Telematic Approach to e-Navigation Architecture

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Abstract. e-Navigation is an IMO (International Maritime Organization) initiative defined as "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". In the paper the Author tries to discuss a telematic approach to e-Navigation architecture and stress that for enhancement of safety, security and environmental protection, the decision makers must be supported not only by the technology, but also in a significant way with effective procedures and training.

Keywords: Maritime Transportation, Navigation, Telematics, e-Navigation.

1 Introduction

The advantage of the latest technical development in the field of automation, electronics, telecommunications, informatics, telematics, geomatics and global position fixing techniques, achievements in data storing, processing, analysing, transferring and visualisation should be taken into account and applied to the maritime technology [7]. In the paper the Author tries to discuss the main tasks of the maritime community for the near future in the field of e-Navigation.

It is now appropriate to develop a broad strategic vision for incorporating the use of new technologies in a structured way and ensuring that their use is compliant with the various electronic navigational and communication technologies and services that are already available [5]. The aim is to develop an overarching accurate, safe, secure and cost-effective system with a potential to provide global coverage for vessels of all sizes [2]. The implementation of this new strategic vision might require modifications to working methods and navigational tools, such as inner ship's computer net, charts, bridge display equipment, electronic aids to navigation, communications and shore infrastructure. At this stage, it is difficult to be precise about the full extent of the changes that might be necessary to fully deliver this vision. However, changes to a number of regulatory instruments might be needed, including the appropriate chapters in the SOLAS Convention. This proposal is not in any way intended to conflict with the clear principle, as confirmed in SOLAS, of the master's authority for the operational safety of the vessel, and in UNCLOS, of freedom of navigation rights.

Fig. 1 displays the conceptual process of e-Navigation. The legal requirements "influence" the whole process. Training and operational procedures are affected by: the

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e-Navigation process, the users' needs, the operational functions to be carried out, and the technical facilities. The user needs and especially the operational functions are influenced by the safety management of the company, the culture, and depend on the ship type and the equipment configuration, and issues of quality and reliability must be addressed throughout the process in terms of data systems and training.

The iterative process and the dependency of the technical facilities are symbolized with the "circle arrows".

It is also certain that the safe and efficient transport will continue to rely on good decisions being made on an increasingly constant and reliable basis. Some decisions may be made with increased dependence on technology, but at some level we will always rely on good human decisions being made and therefore every effort needs to be made to apply an understanding of the Human Element at all stages, of design, development, implementation and operation of e-Navigation. The Nautical Institute [6] as the leading international body for maritime professionals will continue to use the resources of its members, branches, officers and staff to promote the effective application of the Human Element for e-Navigation and other industry developments, and invites all maritime professionals to join in this critical effort.

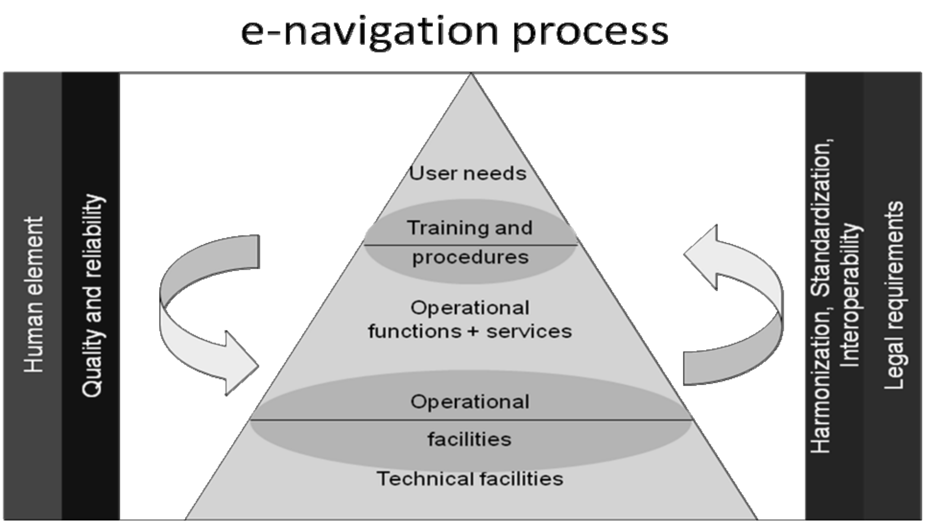

Fig. 1. e-Navigation: structure of the conceptual process [4]

2 Introduction to e-Navigation Architecture

The work of implementing the e-Navigation strategy should begin by the outline of architecture [3]. To become workable, the current definition of e-Navigation needs to be broken down into detail. The work is complex and will require input from a number of experts. For reasons of efficiency and effectiveness the work needs to be conducted in a systematic and consistent way. There is therefore a need to develop an architecture, a framework, within which the definition of e-Navigation as presented may be further refined. The detailed definition will address not only the concept and functions of e-Navigation which are non-technical, but also its technical components, as well as the complex relations between these [1].

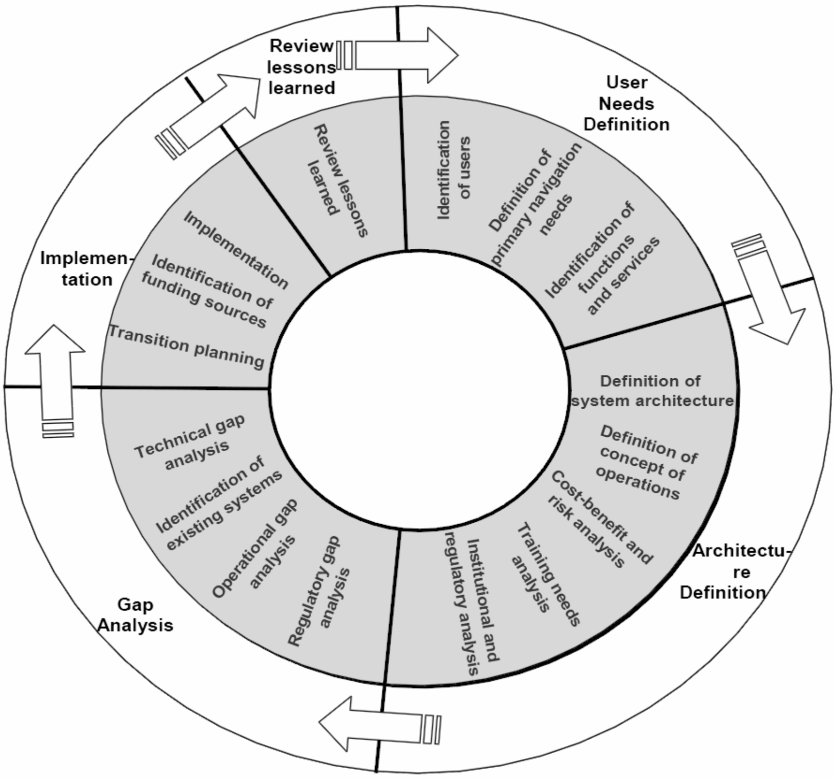

Fig. 2. Potential components of an e-Navigation implementation plan [6]

The architecture serves two purposes [4]:

1. The first is to ensure a common understanding and interpretation of the e-Navigation concept. Although documents [1], [3], and [4] provide an overall definition of e-Navigation, a more detailed definition is required. This definition must be sustainable, meaning that it as far as possible must be stable over time and independent of technology, technical components and systems (which may change over time). The definition should further clarify:

   - The context of e-Navigation. That is the main aspects, scope and environment of e-Navigation and the responsibilities (i.e. roles) to be fulfilled by stakeholders.
   - The logical description of e-Navigation by means of functions that enables stakeholders to meet their responsibilities; and the information that has to be exchanged between these functions. Responsibilities/roles, functions and

information flows should be combined into processes related to specific situations and stages of the ship's voyage.

2. The second purpose is to support the implementation of the e-Navigation concept. The architecture should provide implementation requirements with references to the logical specifications, e.g. specify how to carry out the information flows. The current technologies, standards and solutions to be used should be defined.

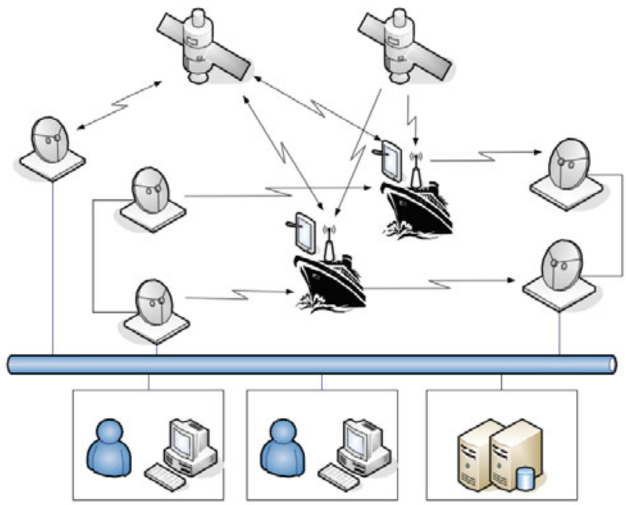

Fig. 3. General telematic approach to e-Navigation [9]

The architecture defines the scope of e-Navigation, its boundaries to the external environment as well as the responsibilities/roles to be met by stakeholders. It describes the information exchange between various functions. Finally it describes the processes in which responsibilities, functions and information flows between these are combined and related to a specific situation, e.g. stages of the ship's voyage.

The technical solutions will follow the conceptual specifications. It may however take time to establish all the implementation requirements because standards and solutions may not yet be available. Therefore at the outset the implementation specifications may not be as complete as the conceptual specifications. These will have to be updated as new technologies, standards and solutions emerge.

The initial technical e-Navigation architecture work is based on the understanding of IMO's e-Navigation concept in general, and telematic approach to e-Navigation architecture specifically.

A sufficiently advanced proper infrastructure needs to be present. This infrastructure would consist of supporting devices, which e.g. allow the application software to be executed (i.e. computers, computer peripherals, operating systems, local area network components, etc.). The infrastructure itself becomes more and more sophisticated and is subject to its own requirements, such as reduction of energy consumption and environmental friendliness.

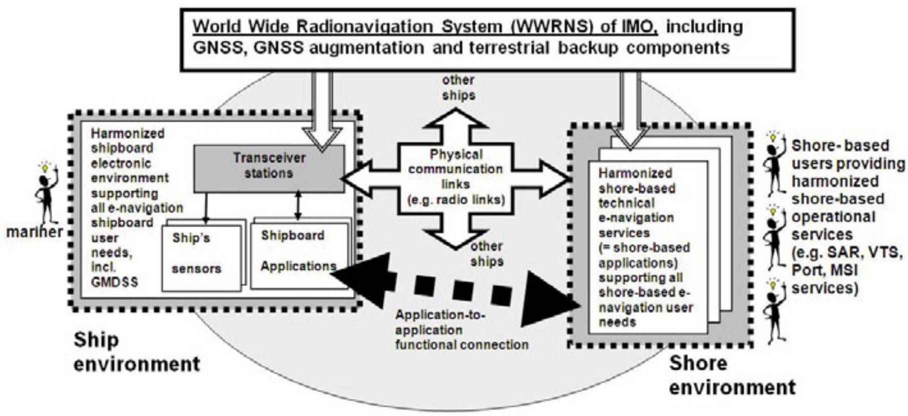

Fig. 4. Conceptual e-Navigation architecture [4]

One important principle is the orientation towards the information flow instead of technology development. That principle is represented by Fig. 4 below, which shows the shipboard environment, the physical link(s) and the shore-based environment.

Fig. 4 is a representation of the e-Navigation environment. On the left there is a single "ship environment". From an e-Navigation perspective, the relevant devices within the ship environment are the transceiver station, the sensors and applications connected to the transceiver station, the Integrated Navigation System (INS) and the Integrated Bridge System (IBS). The GMDSS function has been included in the ship environment, with a direct link to the transceiver station and a link to the World Wide Radio Navigation System (WWRNS).

The transceiver station is shown as a single station although in reality there may be several transceiver stations. It interfaces via links with the appropriate technical e-Navigation services ashore.

As regards shore-based services there are technical services responsible for interfacing with the ship services. Operators ashore, such as VTS, port, pilot station and SAR operators, or lock operators, perform their tasks in co-operation with shipboard applications. From the shore perspective, it is the functional links between the shore-based user applications and the shipboard applications that are most relevant, such as the provision of MSI.

A similar setup of interactions applies for ship-to-ship and shore-to-shore applications, and would include, for example, real-time and near real-time meteorological and oceanographic services. Pilots also perform the same interactions as mariners before and when they are on board ships in pilotage waters. The above functional links are equally important to ensure efficient ship to ship, shore to ship and ship to shore communications. Fig. 4 also shows dependency on the WWRNS.

The bold arrow in Fig. 4 represents the data exchange between the shore-based applications and the "ship's environment", and vice versa. Physical links between (fixed) shore and (mobile) shipboard equipment each employ one or more appropriate methods such as radio or light signals.

3 The Concept of a Common Data Structure

IMO, IHO (International Hydrographic Organization) and IALA (International Association of Lighthouse Authorities) have raised the issue that some form of common data structure, representing the maritime domain (and including both ship and shore aspects), will be essential for e-Navigation.

In January 2010, the IHO introduced a new data model to be known as S-100 - the Universal Hydrographic Data Model (UHDM). This international standard has been developed by the IHO over the last nine years in consultation with a wide range of stakeholders, including key ECDIS and navigation equipment manufactures. The purpose of S-100 is to provide a framework architecture for a contemporary standard for the exchange of hydrographic and related maritime data. S-100 is based on the ISO 19100 series of geographic standards and is fully compatible and interoperable with those standards. As the UHDM is aligned with ISO 19100 it will enable the exchange of hydrographic and other maritime data and information together with the geospatial data from other domains. The use of data standards enables interoperability between geospatial data sets from different domains and could therefore be appropriate for many of the datasets envisaged for data exchange in e-Navigation.

S-100 is not limited to the hydrographic data or hydrographic applications. It has been developed specifically to enable the widest possible range of users to use the hydrographic data in conjunction with the data from other maritime and marine domains. Like traditional applications such as nautical charts and publications, applications based on S-100 already under development by non-IHO stakeholder groups include the sea ice forecast reporting, recording UNCLOS boundaries, and marine information overlays. These are applications that obviously encompass various hydrographic, meteorological and oceanographic parameters that go well beyond the traditional navigation and hydrographic products provided by HO's. S-100 is intended to be a fundamental enabler for hydrographic input to Marine Spatial Data Infrastructures (MSDI) as well as for other developing marine information infrastructures such as e-Navigation.

IALA is currently developing a proposed Universal Maritime Data Model (UMDM) for e-Navigation to meet requirements arising from the future implementation of e-Navigation. It is therefore important to harmonize efforts in data modelling, with the aim of creating and maintaining a robust and extendable maritime data structure.

The common maritime information and data structure will require some form of overarching coordination to ensure the ongoing management and maintenance of the structure. There may be several management roles to be performed by such a coordinating body, (for example, the maintenance of a register). This management role may be able to be shared between relevant organisations.

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

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

4 e-Navigation Architecture Structure

NAV 53/13 [3] states that "e-Navigation can be described in terms of its component elements, as a process model identifying inputs and outputs, or in relation to the different stages of a ship's voyage". NAV 53/13 also presents three diagrams that take an approach to the design of architecture [3]:

- An integrated bridge system diagram illustrating stakeholders, functions/processes, information, technologies and systems
- A diagram identifying inputs and outputs to e-Navigation, functions/processes and benefits
- A diagram from the IALA's E-NAV Committee on the safety of navigation identifying functions/processes, information, technologies and systems [1].

The IMO correspondence group on e-Navigation recommends that the elements depicted in the diagrams be used as inputs to the design of the architecture. The different types of components (functions, information, processes, etc.) must however be organised into viewpoints addressing different aspects of e-Navigations such as the functions required, the information to be exchanged and processes describing the activities in specific situations or at different stages of the ship's voyage. Standards should be stated as the backbone and one of the major pillars of functionalities and interoperability of all the systems and information.

The architecture is organised into 3 abstraction levels as illustrated in Fig. 5. Levels 1 and 2 are non-technical. They are prerequisites for a common understanding of the e-Navigation concept. Level 3 defines the technical realisation and supports the implementation of the e-Navigation concept.

The layered model and the different viewpoints depicted in Fig. 5 will give a well defined structure to the specification of e-Navigation and also promote the establishment of clear definitions, a common understanding of the concept and well defined terminologies. This will support the requirements to the architecture.

The technical implementations of the solutions defined at Level 2 are specified by means of system components and communication solutions.

The architecture and the e-Navigation concept should be based on a consolidation of user needs across the entire range of users, taking into account all possible economies of scale. The architecture should include hardware, data, information, communications and software needed to meet the user needs. The structured and layered approach to architecture as illustrated in Fig. 5 will support the architecture development process.

User requirements can be related to roles (i.e. responsibilities) reflecting the entire range of users. The viewpoints will support the capturing of user requirements and the interaction with them in the development of requirements. Existing user requirements can be entered into the respective viewpoints and be the starting points for further discussions with users and maritime experts. The process viewpoint will support the verification of the other components - the roles, the functions and the information and lead to a consistent result [8].

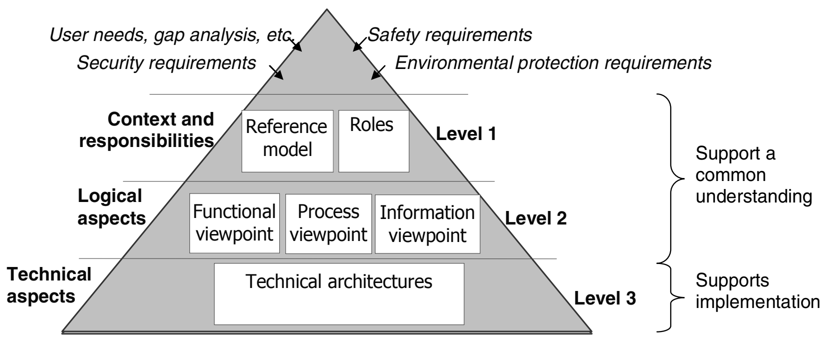

Fig. 5. e-Navigation architecture structure and components [4]

4.1 Architecture Components Should Be Made Modular and Scalable

The architecture should be based on a modular and scalable concept. The hardware and software should be based on open architectures to allow scalability of functions according to the needs of different users to cater for a continued development and enhancement.

The roles (described below) will arrange for a flexible organisation of e-Navigation solutions. Responsibilities, and the associated functions and processes, can be adapted to local stakeholders in a flexible way, or the responsibilities may be handled on a regional basis. Thus the architecture arranges for local, national and regional solutions.

The technical solutions must ensure that the system components are modular and scalable (e.g. adaptable to traffic density, etc.). The logical parts of the architecture will however be a good starting point for the technical aspects by providing a structured specification of the solutions. The information viewpoint will for example provide specifications of the information content to be exchanged through standardised and open interfaces.

4.2 Architecture Should Be Adaptable to New Requirements

The architecture should include the hardware, data, information, communications technology and software needed to meet the user needs. The system architecture should be based on a modular and scalable concept. The system hardware and software should be based on open architectures to allow scalability of functions according to the needs of different users and to cater for continued development and enhancement. The requirement is met by making a separation between the contextual and logical parts and the technical part of the architecture. The non-technical parts will ensure consistent and common understanding of the solutions, and the technical specifications will provide implementation guidelines and requirements by means of the available technologies, standards and solutions. The technical aspects may be updated as new technologies, standards and solutions emerge.

4.3 Architecture Should Support Training Needs Assessment

Training needs analysis should be performed based on the system architecture and the operational concept resulting in a training specification. The process viewpoint specifying processes related to specific situations and stages of the voyage can be used as a starting point for training scenarios. In addition, the technical aspects will identify technologies and systems that should be addressed in the training of the users.

The already defined roles support the addressing of specific responsibilities, and this can also be reflected by the processes. Thus, it should be possible to customise the training scenarios to the individual stakeholders depending on their roles.

4.4 Architecture Should Support Institutional and Regulatory Analysis

Institutional and regulatory requirements' analysis should be undertaken, based on the system architecture and operational concepts.

The roles and the viewpoints will be a tool in the analysis of responsibilities and processes (including functions and information exchange), and the technical aspects can be used to define implementation plans and requirements.

It is also likely that the work with regulations related to the implementation of e-Navigation may benefit from the architecture. The terminology defined by the architecture should be used. This will ensure consistency with respect to terminology across regulations for example with respect to stakeholders and responsibilities and the architecture will support the interpretation of the regulations.

5 Conclusions

e-Navigation is a broad concept that is aimed at enhancing navigation safety, security and the protection of the marine environment through a harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means. A telematic approach to e-Navigation is very important.

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

The overall conceptual, functional and technical architecture will need to be developed and maintained, particularly in terms of process description, data structures, information systems, communications technology and regulations. The architecture should include the hardware, data, information, communications technology and software needed to meet the user needs. The system architecture should be based on a modular and scalable concept. The system hardware and software should be based on open architectures to allow scalability of functions according to the needs of different users and to cater for continued development and enhancement. The architecture should contribute to the common understanding and interpretation of the e-Navigation concept. The current definition needs to be broken down into a detailed definition/description of e-Navigation. The description should be made sustainable, i.e. stable over time. It further needs to have the capacity to integrate developments in technical components and systems.

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