmitted, stored, and processed as *data objects* by the technical systems involved. They are exchanged using the *functional links* between applications, both shipboard and ashore.

The following Table 1 (overleaf) summarizes the above relationships.

For the precise definitions of information vs. data compare the glossary.

|  |
| --- |
| * User needs (**user/information domain**) * Identified information needs (**user/information domain**) * Functions and services (**user/information domain**)   ------- **Human-machine-interface (Operational presentation surface)** --------   * Maritime data items (**datadomain**) * Maritime data encoding for data exchange (**data** **domain)** |

(From: IMO NAV56/8, paragraph 26)

1. Relationship between User/Information domain and Data domain

Hence, the key elements of the e-Navigation concept are the information flow between users and the associated data flow between applications. When there is an information flow between users, there is *always* a parallel data flow between applications associated with it.

The imagery of a “flow” is borrowed from the flow of water; hence, by analogy, the terms “information/data source” and “information/data sink” can be used with a similar meaning: They designate the ultimate originator and the ultimate destination respectively.

In addition, storage of data over longer periods of time together with the retrieval of that data is part of the e-Navigation concept.

This is because IMO specifically requested a “common information/data structure”, as follows:

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. (IMO MSC85/25, Annex 20 Section 8.2.1)

User requirements or operational requirements and their associated *information* *needs* can be represented in terms of appropriate *information structures* together with abstract descriptions of the processes and of the functionalities (including interactions) which are required to properly process the *data* to arrive at meaningful *information* for the users involved.

Since information items can and should thus be structured in an *orderly and meaningful* manner, the same should be required for data: Data can and should be structured in an orderly and meaningful way. When adhering to certain stated principles of structuring, such a structure is called a model, hence *data modelling* or *data model*.

Co-operation in *information*/*data* exchange ship to ship, ship to shore, shore to ship, shore to shore and other users is at the core of the e-Navigation architecture. It is this co-operative nature that prompts the need for harmonization in the definition of e-Navigation. Hence the co-operative nature is at the core of the e-Navigation concept, too.[[3]](#footnote-3)

Consequentially, the different dimensions of information/data flow need to be considered to understand the e-Navigation concept. These different dimensions include the following:

1. *Location of the participating users and/or applications:* on board ships, onboard aircrafts interacting with the maritime community and on shore, on board floating AtoNs, etc. This dimension highlights the requirement of a high connectivity.
2. *Distributed responsibilities* of stake holders, e.g. different authorities ashore operating in the same area, but with different tasks.
3. The large *variety of the nature and amount of information/data to be exchanged* between users/applications will result in a large variety of appropriate technologies to be considered.
4. *Quality (Quality of Service; QoS) requirements:* The usability, accuracy, integrity, reliability or availability, continuity, time behaviour, maintainability etc. need to be defined when analysing the operational requirements (user requirements).
5. *Security requirements:* Security, confidentiality etc. need to be defined when analysing the operational requirements (user requirements). Refer to ISO 27001 for further detail.

Eventually the data exchange and the processes and functionalities using that data need to be manifested in physical links, e.g. a physical communication link, and physical entities and devices, e. g. computer systems. Hence, requirements and limitations stemming from that physical world will have their impact on the e-Navigation architecture.

Following from the general requirement for *appropriate standardisation*, the *technical interfaces* of the entities involved as well as their *protocols* and *encoding techniques* used throughout the data flow chain should be standardised.

## From the e-Navigation concept to an e-Navigation architecture

### The overarching e-Navigation architecture

One more elaborate resulting representation of the overarching e-Navigation architecture is shown in Figure 2 overleaf. The shipboard entities, the physical link(s) and the shore-based entities are included in this representation of the overarching e-Navigation architecture.

On the left within Figure 2 is represented, for simplicity’s sake, a single *“ship technology environment”*. From the e-Navigation concept’s perspective the relevant devices within the ship technology environment are the transceiver station, the data sources and the data sinks connected to the transceiver station. The transceiver station is shown as a single station for simplicity’s sake, although there may be several transceiver stations. These devises receive or feed their data from/into a future “harmonized shipboard electronic environment supporting all e-Navigation shipboard user needs”.

The transceiver station interfaces the shipboard electronic environment with the *physical link(s)* to the appropriate technical services ashore.

The *shore-based services* provide the interfaces of the shore-based applications to the physical link(s). They *also encapsulate their specific technology* to the whole of the shore-based system architecture.

“Encapsulation” is “the process of compartmentalizing the elements of an abstraction that constitute its structure and behavior; encapsulation serves to separate the contractual interface of an abstraction and its implementation”. The encapsulation principle hides the technology’s sophistication from the shore-based system as a whole and thus *reduces complexity*. Amongst other benefits, it allows for *parallel work of the appropriate experts* in the particular technology of a given physical link.

The shore-based technical services use *data transfer network(s)*, which *distribute(s) the data*. [[4]](#footnote-4)

Similarly to the shipboard side the term “harmonized shore-based technical services (…) supporting all shore-based e-Navigation user needs” implies that present technologies and system architecture may not be fully supportive of the demands of e-Navigation.

The *user ashore*, e. g. VTS operators, pilot station operators, lock operators, etc., need the 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 services that matter – they have been encapsulated for that reason. It is the *functional links between the shore-based applications at hand and the shipboard applications* which matter to the users on both sides. It is appropriate, when considering abstract flow of data between applications, to use the term of functional links between participating applications. The relationship of functional to physical links is discussed in Appendix 1 as well as examples of physical links.

A similar setup of interactions applies for ship-to-ship and shore-to-shore applications.

Figure 2 also shows IMO’s *World Wide Radionavigation System (WWRNS)*, which includes GNSS, being presented as a system external to the e-Navigation architecture providing position and time information. A further discussion of that dependency is contained in a section below.

In Figure 2 the *IMO envisaged “Common Maritime Data Structure (CMDS)”* was introduced. The features of that CMDS and the role and contribution of IALA within it / to it are explained in the following section.

Figure 2 also shows the concept of the Maritime Cloud with the goal to show its context within the overarching e-Navigation architecture, thereby demonstrating the concept’s compatibility. In substance, the Maritime Cloud is a generalized communications infrastructure that includes all available methods of communication.[[5]](#footnote-5)

**Ship   
environment**

**Harmonized**

**shipboardI  
electronic  
environment  
supporting  
shipboard   
applications.**

**Communication.**

**Equipment**

Application-to-  
application   
functional connection



**mariner**



**Shore- based users providing harmonized shore-based operational services   
(e.g. SAR, VTS,**

**Port, MSI services)**

**Shore   
environment**

**Harmonized  
shore-based**

**technical**

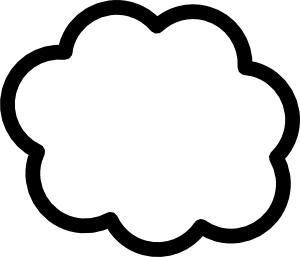
**services**

**supporting**

**shore-based applications.**

**World Wide Radionavigation System (WWRNS) of IMO, including GNSS, GNSS augmentation and terrestrial backup components**

**Common Maritime Data Structure**



**Physical**

**communication**

**links**

The Maritime Cloud

**INS/**

**IBS**

**Ship’s  
sensors**

1. Overarching e-Navigation Architecture showing the context of the Maritime Cloud and of applications

### Information-flow-oriented graphical representation of the overarching e-Navigation architecture

Figure 2 above does not yet convey the full notion of the e-Navigation concept, however: When considering the e-Navigation architecture, one should think in terms of information/data flow, application interactions, and user interfaces, as explained above. It is therefore necessary to refine that figure into an information/data flow oriented graphical representation.

Figure 3 shows the IMO recognized overarching 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” (which are still there of course).



(From: IMO NAV57, WP.6, as referenced by IMO NAV57 report to MSC and subsequently endorsed by MSC)

1. The overarching e-Navigation architecture

Figure 3 further develops Figure 2 by

* mapping the fundamental distinction between information and data domains (compare Table 1) to the vertical axis, while mapping the distinction ship-board, shore-based and links in-between (compare Figure 1) to the horizontal axis;
* explaining the relationship between the user requested information items, i.e. the stated information needs on the part of the users, on one hand and the “data provided in required format” by a Human-Machine-Interface in terms of a client-server-relationship;
* putting the concepts of operational Services, technical Services as well as Functional and Physical Links into a hierarchical perspective: The operational services prompt technical services, which use or constitute Functional Links, which in turn use or constitute Physical Links;
* identifying the place of the IMO introduced concept of “Maritime Service Portfolio”. The “Maritime Service Portfolio” is the overlay sum of all operational and technical services provided to shipping at the boundary indicated. The concept of the “Maritime Service Portfolio” will be further described in a section below;
* unfolding the relationship of shore-to-shore data exchange.

It should also be noted, that Figure 3 returns the usage of the term VTS completely to the operational realm.[[6]](#footnote-6)

The following *conclusions* can be drawn from Figure 3:

* When designing and describing e-Navigation applications, they should be described as interactions between applications using the data flow concept:
* *(Ultimate) sources of data* should be identified together with the data objectsstemming from those sources, i.e. the *source data*;
* Likewise, *(ultimate) sinks for data* should be identified, together with the data objects required by a particular sink in the information flow, i.e. *recipient data*;
* When there is *intermediate processing of data objects involved*, the appropriate algorithms should be stated;
* *For all data objects* should be described their relevant *attributes or properties*, including their constraints (such as permissible min/max values).
* Figure 3 also represents a statement regarding the distribution of responsibilities between operational stakeholders and engineers:
* *Operational stakeholders* state their information needs and the format at the user interfaces. The operational stakeholders should be continuously involved in the design and implementation process to ensure that their information needs and format requirements are met by the engineering process;
* *Engineers* analyse these information needs and take into account the management goals, in particular considering the life-cycle-management aspects of any system or component. The result of their analysis is *an engineering-like representation*;
* This engineering-like representation constitutes a kind of Service Level Agreement (SLA) between the operational stakeholders and the engineers, i.e. a statement/promise regarding a service level that a technical service delivers;
* *Engineers* will eventually provide the appropriate technical Human-Machine-Interface(s) (HMI), which fulfil(s) the stated information needs and the stated format requirements;
* A *Human-Machine-Interface (HMI)* can be any kind of appropriate combination of displays, keyboards, voice interfaces (microphone / loudspeaker), and other human interaction devices. The suite of those devices at one operational working position is called the *Operational Presentation Surface (OPS)*;
* The distribution of responsibilities is reflected in an *appropriate documentation framework.* This *engineering-like representation* is contained in several documents which are orderly arranged in an appropriate documentation framework that reflects the e-Navigation paradigm.
* The Common Maritime Data Structure (CMDS) spans the whole of the horizontal axis, i.e. it applies to the ship, shore and link parts of the overarching e-Navigation architecture. It is completely confined to the data domain in the vertical axis, however, as the name implies. There is a further description in a section below;
* The World Wide Radionavigation System (WWRNS) likewise affects many if not all technical components of both the shipboard and the shore-side regarding PNT, thus rendering it confined to the data domain. The dependency on the WWRNS will be further explored in a section at the end of this Annex.

### The IMO governed Common Maritime Data Structure (CMDS) at the core of e-Navigation

IMO has identified a “common data structure” at the core of e-Navigation, to be governed by IMO (compare Figures above). The scope of this “common data structure” is confined to the maritime domain, hence Common Maritime Data Structure (CMDS). Hence, the CMDS will serve as a common reference for all implementers and thereby accommodate for a certain of harmonization.

The functional relationships of the *Common Maritime Data Structure* are introduced in Figure 4:

1. The CMDS can represent any maritime entity, can be extended by the addition of new entities, and is accessible to any stakeholder or implementer.
2. The CMDS is an abstract representation of parts 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 engineers a common understanding of the entities and relationships and thereby allows for harmonization. The CMDS will contain some degree of data modelling.
3. The CMDS is neither a database nor an interface. The CMDS contains no details about physical representation of the entities within it. However, the CMDS can be used to guide the development of databases and interfaces, which are the physical representations of entities.
4. The CMDS is flexible and extendable for meeting future requirements. New entities can be added by any stakeholder through a process known as registration. Once registered, an entity is available to all stakeholders; there is open, public access. The CMDS is modular, and its subsets may be independently referenced.

Figure 4 illustrates how the CMDS will be created *– based on user requirements –* and how it will influence the components of the e-Navigation architecture when used by (software) engineers.[[7]](#footnote-7)

IMO   
governed   
**Common Maritime Data Structure (CMDS)**



User requirements

User requirements

Templates + methodology

Templates + methodology

(From: IMO NAV57, WP.6, as referenced by IMO NAV57 report to MSC and subsequently endorsed by MSC)

1. Scope and Impact of the IMO governed Common Maritime Data Structure

Figure 4 also illustrates the impact of the IMO governed Common Maritime Data Structure on

* the ship *technology environment harmonized for e-Navigation:* ship-board technical systems, devices and functions will need to be capable to process and use the CMDS;
* the *shore-based systems harmonized for e-Navigation:* similarly, shore-based technical services, systems, and functions need to be capable to process and use the CMDS;
* the *encoding for Physical Links*: any encoding needs to be compliant with the CMDS.

### The co-operation between IHO and IALA regarding IMO’s intended Common Maritime Data Structure

IMO has determined that the IHO standard S-100 should be the baseline for the IMO intended Common Maritime Data Structure. This standard describes, amongst other things, the IHO GI Registry which is structured using several “registers” to store metalevel formalized descriptions of, in particular, “portrayal” and “feature concepts.” The IHO standard S-100 introduces also the notion of “products”. Figure 5 below shows the relationship between the IHO GI Registry, the products being defined or envisaged by IHO and IALA, as well as the (future) options of IMO to reference those product specifications when implementing their e-Navigation strategy.



(From: IMO NAV57, WP.6, as referenced by IMO NAV57 report to MSC and subsequently endorsed by MSC; Note: IHO has dropped the distinction between “main registers” and “supplementary registers” in the meantime.)

1. The co-operation between IHO and IALA regarding IMO’s intended CMDS

### The concept of the Maritime Service Portfolio

The IMO has introduced the term “Maritime Service Portfolio”. A Maritime Service Portfolio (MSP) defines and describes a 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. Mainly, the services and MSPs are provided from a-shore or shore-based. MSPs should be developed to achieve harmonization, modernization, integration and simplification on board and ashore, taking into account the use of the IHO's S-100 standard.

The objective of the MSP concept is to align global maritime service with the need for information and communication services in a defined operational area. To achieve that, the first step should be to identify the need for information services and communication infrastructure in the different areas. A set of services will require a certain communication infrastructure capacity, varying from area to area.

The international work on Maritime Service Portfolios (MSPs) has only now started, and several interested parties such as IALA members or regional projects, are creating first contributions. Thus, any definition regarding the details of MSPs at this stage should be considered tentative and subject to change.

IALA has started work to explore the structure of the MSPs, which is eventually expected to contribute to IMO when defining MSPs. The following are initial findings from IALA’s work in this regard.

The starting point for understanding the concept and the potential of the MSPs is the individual service. A service is the fundamental building block of any MSP. *The generically defined operational and technical services can be arranged in a linear list,* which is only subdivided by the distinction of “operational” and “technical”.

Examples of operational services are the well-established services “Navigational Information Service (NIS)”, “Navigational Assistance Service (NAS)”, “Traffic Organisation Service (TOS)” or “Search and Rescue Service (SAR)”, to name a few. Technical services are for example any and all radio communication services. There may be some services which exhibit two faces, depending on how they are approached. Examples for these services are the visual Aids-to-Navigation services, which could be subdivided further into floating and fixed.

It should be noted, that there are interdependency relationships between the services, i.e. an operational service would require one or several technical service(s) to perform its desired functionality or a technical service would require one or several technical service(s) to perform its desired functionality. Thus, there would be interdependency cascades between the services which will become apparent as soon as one would look into the service description. For example, any of the above mentioned examples for operational services would require at least one technical service for radio communication.

The point of the MSP is *to* ***purposefully*** *bundle together a selection of those individual operational and technical services into a set and designate a specific name to that set.*

Both aspects are equally important:

* The *purpose* of the intended set determines the selection of the specific operational and technical services to be bundled together in a MSP. The variety of different purposes to compose MSPs introduces a degree of liberty and flexibility.

Possible dimensions for purposes may be e.g.:

* + functional: the purpose would be to provide a certain functionality to the maritime domain (examples are given below).
  + geographical: the purpose would be to designate which services would be available in a defined geographical area.
  + Stakeholder oriented: A specific stakeholder may wish to define his own MSP for describing his portfolio offered to the maritime community.
  + Regulatory oriented: A regulatory body may use a MSP to achieve regulatory goals in simultaneously simple and precise terms, such as prescribing a minimum level of service provision in its area of competency.
* The *name* of a MSP must be carefully chosen to reflect the purpose of the MSP on one hand, being *practical* for usage on the other hand. While thus already *conveying purpose* and providing a means to handle, the name also provides *a means to reduce complexity by encapsulation,* i.e. the name of the MSP encapsulates all services bundled by this MSP.
* *Illustration:* The relationship between services and MSPs could be illustrated by analogy given by chemistry. The atomic elements (in chemistry) would by analogy be the services, while the molecules (in chemistry) would be the MSPs. Thus as a limited number of elements (in chemistry) allows for a large number of molecules to be composed (in chemistry), a limited number of well defined services eventually would allow to defined a number of MSPs. This analogy would also hold true in some other important regards: “Water” (in chemistry) is a simple name for the molecule consisting of two hydrogen and one oxygen atoms, and this name meaningfully conveys the features of water and also effectively encapsulates all the details of the chemistry of water. The encapsulation of the MSPs in regard to the services could be understood similarly.

Different MSPs will eventually reference the very same services. Thus a *synergy* is created, because the very same service definition (as contained in appropriate international documentation or standards) will be “re-used”.

The concept of the MSP thus introduces a certain degree of liberty to create MSP definitions, thus providing the required flexibility. To prevent loss of common understanding it would be required to thoroughly standardize the relevant services internationally.

There could exist cascades of MSPs, too, as one MSP may use another existing MSP for ease of reference.

The above description is in the generic domain; i.e. it does not yet consider the several instances of one specific generic service provided by different individual competent authorities or stakeholders. The requirement for international standardization of the services follows from the desire to harmonize the service quality delivered by different individual providers of this service on the instance level. The challenge will be for any such international standardization to strike an appropriate balance between international harmonization on one hand and necessary flexibility to adapt a service provision to local needs.

A relevant part of the international MSP definitions are, should and will be done at and by IMO. On the other hand, there are regional, national, and local competent authorities who legitimately would use the MSP concept for their purposes, e. g. by defining their specific MSPs. In addition, there may be stakeholders beyond the competent authorities domain, which also may wish define their specific MSPs for their purposes. The goal of e-Navigation, namely to achieve a maximum harmonization in the maritime domain, would be achieved once there is a common, agreed, standardized list of both services and fundamental MSP definitions, to which the more specific MSPs could point or reference.

Thereby, there is margin to reduce complexity (namely by encapsulation of individual services in MSP, and less comprehensive MSPs in more comprehensive MSPs) while maintaining consistency by using the common building blocks, i.e. the individual services.

MSPs are only valid together with at statemento where they are applied. There have been proposed several equally valid methods of applications of MSPs:

* the MSPs applied to *geographical areas*, i.e. the *coverage concept*: IMO already seems to have given an area definition regarding MSPs in this regard: Port/Harbour, Coastal, Ocean, Off-Shore, Remote/Polar. This concept introduces the notion of “blanket coverage”, and there are certain operational and technical services which – due to their nature - are provided in “blanket coverage” fashion.
* the MSPs applied to a *shipping route topology based on the analysis of the traffic pattern* in a given sea area. Thus, different MPSs may be applied to different routes, according to requirements of the traffic pattern in a route. This concept would require a route topology modelling and a traffic pattern analysis of the sea area under consideration.
* the MSPs applied to *phases of vessel voyage*: Different phases of a vessel’s voyage have different needs for service provisions, i.e. different MSPs to be provided.

It is expected, that there will be an identified margin, for all three concepts to co-exist eventually, as it is clearly recognized that not just one concept will satisfy all requirements or fit all relevant circumstances. The present state of discussion regarding categorization of MSPs at IMO NAV is that a (future) MSP categorization should be based on geographical area definitions (IMO NAV59 WP.8, paragraph 3.18f). In the absence of a complete understanding of the structure and content of the MSPs, more work has to be done on this internationally.

## The meaning of “harmonized equipment supporting applications”

In Figure 2 (see above), i.e. in the graphical representation of the overarching e-Navigation architecture, the term “*harmonized shipboard electronic environment* *supporting shipboard applications*” implies that there is expected to be in the future a well-defined set of functions and/or components with a potentially different shipboard technical architecture.

It is recognized that the presently available *modular concepts of the Integrated Navigation System (INS)[[8]](#footnote-8)* and of the *Integrated* *Bridge System (IBS)* will be foundational when defining the future shipboard technical architecture harmonized for e-Navigation. Compare IMO NAV58/6, Annex 1, for a “more detailed shipboard architecture” which centers on the IMO defined concepts of INS and IBS.

Similarly to the shipboard side the term “*harmonized shore-based technical services* (…) *supporting applications”* implies that present technologies and system architectures may not be fully supportive of the demands of e-Navigation.

# Focus on the shore-side – the Common Shore-Based System Architecture

This section focuses on the shore-side system architecture, as introduced in Figure 3 and explained in the previous section. Since the e-Navigation concept is mainly about information/data flow as introduced above, the shore-based system architecture under consideration in this section extensively uses Information Technology (IT) concepts and terms.

The shore-based systems of IALA National Members are built to serve similar purposes and to perform similar tasks in particular in the realms of Aids-to-Navigation and VTS/VTM. Therefore, already today they have similar architectures. By standardizing the architecture of IALA National Members’ shore-based systems benefits could be gained.

An additional impact is created by the globalization of the system architecture by the e-Navigation concept. E-Navigation will require as a key strategic element internationally harmonized system architecture.

Therefore, it follows that IALA National Members’ shore-based systems should have a common architecture, which would comply with the e-Navigation concept, i.e. the Common Shore-based System Architecture (CSSA). It is introduced in this section and illustrated by Figure 7 overleaf.

In Figure 7 the following graphical symbols are used:

* *Interfaces* between entities involved are symbolised by a little circle and a line leading to the system which provides and owns the interface;
* *Technical systems* are symbolised by cubes, which expresses the encapsulation principle explained above (black boxes);
* *Human-Machine-Interfaces*, indicated by the acronym *HMI*, and Machine-Machine-Interfaces, i.e. mainly IT or computer interfaces, indicated by the acronym *M2M*. The figure shows, that the CSSA can be used to support a variety of HMI to different shore-based users simultaneously.
* The arrows with the dotted lines indicate requirements, which are put forward by the entity at which the dotted line starts;
* Requirement arrow(s) always point to interfaces (circles). This is to indicate, that the interface(s) fulfil the requirement(s).

The CSSA is further detailed in the IALA Recommendation on the Common Shore-based System Architecture.



1. The e-Navigation architecture with focus on the shore-side (simplified representation; i.e. without CMDS and WWRNS)

# The “IALA e-Navigation Stack”

## Introduction and Scope

So far the question is still unanswered, how can engineering requirements be seamlessly derived from stated user requirements, which are informed by user needs. This derivation is required because IMO required a user needs driven design for the e-Navigation architecture; quote:

“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 scaleable 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.” (MSC85/25, Annex 21, §5)

Besides, the so-called **traceability** achieved by the seamless derivation is a highly desirable goal in system engineering. To that end, the so-called *“IALA e-Navigation stack”* was devised as introduced in this section: The IALA e-Navigation Stack is an internationally harmonized/unified modelling layer for the shore-side, specifically developed for e-Navigation. The idea of the stack is to represent the different working areas of IALA regarding e-Navigation in a layered model. It follows the philosophy of the Open System layered model, providing a seamless framework for IALA’s work for the shore side starting top from User Requirements down to the shore-based system architecture and the specific technical e-Navigation services. The IALA e-Navigation Stack is informed by maritime transportation processes and user needs.

This section will remain focussed on the shore-side first, but will eventually show the place of the “IALA e-Navigation stack” within the overarching e-Navigation architecture and will then specifically investigate its relationship with the ship-board side.

Table 2 provides an overview of the “IALA e-Navigation Stack”.

|  |  |  |
| --- | --- | --- |
| **Acronym of layer** | **Name of layer** | **Name of sub-layer** |
| **Maritime Transportation Processes (incl. Logistics Chain)** | | N/A |
| **IMO User Needs** | | N/A |
| **ISHR** | **IALA Stakeholders Harmonized User Requirements** | |
| **UOPS** | **IALA Unified Operational Presentation Surface** | |
| **IHDM** | **IALA’s contribution to the IMO governed Common Maritime Data Structure (CMDS)** | Data properties definitions |
| Data objects definitions |
| **MDEF** | **IALA Maritime Data Exchange Format** | Encoding-free sentence definitions |
| Technology specific encoded sentences |
| **CSSA** | **IALA Common Shore-Based System Architecture**  **Technology-specific level** | Generic part of CSSA |
| Technology-specific part of CSSA |
| **National / regional adaptation** in their appropriate procurement documentation | | |
| **Contractor / industry implementation** | | |

1. Simplified representation of the “IALA e-Navigation stack” (highlighted by double lines) within its context

The IALA e-Navigation stack consists of the following layers:

* **IALA Stakeholder’s Harmonized Requirements (ISHR);** informed by maritime transport processes and by user needs of stakeholders as represented at IALA. The goal is to create *one (1) common comprehensive, persistent*, *harmonized*, and *consistent* representation of *agreed* user requirements of IALA stakeholders.

This layer would consist of a harmonized collection of these user requirement statements, the documentation of which should be in the required depth of detail and should also be using *validation-supportive* format(s) such as a *requirement description / modelling languag*e. Hence, the user requirements would be captured in an appropriate template.

Complementing the ISHR and as a consequence, a set of *commonly agreed, harmonized, and consistent operational procedures* will follow from and thereby complement the ISHR.

* **IALA UOPS: IALA Unified Operational Presentation Surface**; the idea is, that there is a *globally unified* description for the functionality of the Human Machine Interfaces provided to operators at *shore-based work places*, e.g. at VTS Centres. This layer would consist of a harmonized and – as far as possible – unified collection of *presentation, portrayal and functionality requirement statements for the Operational Presentation Surface*, i.e. for all aspects of HMIs at shore-based work places. It could be used both by administrations and manufacturers of such equipment as a common requirement statement.

It is understood, that the degree of unification which can be achieved within the UOPS may vary with different functionality under consideration; there may be areas of functionality were there can be achieved a large degree of unification, while there are areas of functionality, where there can only be achieved harmonization. Various configuration options should also be considered a viable avenue to achieve harmonization or even unification because regionally different settings could be mapped into configuration options.

The individual presentation, portrayal, and functionality requirement statements would be captured in appropriate templates.

* **IALA Harmonized Data Model (IHDM)**; the notion of data models has been introduced in previous sections. The IHDM is a subset of CMDS and would incorporate and thereby absorb the IALA knowledge – as far as relevant to data modelling – at large as expressed in IALA Guidelines, IALA Recommendations. The IHDM specifies relevant material from concurrent IALA initiatives, such as the IVEF and the AtoN metalevel description.
* **IALA Maritime Data Exchange Format (MDEF)**; this would be based on the IHDM and would facilitate a *flexible application level encoding* description, allowing for a variety of different application level encoding techniques and interfacing protocols making use of the same set of defined IALA MDEF sentences. The IALA MDEF would allow for the application-oriented composition of “sentences” using, as building blocks, the IHDM defined data objects, thus allowing flexible usage of the same IHDM defined data objects in different application data exchange contexts, while still staying away from encoding constraints. These encoding-free sentences would be contained in an appropriate sub-layer (see Table 2).

The technology-specific encoding derived from these encoding-free sentences would only later be introduced at the technology level. Since some technologies are also internationally employed, such as the AIS Application-specific Messages (ASM), the MDEF contains an additional sub-layer to capture these internationally harmonized sentences with technology-specific encoding. Examples for these sentences would be the AIS Application-specific Data Containers (ASC).

* **IALA Common Shore-based System Architecture** (**CSSA**) (including the Technical Services). The IALA CSSA would cover the following two aspects:
  + *Generic definition/description* of the system layout of the Common Shore-based System and the layout and generic functions of a Technical Service;
  + *technology specific descriptions of the individual technologies within the scope of the CSSA*; the AIS Service (Ed 2.0) serves as an example in this regard.

The IALA e-Navigation stack comprises the layers from ISHR to CSSA; **national and/or regional bodies**, indicated below the IALA e-Navigation stack in the above Table 2, adapt the stipulations of the IALA e-Navigation stack to their national and/or domestic procurement environments, while **contractors or industry** at large implement them to create really existing systems and devices. Both national and regional bodies as well as industry are not part of the IALA e-Navigation stack but participate in the system engineering process and provide feedback to IALA appropriately.

A derivation of the “IALA e-Navigation Stack” from general principles is contained in Appendix 2.

## The need to employ a system engineering model in conjunction with the IALA e-Navigation Stack

Considering the rather complex nature of the e-Navigation architecture and the many technologies involved, IALA *encourages* its members to apply *a* state-of-the-art **system engineering model** for the information/data, the abstract models, and the technical systems involved: Hence, a system engineering model governs the interactions between different layers of the IALA e-Navigation stack. Also, the system engineering model provides a life cycle management concept for the IALA e-Navigation stack.

*An* internationally agreed and recognized system engineering model is employed for the IALA e-Navigation stack, as described in accordance with ISO/IEC 15288 standards series. It facilitates both a seamless top-down derivation of technical functionality from stated user requirements as well as a bottom-up feedback chain taking into account the impact of technology on human-machine-interaction. In both directions traceability and consistency of the respective requirements is maintained, as well as the integrity of the process at large.

## Documentation framework for IALA e-Navigation stack

Recognizing the need for a harmonized documentation scheme providing an orderly and systematic methodology for documentation housekeeping within IALA (i.e. the “landing pads” for the different aspects of the IALA e-Navigation stack), an **IALA documentation plan** will be required eventually. It should be harmonized with the proposed IALA e-Navigation stack.

## The IALA e-Navigation Stack – summary and conclusions

The IALA e-Navigation stack consists of a number of well defined “layers”, which are arranged hierarchically. The different layers are arranged in a top-down fashion, starting with user requirements as the top layer, which are informed by maritime transportation processes, including logistics chain, and IMO defined user needs. Thereby the IALA e-Navigation stack is “user needs driven” from its very outset.

The different layers of the IALA e-Navigation stack are shown in Table 3 overleaf in top-down order of appearance and within the context of maritime transportation processes and IMO defined user needs on one hand and national/regional bodies and/or industry on the other hand.

Future work of IALA should be structured in accordance with the so-called IALA e-Navigation Stack since the IALA e-Navigation Stack would provide the conceptional framework for practically all working areas of IALA while being in harmony with the “core objectives” and the “key strategic elements” of the IMO e-Navigation strategy concept.

By employing the IALA e-Navigation Stack, IALA would prepare itself for the international harmonization intended and required by IMO’s e-Navigation strategy concept from the perspective of the IALA membership.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Acronym of layer** | **Name of layer** | **Name of sub-layer** | | **Administered item of layer** | **Interaction between layers  in accordance with system engineering model ISO/IEC 15288** |
| **Maritime Transportation processes (incl. logistics)** | | N/A | | N/A | Informs upper layers of IALA e-Navigation Stack |
| **IMO User Needs** | |
| **ISHR** | **IALA Stakeholders Harmonized User Requirements** | | | user requirements | Top-Down  Path  Bottom-Up-Path |
| **UOPS** | **IALA Unified Operational Presentation Surface** | | | presentation library entries, portrayal descriptions, and/or presentation requirements |  |
| **IHDM** | **IALA Har-monized Data Model** | | Data properties definitions | data properties |  |
| Data objects definitions | data objects |  |
| **MDEF** | **IALA Maritime Data Exchange Format** | | Generic sentence definition layer | Encoding-free “sentences” (syntax and semantics for data exchange without giving encoding constraints) |  |
| Technology-specific sublayer(s) | Internationally harmonized technology-specific encoded “sentences” (e.g. in IEC61162, AIS VDL message, or XML) |  |
| **CSSA** | **IALA Common Shore-Based System Architecture**  **Technology-specific level** | Generic part of CSSA | | N/A |  |
| Technology-specific part of CSSA | |  |
| **National / regional adaptation** in their procurement documentation | | | | |  |
| **Contractor / industry implementation** | | | | |  |

Notes:

* The IALA e-Navigation stack is highlighted by a box in above table; the layers not included in the highlighted box do not belong to the IALA e-Navigation stack but describe main parts of the context in which the IALA e-Navigation stack operates.
* The entries in the respective registries above are defined and described using appropriate templates.
* The “sentence” at that IALA MDEF should not be construed as an interface sentence (such as e.g. IEC 61162 sentences) in the encoding-free sublayer, but is an encoding-free and orderly arrangement of IHDM defined data objects taking into account semantic considerations. Any IALA MDEF “sentence” can be encoded for transmission in various ways, eventually. Examples of this internationally harmonized encoding are collected in the appropriate sublayer.

1. Complete graphical representation of the IALA e-Navigation stack

# The Place of the IALA e-Navigation Stack within IMO’s e-Navigation

## The context of the IALA e-Navigation stack within the wider context of IMO’s e-Navigation strategy

Figure 7 shows the place of the IALA e-Navigation stack within the overarching e-Navigation architecture in general. It also shows, to which part of the overarching e-Navigation architecture the layers correspond.



1. The place of the IALA e-Navigation stack and its layers within the overarching e-Navigation architecture

It should be noted, that this correspondence also serves as a proof of concept.

It should further be noted that the principles implied for the IALA e-Navigation stack may, could and – in some regard – should be applied to the emerging “detailed shipboard e-Navigation architecture” as well (Table 4 (overleaf) shows these relationships in a graphical representation):

* Some analogy exists between the stipulations and requirements that lead to the IALA e-Navigation stack and stipulations and requirements that exist for the shipboard side of IMO’s e-Navigation concept;
* A similarly layered architecture for the shipboard side may be beneficial for all stakeholders involved, or may even be required as a necessity to reap the full benefits intended by IMO’s e-Navigation concept;
* Most specifically, the IALA Harmonized Data Model (IHDM) eventually would be part of the same IMO governed Common Maritime Data Structure (CMDS).

| **Description of Layer** | **Shipboard side** | **Kind of interactions on layer** | **Shore-side** |
| --- | --- | --- | --- |
| **Maritime Transportation Processes, including Logistic Chains** | | | |
| IMO defined user needs inform respective stacks | **Shipboard User Needs** |  | **Shore-based User needs** |
| **---------------------------------- SAR User Needs -----------------------------------------** | | |
|  | **Shipboard e-Navigation stack** |  | **IALA e-Navigation stack** |
| Harmonized user requirements, captured in dedicated documents and/or in appropriate user requirement registers | **Shipboard user requirements** | *Harmonized interaction on user task level and/or operational service required*, hence also consequential harmonization of information needs of users required | **IALA Stakeholder’s Harmonized Requirements (ISHR)**  (to be easily referenced by IMO) |
| Harmonized requirements for presentation of data to users on human machine interfaces, requirements for presentation captured in appropriate registers | **Shipboard presentation/portrayal requirements** | *Certain degree of similarity* of operational presentation surfaces of shipboard and shore-side *desirable*. | **IALA Unified Operational Presentation Surface (UOPS)** |
| IMO governed Common Maritime Data Structure (CMDS) | **A shipboard subset of the CMDS** | *Certain degree of harmonisation may be achieved by the CMDS.*  *Note: Stringent harmonization* would be required to achieve the goals of e-Navigation completely. The degree of IMO governance determines the degree of harmonization achieved. | **IALA stakeholder’s subset of the IMO CMDS**, i.e. **IHDM** |
| Harmonized Data Exchange Format(s), encoding-free definitions | **A shipboard data exchange format**, using CMDS definitions | *Certain degree of similarity* of exchange formats of shipboard and shore-side imposed by use of CMDS defined data objects | **IALA Maritime Data Exchange Format (MDEF)** |
| Technical system architecture and technologies, including encoding techniques, interfacing technologies and protocols | **A shipboard technical e-Navigation architecture** | *Similarity of design principles* | **IALA Common Shore-based System Architecture (CSSA)** |
| \* generic |  | \* generic |
| \* technology-specific |  | \* technology-specific |
| **Specific Communications technologies providing physical links,** i.e. ***technical compatibility and interoperability required*** |
|  |

* Note regarding the **“Shipboard e-Navigation Stack”:** The names of the layers need to be determined.

1. The interactions between layers of the IALA e-Navigation stack and peer layers on the shipboard side

The following features exposed in Table 4 should particularly be noted:

* Different degrees of co-operation and/or similarity between peer layers on the shipboard side and the shore side: At each layer of the IALA e-Navigation stack, there is a corresponding level in the shipboard e-navigation stack. IMO has developed shipboard user requirements and these relate to the ISHR in the IALA e-Navigation stack. Similarly, shipboard portrayal / presentation requirements are a peer layer of the IALA UOPS. Moving down the stack, the shipboard data model and IHDM will be subsets of the same IMO governed Common Maritime Data Structure. Finally, the detailed shipboard technical architecture for e-Navigation and the IALA CSSA will correspond to each other by virtue of the similarity of underlying design principles. Compatibility and interoperability will be required for the physical communication links between ships and shore, however.
* Stringent international harmonization would be required for some communication link technologies to be established between ship and shore. Stringent international harmonization within the IMO governed Common Maritime Data Structure (CMDS) would be required to achieve the main goal of e-Navigation completely, i.e. harmonization. The degree of IMO governance determines the degree of harmonization achieved by the e-Navigation strategy.

It should be noted that the above stack approach complements the present considerations of IMO regarding a detailed shipboard architecture (such as given in NAV58/6, Annex 1), adding a certain additional view point as described above. It does not contradict those IMO considerations regarding detailed shipboard architecture.

## The relationship between the IALA e-Navigation Stack and the IHO GI Registry

The following Figure 8 (overleaf) demonstrates the relationship of the IALA e-Navigation Stack with the IHO GI Registry and its individual registers.



1. Relationship of the IALA e-Navigation Stack with the IHO GI Registry

# Relationship with other international initiatives

## Relationship of a shore-based system with other shore-based systems

### Topologies for shore-based systems

Along the maritime and inland waterways there are and will be different shore-based systems operating giving services to the mariners and the shore-based users, i.e. “e-Navigation compliant” systems and legacy systems. Those different shore-based systems should interact with the systems on board of ships and other shore-based systems.

This can be on a local, national, regional or global scale.

* *Local systems:* Local systems provide services to users in geographically confined areas of waterways. Their main goal is to serve the mariner in that confined area.
* *National systems:* National systems provide services to users of appropriate waterways in their respective countries.
* *Regional systems:* Regional systems provide services to users in a specific region of the world. Such a system could for instance serve the St-Lawrence-Seaway, the whole Baltic area, the Malacca Strait, as a region.
* *Global systems:* Global systems provide services on a world-wide scale.

Every system comprises a set of components which provide the specific services for the different users in their appropriate area of responsibility.

At present, connectivity between shore-based systems is sometimes limited due to present architectural constraints, i.e. at present not every shore-based system is able to interact with any other system on whatever scale in principle.

Figure 9 (overleaf) illustrates how the above systems communicate with each other and with the mariner. The lines show a substantial sample of the possible relations between systems and mariners. In order for these relationships to work efficiently there needs to be commonality of the data objects and their format.

An IALA National Member generally operates and maintains one of the national systems (compare highlighted national system in Figure 9). Hence, an IALA National Member needs to take into account the required connectivity to the other shore-based systems operated and maintained by other stakeholders (compare e.g. Annex 2 to Annex 20 of IMO MSC85/25 for a list).

Figure 9 also provides an example of a vessel interacting with shore-based authorities using a “single window” provided by the national system No.3. National system No. 3 would be responsible to disseminate the data required by the other shore-based systems indicated by the dotted rectangle, i.e. national system No. 4 and regional system No. 2.

### Necessary Inter-System data exchange as a resulting consequence

For the shore-based systems to work in an efficient way, i.e. increasingly automated, standardized data exchange between those systems is necessary. Standardized data exchange between the shore-based systems will result in a more consistent and reliable system interaction and data.

Standardized data exchange will also minimize the burden on the mariner for giving information to the shore-based authorities and will ensure more reliable and more complete information about shipping.

Standardized data exchange requires both a standardized data model *and* standardized data exchange formats: A standardized data model describes the data exchanged by using data property definitions. Each and every data object as well as each and every property needs to be identified by an appropriate universal identifier.

There are several *data encoding* *options* to exchange the same data item of the IHDM by using different data exchange formats, each of which is tailored to a specific need.

In addition, there are several *data transmission technology options* available to transmit the encoded data.



1. Topology of different kind of shore-based systems

## Relationship with an IMO envisaged “Sustainable Maritime Transportation System”

**IMO** has stated as one “core objective” of their e-Navigation strategy *that e-Navigation should “provide opportunities for improving the efficiency of transport and logistics”* (MSC85/25, Annex 20, section 5.1.4). This puts the IMO’s e-Navigation strategy into a larger context, which transcends the berth-to-berth scope of the e-Navigation strategy (compare definition of e-Navigation and following Figure 10)..

Global Logistics

(Intermodal Transportation)

1. The generic context of IMO’s e-Navigation initiative within the global framework of maritime transportation processes, including the logistics chains

The IMO envisaged “Sustainable Maritime Transportation System” aims to improve, harmonize and optimize the international/global maritime transportation processes. That would require exchange of data on cargo, vessels and vessel traffic: The overarching e-Navigation architecture is able to support this exchange of data, namely in that it may eventually provide the platform for data exchange that connects all the different stakeholders of the global maritime transport processes, including logistics chain. .

# Dependency on external systems and on infrastructure

## Dependency on GNSS, augmentation and backup systems for position and time

As indicated in Figure 2, there is a dependency of the e-Navigation architecture on external systems such as Global Navigation Satellite Systems (GNSS), augmentation, and backup systems for position fixing and for timing. This may pose certain vulnerabilities for all e-Navigation applications, since dynamic position information is involved in most and time information is required in each one. Hence, mitigation methods are important.

Thus, GNSS signals are monitored by augmentation systems whose use is twofold. They improve the accuracy of GNSS positioning in accordance with the requirements for different phases of berth to berth navigation (ocean, coastal, harbour approach, canal/river, docking). But augmentation systems also inform the user by means of integrity information, if the system can be used for a specific application. A prominent example for a shore-based augmentation system is the IALA radio beacon DGNSS which can be considered as a technical e-Navigation service within the CSSA.

In case of GNSS failure, the e-Navigation architecture takes into account terrestrial backup systems that are an independent source of positioning and timing information. However, it has to be ensured that the terrestrial navigation systems can fulfil the required performance (e.g., accuracy, integrity, continuity).

Once accuracy and integrity information is obtained at the user, it should be transferred and incorporated appropriately to all e-Navigation applications and services that rely on position and timing information (e.g. AIS service). As data and system integrity is a stated user need of e-Navigation, this could converge into a more general approach to provide accuracy and integrity information to other than positioning related data and services.

## Dependency on On-site infrastructure

The on-site infrastructureprovides resource building blocks needed to support the components of technical services on their sites of installation. Main topics include housing and other structures, traditional utility provision such as power, water, sewer and roads, precise timing, local data networking (LAN), independent fault detection and alert management, HMIs for technicians. It is important to note that this is where there is usually the largest part of the cost for the IALA National member to support and maintain its shore-based system.

It should be noted, that on-site infrastructure may have a strong impact on the quality of products / services offered by shore-based systems. When setting up a shore-based e-Navigation system, the on-site infrastructure should be planned carefully to mitigate harmful consequences of that dependency.

1. Functional and Physical Links

This Appendix discusses the relationship between functional and physical links and provides examples of different physical links.

* 1. The relationship between functional and physical links

The bold arrow in Figure 2 (in the main body) is a graphical symbol for the functional connections for data exchange between the shore-based applications and the ship’s technology environment, and vice versa. In IT terms the originating entity of data in a functional link is called source, while the receiving entity of that data in the same functional link is called sink. 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 technology environment, as indicated by the small arrows. The functional connection is the abstract statement in regard to requirement analysis for the application-to-application data exchange. The physical path may take a completely different and more sophisticated route. Thus the analysis is simplified by looking at the links between tasks, rather than the routes of the transmissions.

* 1. Relevant physical link technologies

Physical links between (fixed) shore and (mobile) shipboard equipment each employ one or more appropriate mediums such as radio waves or light.

Figure 11a shows a variety of physical link technologies which are relevant for the e-Navigation architecture. It also shows that well-known technologies such as VTS radar can be modelled as a physical link: the data exchanged is the ship’s radar echo signature. Figure 11b shows that visual or traditional Aids-to-Navigations (either fixed or floating) can also be modelled in the same way. In fact, visual Aids-to-Navigation may employ a variety of state-of-the-art physical link technologies simultaneously, not just light.[[9]](#footnote-9)

Every technical service of the shore-based system architecture employs at least one physical link technology.

While Figure 11 addresses the ship-shore/shore-ship links, it is understood that there are functional and physical connections between ship-ship and shore-shore as well.



1. A Variety of physical link technologies relevant for the e-Navigation architecture
2. Approach used creating the IALA e-Navigation Stack

This Appendix derives the “IALA e-Navigation stack” using certain principles. The features of the different resulting layers will be described in the next chapter.

* 1. The implications of a “stack” – the layered structure

The idea of a “the IALA e-Navigation stack” is to represent – using already existing building blocks – the different working areas of IALA regarding the shore-based aspects of e-Navigation in a layered model, thus providing a seamless framework for IALA’s work for the shore side in the context of IMO’s e-Navigation strategy, starting (top) from User Requirements down to the shore-based system architecture and the specific technical e-Navigation services in a top-down approach.

Layering (or stacking) is a structuring technique which permits the relevant aspects of the desired information/data, services, and systems to be viewed logically in a composed hierarchy of layers, each wrapping the lower layers and separating them from the higher layers. The “wrapping” and the “separation” incur certain benefits, in particular a reduction in complexity, relative independency of work on different layers concurrently, encapsulation, and the appropriate design of interfaces.

The basic concept of layering is that each layer adds further value to results provided by the set of lower layers in such a way that the highest layer is offered the fullest set of desired results. Layering thus divides the total problem into smaller pieces.

Another basic principle of layering is to ensure relative independence of each layer by defining the requirements for the results to be achieved by a lower layer under consideration, independent of how these results are achieved in detail. This allows also for different methodologies and structures for different layers, which in turn allows for applying the best methodology and structure to the problems to be solved by the layer under consideration, layer by layer. Layering also permits changes to be made in the way a layer or a set of layers operate, provided they still offer the same results to the next higher layer(s).

All objects within a layer or at the boundary between adjacent layers need to be uniquely identifiable.

* 1. Relationship between the IMO user needs and the IALA e-Navigation stack

The IMO user needs definitions sit on top of the “IALA e-Navigation stack”, and thereby dominate the hierarchical “IALA e-Navigation stack” content-wise: The uppermost layer of “IALA e-Navigation stack”, such as the user requirements and information needs/items and Maritime Information Objects are thus informed by IMO defined user needs.

Hence, the “IALA e-Navigation stack” is “user needs-driven”.

The following sections derive the complete “IALA e-Navigation stack” in terms of fundamental principles in a step-by-step “top down” approach.

* 1. Differences between information structure and data model

It is important to distinguish between information and the way in which it is structured, i.e. the information structure, on one hand and data and the way in which it is arranged and described, i.e. the data model. It is necessary to define both the **information structure** and a **data model**.

* **Information** is “knowledge concerning objects, such as facts, events, things, processes or ideas, including concepts, that within a certain context has a particular meaning” (ISO/PAS 16917:2002(E)); and
* **Data** is “representation of facts, concepts or instructions in a formalized manner, suitable for communication, interpretation or processing by humans or by automatic means” (ISO/PAS 16917:2002(E)).

Humans (i.e. users) want information while machine are most efficient with data. Within both domains information and data respectively regularly exhibit a certain **structure**, which is specific to the respective domain. Such structure to a plurality of entities is usually included in a “**model**”, which is the result of a conscious process to create it. Because of the separation between information and data domains, the best model suited to its respective context can be developed and used.

According to IMO strategy for the development and implementation of the e-Navigation the user required information should be provided (by machines) in an internationally agreed common data structure (data model). That data structure is also essential for the sharing of information on a regional and international basis.

This results in two distinct layers within the IALA e-Navigation stack, namely

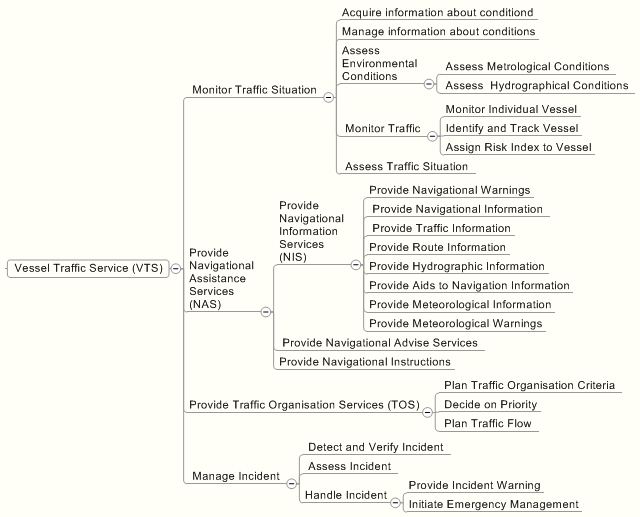
* a layer dealing with the **information structure/model**, and
* a layer dealing with **data structure/model**.

By having different layers for the information structure and the data model, this has the following benefits:

* **Users**, in particular different user groups even, can express their information needs in a format most appropriate to expressing and managing information needs and items, while not being constraint by limitations possibly imposed on them by engineering in the data domain.
* **Engineers** can solve their machine-related problems using machine-oriented concepts, methods, and tools, while these don’t need user involvement.
  1. Layer for information model and associated user requirements: IALA Stakeholder’s Harmonized User Requirements (ISHR) layer

The information structure (or model) could be defined as information items, sometimes called Maritime Information Objects (MIO), and their properties, arranged and structured in accordance with user requirements (informed by used needs). The information structure (or model) is tree-like, where the roots are operational task and / or the “Operational Services” while the “leafs” of those trees are the above information items (MIOs). Figure 12 below is shown as an *example* of how information items (MIOs, “leafs”) at the right hand side of the Figure are derived from an “Operational Service” at the left hand side of the Figure.

.



1. Example on how information items are derived from operational service definitions

User requirements are tied to the information items because the user wants to do something with these information items. The most fundamental user requirement is to have the information determined and delivered to him in a user friendly presentation.

The layer where both information items and associated user requirements are defined is called **“IALA Stakeholder’s Harmonized User Requirements (ISHR)” layer**. The precise meaning of the additional attributes will be explained later on. It is informed by IMO stated user needs by undergoing a transformation process.

* 1. Layer for data model: IALA Harmonized Data Model (IHDM)

The layer which contains the data modelling within the IALA e-Navigation stack is called “**IALA Harmonized Data Model (IHDM)**”. It belongs to the data/machine domain. It is developed and maintained by engineers, but could be used by users as well.

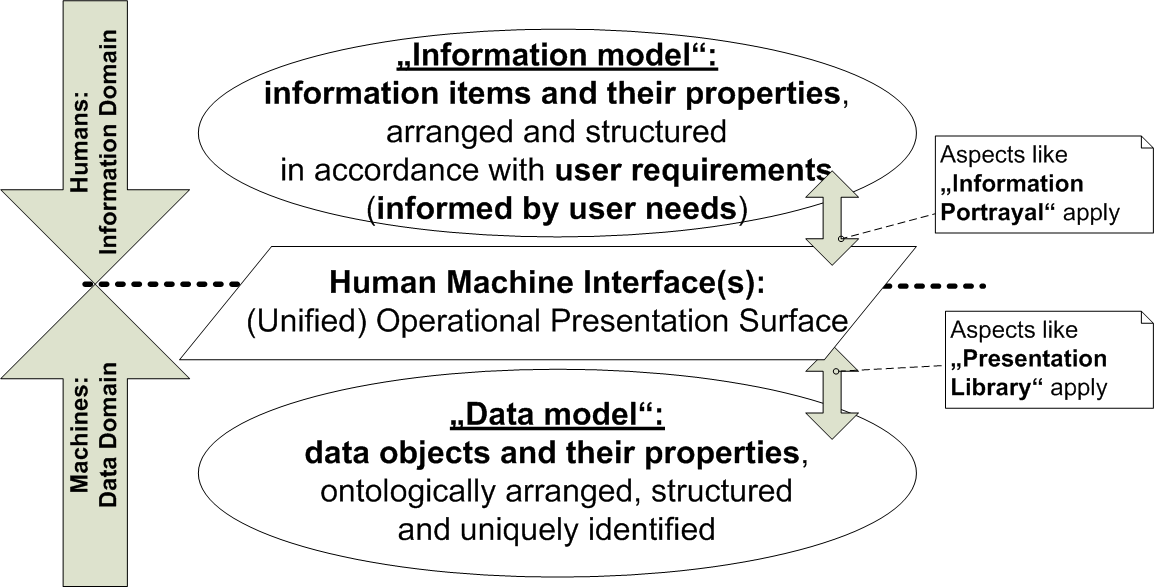
By the application of principles as indicated above, seamless derivation of data objects from user’s information needs is possible.

Also, data objects and their properties are uniquely identified within this layer.

* 1. Layer for presentation of data to users: IALA Unified Operational Presentation Surface (UOPS) layer

The data model is the data objects and their properties, ontologically arranged, structured and uniquely identified. These two domains could also be classified as Information Domain (humans) and Data Domain (machines) respectively and are interconnected by means of Human Machine Interfaces (HMI) where the tactical picture is re-presented unified to operator(s). HMI is also where interaction between information and data realise.

The following Figure 13 illustrates the relative position of the IALA UOPS in the IALA e-Navigation stack and within the data domain. The IALA UOPS belongs to the data/machine domain because machines provide the HMI.



1. Fundamental layer approach introducing “information model”, “data model” and Human-Machine-Interfaces
   1. Data encoding vs. data modelling

It is now also be appropriate to point out that data modelling is not equal to data encoding because **encoding** is tailored to specific interface technologies and it is necessary for data exchange between machines (e.g. XML encoding or AIS application specific message).

By separation between data modelling and data encoding, the data model contains encoding-free essence of data. Hence, it could be technology independent, i.e. multiple technologies can be used to exchange the same data objects. Thus, data model contains encoding-free essence of data to be treated by humans/machines with no limitations of technology.

* 1. The composition of data exchange sentence: The IALA Maritime Data Exchange Format (MDEF)

In this layer, the above mentioned data objects and their properties are arranged in so-called “**sentences**” and are provide a **specific context** **by their arrangement**. The sentences as such are also still free of encoding techniques, though. Hence, different encoding techniques may use the *same* sentences, creating *different* encoding formats, which are required by the specific constraints of interfacing or communication technologies.

This layer of the IALA e-Navigation stack is called the “**IALA Maritime Data Exchange Format (MDEF)**”.

The sentences of the MDEF are categorized in accordance with **fields of application**. The MDEF therefore directly supports the **application domain** by allowing the application-specific composition of sentences while using the same – application-independent – data object definitions. Hence, the MDEF also constitutes a powerful **management tool** for application stakeholders.[[10]](#footnote-10)

Because different sentences may be generated by using the same data object, this layer introduces a certain flexibility which is necessary for different data exchange requirements.

* 1. Systems and devices – and their architecture: Common Shore-Based e-Navigation System Architecture (CSSA)

Last but not least we arrive at the lowest layer of the “IALA e-Navigation stack”, namely the layer which describes systems and devices, i. e. the “machines proper”, including both hard- and software as applicable. This layer is called **Common Shore-Based System Architecture (CSSA)**.

**This layer will be informed by the above layers of the IALA e-Navigation Stack**, namely as follows:

* The **required functionality, as stipulated by** the IALA Stakeholder’s Harmonized User Requirements (**ISHR**) and the IALA Unified Operational Presentation Surface (**UOPS**), will be provided by the systems and devices within this layer, i.e. by the CSSA.
* The CSSA will also use the IALA Harmonized Data Model (**IHDM**) and the IALA Maritime Data Exchange Format (**MDEF**), both for its interfacing between different systems and devices.

The CSSA is subdivided in a **generic part** and a **technology specific part**.

* The generic part contains **generic engineering models**, both for the shore-based system layout and for the “technical e-Navigation services” which are the main building blocks of the shore-based system layout.
* The technology specific part contains all descriptions and definitions which result from the **application of the generic engineering model to specific shore-based technologies**. Examples are e. g. the so-called AIS Service, Radar Service, and the User Interaction Service which actually creates the Unified Operational Presentation Surface to the shore-based users e.g. in VTS centres at runtime.

**Within the CSSA well-known concepts and technologies will be found**, for example data base technology, base stations, radio antennas, client-server-concepts, servers, computers, Local Area Networking, supporting infrastructure such energy supply, housing, EMC protection, etc.

“Common” in the term CSSA implies that both the generic and the technology specific descriptions and definitions are expected to be used as a **common reference framework** by many, most or even all IALA members. IALA members may even wish to go to the extent of procuring their domestic systems fully or almost identical to the CSSA eventually, thus reaping maximum benefit from the international standardisation done at IALA.

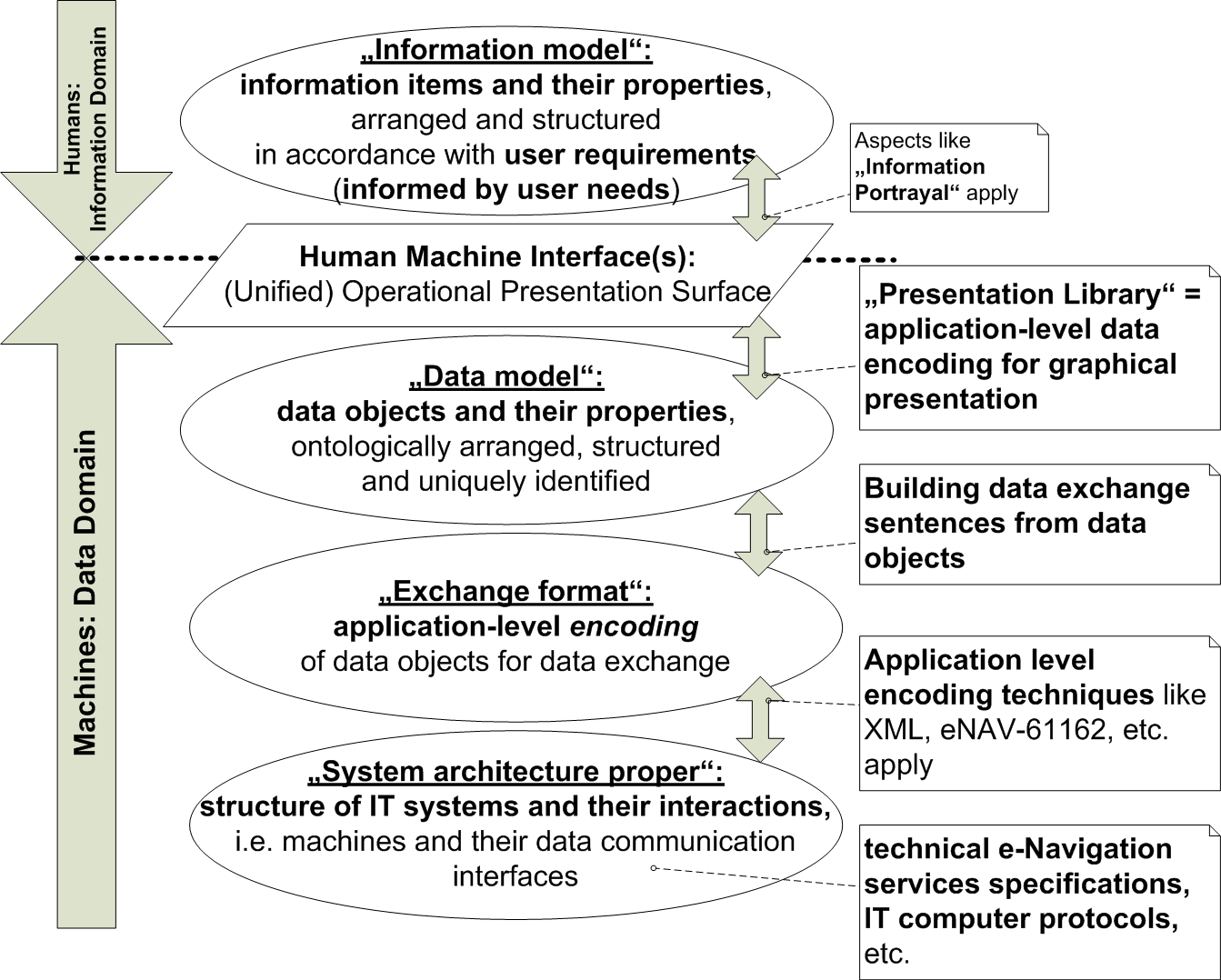
To apply and adapt the generic and also the technology specific definitions and descriptions of the common CSSA to local and regional needs, a considerable amount of both **flexibility** and **configuration** in various degrees has been designed into the CSSA.

Hence, the CSSA would **allow** for a **certain degree of uniformity** – at the discretion of the procuring IALA member –, but would **always provide** a **harmonized solution**.

Also, the CSSA should be construed as a **minimum set** to achieve the user requirements; there is **always margin for additional features** proprietary to individual industrial members to allow them to excel on the markets and to allow for progress.

* 1. The “IALA e-Navigation Stack”: resulting overview

The Figure 14 shows the resulting “IALA e-Navigation Stack” in regard to its underlying principles in an overview.



1. Complete overview of “IALA e-Navigation Stack” and its underlying principles

1. IMO has expressively stated that one of the core objectives of the e-Navigation concept is to “provide opportunities for improving the efficiency of transport and logistics” (IMO MSC85, Annex 20, §5.1.4). [↑](#footnote-ref-1)
2. „Co-operation agreement between the International Hydrographic Organisation (IHO) and the International Association of Marine Aids-to-Navigation and Lighthouse Authorities (IALA)”, 2001 [↑](#footnote-ref-2)
3. By the same token, some technical services are called co-operative services. There are also so-called non-co-operative technical services, which for the ship-shore/shore-ship data flow do not require a specific shipboard device (e.g. radar detection in the data flow direction ship-to-shore or visual Aids-to-Navigation in the data flow direction shore-to-ship). That means that information/data may be derived without the contribution of an active component on the other side. These non-co-operative services are an integral part of the e-Navigation architecture. [↑](#footnote-ref-3)
4. The requirements for data transfer are dependent on the specifics of the technology of the shore-based technical service. For example, a shore-based Radar Service may require different data transfer network capabilities than a shore-based AIS Service. Hence, the individual requirements for data transfer network of a shore-based technical service are also encapsulated. This also reduces complexity. [↑](#footnote-ref-4)
5. As IMO is still in the process to discuss the implications of the Maritime Cloud concept, it should be noted, that the overarching e-Navigation architecture as presented by Figure 2 is valid even if the notion of the Maritime Cloud should not be accepted by IMO finally. [↑](#footnote-ref-5)
6. Vessel Traffic Services” (VTS) strictly speaking is an operational term. It comprises the three operational services: Traffic Information Service, Traffic Organisation Service, and Navigational Assistance (IALA VTS Manual). Over time, the term VTS came to be used as a synonym for the technical system, which supports the above operational services. Common usage was to consider a “VTS” as a well defined set of certain technologies, in particular radar and VHF voice communication. When referring to the technical equipment needed to support the Vessel Traffic *Services*, the technical term VTS *System* should be used. [↑](#footnote-ref-6)
7. It should be noted, that the users of the Common Maritime Data Structure (CMDS) are (software) engineers pre-dominantly. [↑](#footnote-ref-7)
8. The INS is a well-defined concept for shipboard equipment (compare IMO Performance Standards on INS). The shipboard INS should not to be confused with the VTS service “Information Service (INS)”. [↑](#footnote-ref-8)
9. Due to that development it is strictly speaking a misnomer to use the word “visual” aids-to-navigation. Since “visual” aids-to-navigation is a well-known term, it will be used throughout the description of the e-Navigation concept and the common shore-based e-Navigation system architecture. [↑](#footnote-ref-9)
10. „Application stakeholders“ are for example Maritime Information Systems (MIS), the integrator companies, and regional data exchange networks. [↑](#footnote-ref-10)