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MAIN ASPECTS OF A MARITIME E-NAVIGATION PROJECT

Karol Korcz

Gdynia Maritime University
Department of Marine Telecommunication
Morska Street 81-87, 81-225 Gdynia, Poland
tel.: +48 58 5586406, fax: +48 585586556
e-mail: k.korcz@we.am.gdynia.pl

Abstract

Many devices and systems, including electronic ones, are used in the operation of sea-going vessels. Fast technological development in the field of electronics, radio communications and computer science inspires the more and more new proposals for the changes of these devices and systems. The rules and scope of sea-going vessels equipment, related to ensuring their safety, are strictly regulated by the International Maritime Organization (IMO). Considering the above, several countries have submitted to the IMO-Maritime Safety Committee (MSC) a proposal to prepare a vision of a broad strategy for incorporating new technologies in a structural manner, ensuring their compatibility with already existing different navigation and communication technologies and services. The overriding goal of this strategy would be to improve the efficiency, safety and reducing the cost of the entire system, providing global coverage and applicable to all types of sea-going vessels. In response to this proposal, the MSC decided to start work on the project "Preparation of e-navigation strategy". The article presents the general concepts and goals of the e-navigation project. Priority needs of e-navigation users were also discussed. The key elements of the project are presented too. The radio communication aspects of the e-navigation project were also considered. Finally, the e-navigation Strategy Implementation Plan (SIP) and its progress were presented.

Keywords: *navigation, shipping, maritime e-navigation, maritime radio communication, ship safety*

1. Introduction

Over 80% of world trade is transported by sea. This totals some 10 billion tonnes (53,600 billion tonne miles), of which about 29% is oil and gas, 30% is bulk (ore, coal, grain and phosphates), the remaining 41% being general cargo. Operating these merchant ships generates an estimated annual income of $380 billion in freight rates within the global economy, amounting to 5% of total world trade. The industry employs over 1.5 million seafarers.

Many devices and systems, including electronic ones, are used in the operation of sea-going vessels. Rapid technological development in the field of electronics, radio communications, and computer science inspires the new proposals for the changes of these devices and systems.

The rules and scope of equipping marine vessels, related to ensuring their safety, are strictly regulated by the International Maritime Organization (IMO) [1], with the support of its committees and subcommittees. Considering the above, several countries have submitted to the IMO-Maritime Safety Committee (MSC) a proposal to prepare a vision of a broad strategy for incorporating new technologies in a structural manner, ensuring their compatibility with already existing different navigation and communication technologies and services.

In response to this offer, the MSC at its 81st session in 2006 decided to include, in the work programmes of the Navigation (NAV) and Radio communications and Search and Rescue (COMSAR) Sub-Committees, a high priority item on ęDevelopment of an e-navigation strategy. The main aim is to develop a strategic vision for e-navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety (with all the positive repercussions this will have on maritime safety overall and environmental protection) while simultaneously reducing the burden on the navigator.

As the basic technology for such an innovative step is already available, the challenge lies in ensuring the availability of all the other components of the system, including electronic navigational charts, and in using it effectively in order to simplify, to the benefit of the mariner, the display of the occasional local navigational environment. E-navigation would thus incorporate new technologies in a structured way and ensure that their use is compliant with the various navigational communication technologies and services that are already available, providing an overarching, accurate, secure, and cost-effective system with the potential to provide global coverage for ships of all sizes.

The work on the e-navigation project is still ongoing. At present, work on e-navigation is carried out by the IMO Sub-Committee on Navigation, Communications and Search and Rescue (NCSR). Presented in the article the main aspects of a maritime e-navigation project are the results of NCSR's work, in which the author of this article participates.

2. Strategy for the e-navigation

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 main goal of this approach is to improve safety of navigation and to reduce errors.

After the discussion, the following definition of e-navigation was adopted [2]:

„*E-navigation is the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.*"

Therefore, e-navigation is intended to meet present and future user needs through harmonization of marine navigation systems and supporting shore services.

A vision of e-navigation is embedded in the following general expectations for the on-board, ashore and communications elements [2]:

- **On board** – Navigation systems that benefit from the integration of own ship sensors, supporting information, a standard user interface, and a comprehensive system for managing guard zones and alerts;
- **Ashore** – The management of vessel traffic and related services from ashore enhanced through better provision, coordination, and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency;
- **Communications** – An infrastructure providing authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits.

To attain the benefits of e-navigation, a number of basic requirements should be fulfilled as enablers to the implementation and operation of e-navigation. In particular:

1. Implementation of e-navigation should be based on user needs not technology-driven and over-reliance should not be placed on technology to avoid;
2. Operating procedures should be put in place and kept under review, most notably in relation to the human/machine interface, the training and development of mariners and the roles, responsibilities and accountabilities of ship- and shore-based users;
3. The mariner should continue to play the core role in decision-making even as the supporting role of the shore-based users increases;
4. human factors and ergonomics should be core to the system design to ensure optimum integration including the Human Machine Interface (HMI), presentation and scope of information avoiding overload, assurance of integrity and adequate training;

5. Adequate resources should be made available and assured for both e-navigation itself and the necessary enablers such as training and radio spectrum;
6. Implementation should be measured and not over-hasty;
7. Costs should not be excessive.

Potential users of e-navigation

A significant number of potential ship and shore-based users of e-navigation have been identified [2, 5]. Examples of e-navigation users are given in the Tab. 1.

Tab. 1. Examples of e-navigation users

Shipborne users	Shore-based users
Generic SOLAS ships	*Ship owners and operators, safety managers*
Commercial tourism craft	*Pilot organizations*
High-speed craft	*VTS centres*
SAR vessels	*National administrations*
Law enforcement vessels (police, customs, border control, immigration)	*Coastal administrations, Port authorities*
Nautical assistance vessels (tugs, salvage vessels, tenders, firefighting, etc.)	*Security organizations*
Fishing vessels	*Counter pollution organizations*
Leisure craft	*Military organizations*
Ferries	*Meteorological organizations*
Ice patrol/breakers	*Hydrographic Offices/Agencies*
Offshore energy vessels (rigs, supply vessels, lay barges, survey vessels,	*Ship owners and operators, logistics managers*

The key strategy elements for e-navigation based on user needs include: Architecture, Human Element, Convention and Standards, Position Fixing, Communication Technology and Information Systems, ENCs, Equipment and Standardization and Scalability are detailed below.

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.

Training, competency, language skills, workload and motivation are identified as essential. Alert management, information overload and ergonomics are prominent concerns. These aspects of e-navigation will have to be taken into account in accordance with IMO.s *human element* work.

The provision and development of e-navigation should consider relevant international *conventions*, regulations and guidelines, national legislation and standards. The development and implementation of e-navigation should build upon the work of IMO.

Position fixing systems will need to be provided that meet user needs in terms of accuracy, integrity, reliability and system redundancy in accordance with the level of risk and volume of traffic.

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.

There would be adequate coverage of consistent *ENCs* (Electronic Navigational Charts) by the time any further mandatory carriage requirements were likely to be adopted by IMO.

The work will follow the development of *performance standards* and will involve users and manufacturers.

IMO Member States have a responsibility for the safety of all classes of vessels. This may include the *scalability* of e-navigation for all potential users.

Components of an e-navigation implementation process

Implementation of e-navigation should be a phased iterative process of continuous development including, but not necessarily limited to, the steps shown in Fig. 1 [2, 5].

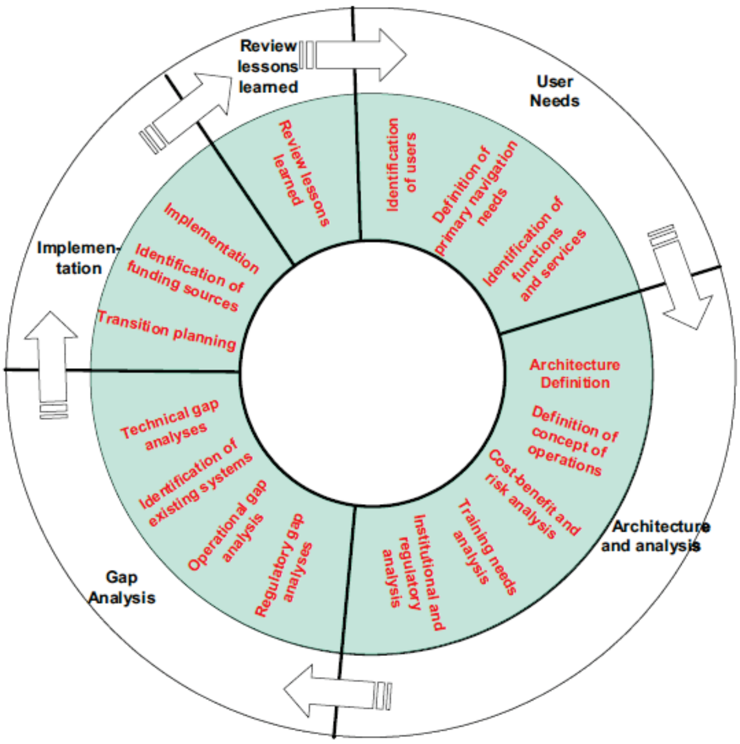

Fig. 1. E-navigation implementation process [2]

User needs

The first step in the plan is that of identification of users and their requirements. The next step should be the identification of the groups of functions or services needed to meet these primary navigational needs, based on a structured, systematic and traceable methodology that relates the functions to tangible operational benefits;

Architecture and analysis

Definition of the integrated e-navigation system architecture and concept of operations should be based on consolidation of the user needs across the entire range of users, taking account all possible economies of scale. The architecture should include hardware, data, information, communications and software needed to meet the user needs.

Cost-benefit and risk analysis should be an integral part of the programme. It should be used to inform strategic decisions, but also to support decision-making on where and when certain functions need to be enabled.

Training needs analysis should be performed based on the system architecture and operational concept resulting in a training specification.

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

Gap analysis

The gap analysis should focus on the following elements:

– regulatory gap analyses particularly identifying gaps in the present frameworks that need to be filled,

- operational gap analysis to define a reduced concept of operations that could be used based on the integration of existing technology and systems,
- identification and description of existing systems that could be integrated into the e-navigation concept covering functionality, reliability, operational management responsibilities, regulatory status as to specification/standardization, fitment and use;
- technical gap analyses, comparing the capabilities and properties of existing systems with the architectural requirements to identify any technology or system development that might be needed, based solely on the user needs.

Implementation of e-navigation

The implementation plan should identify responsibilities to the appropriate parties. IMO, other international organizations, States, users and industry as well as timelines for implementation actions and reviews. A stable and realistic implementation plan will create forward enthusiasm and momentum for e-navigation across the maritime sector.

Review of lessons learnt

The final phase of the iterative implementation programme should be to review, lessons learned and re-plan the subsequent phases of the plan. It is important to understand that e-navigation is not a static concept, and that development of logical implementation phases will be ongoing as user requirements evolve and also as technology develops enabling more efficient and effective systems. However, it is critical that this development takes place around a stable set of core systems and functions configured to allow extension over time.

Framework for the implementation process for the e-navigation strategy

In order to implement e-navigation strategy several steps are required. This includes a number of elements such as developing an initial user needs (completed in 2009), initial architecture (completed in 2010), initial gap analysis (completed in 2010), cost benefit and risk analysis (completed in 2011) and the creation of an implementation plan (planed in 2012 but completed in 2014).

3. E-navigation strategy implementation plan

The e-navigation Strategy Implementation Plan (SIP), after a wide discussion, was approved by MSC in November 2014 [3]. The e-navigation SIP introduces a vision of e-navigation, which is embedded in general expectations for the on board, onshore and communications elements.

The main objective of the SIP is to implement the five prioritized e-navigation solutions, taking into account the IMO Formal Safety Assessment (FSA), from which a number of required tasks have been identified. These tasks should, when completed in the period 2015-2019, provide the industry with the harmonized information, in order to start designing products and services to meet the e-navigation solutions.

Strategy Implementation Plan for the five prioritized e-navigation solutions

The approved in 2014 SIP is based on the following five prioritized e-navigation solutions [3]:

S1: improved, harmonized and user-friendly bridge design;
S2: means for standardized and automated reporting;
S3: improved reliability, resilience and integrity of bridge equipment and navigation information;
S4: integration and presentation of available information in graphical displays received via communication equipment; and
S5: improved Communication of VTS Service Portfolio (not limited to VTS stations).

Solutions S2, S4 and S5 focus on efficient transfer of marine information and data between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore). Solutions S1 and S3 promote the workable and practical use of the information and data on board. As part of each one of the above prioritized e-navigation solutions, several sub-solutions were identified.

Whilst the first steps involve implementing the five prioritized e-navigation solutions, it is important to recognize that further e-navigation development will be a continuous process following user needs for additional functionalities of existing and possible future systems (e.g. implementation of on-board and/or ashore navigational decision support systems). As user needs evolve and new technology is introduced, other e-navigation solutions may be incorporated into the strategy, as appropriate.

Worth noticing, that as part of the improved provision of services to vessels through e-navigation, Maritime Service Portfolios (MSPs) have been identified as the means of providing electronic information in a harmonized way, which is part of solution 5.

To implement five priority e-navigation solutions, eighteen detailed tasks were adopted. The identified tasks with an indication of the implementation schedule are presented in Tab. 2 [3].

Tab. 2. The identified tasks adopted to implement five priority e-navigation solutions

Task No.	Task	Implementation schedule
T 1	*Development of draft Guidelines on Human Centred Design (HCD) for e-navigation systems*	2014/2015
T 2	*Development of draft Guidelines on Usability Testing, Evaluation and Assessment (UTEA) of e-navigation systems*	2014/2015
T 3	*Develop the concept of electronic manuals and harmonize the layout to provide mariner with an easy way of familiarization for relevant equipment*	2019
T 4	*Formulate the concept of standardized modes of operation, including store and recall for various situations, as well as S-mode functionality on relevant equipment*	2017
T 5	*Investigate whether and extension of existing Bridge Alert Management Performance Standards (BAMPS) is necessary*	2019
T 6	*Develop a methodology of how accuracy and reliability of navigation equipment may be displayed (includes a harmonized display system)*	2017
T 7	*Investigate if an INS, as defined by resolution MSC.252 (83), is the right integrator and display of navigation information for e-navigation and identify the modifications it will need.*	2019
T 8	*To agree on standardized format guideline for ship reporting so as to enable "single window" worldwide*	2019
T 9	*Investigate the best way to automate the collection of internal ship data for reporting including static and dynamic information.*	2016
T 10	*Investigate the general requirements resolution A.694(17) and IEC 60945 to see how Built In Integrity Testing (BIIT) can be incorporated*	2019
T 11	*Development of draft Guidelines for Software Quality Assurance (SQA) in e-navigation*	2014/2015
T 12	*Develop guidelines on how to improve reliability and resilience of on-board PNT (Position, Navigation, Timing) systems by integration with external systems*	2016
T 13	*Develop guidelines showing how navigation information received by communications equipment can be displayed in a harmonized way and what equipment functionality is necessary*	2019
T 14	*Develop a Common Maritime Data Structure (CMDS) and include parameters for priority, source, and ownership of information based on the IHO S-100 data model*	2019
T 15	*Identify and draft guidelines on seamless integration of all currently available communications infrastructure and how they can be used and what systems are being developed and could be used for e-navigation*	2019
T 16	*Investigate how the Harmonization of conventions and regulations for navigation and communication equipment would be best carried out*	2017
T 17	*Further develop the MSPs to refine services and responsibilities ahead of implementing transition arrangements*	2019
T 18	*Development of Draft Guidelines for the Harmonization of testbeds reporting*	2014/2015

As we can see, some of the planned tasks have already been implemented others are in progress. Unfortunately, there are also tasks whose implementation has been postponed (e.g., task 13 has been postponed to 2020/2021 [4]).

The ship and shore architecture for the prioritized solutions

Figure 2 shows the principle of an information/data flow in the e-navigation architecture [3].

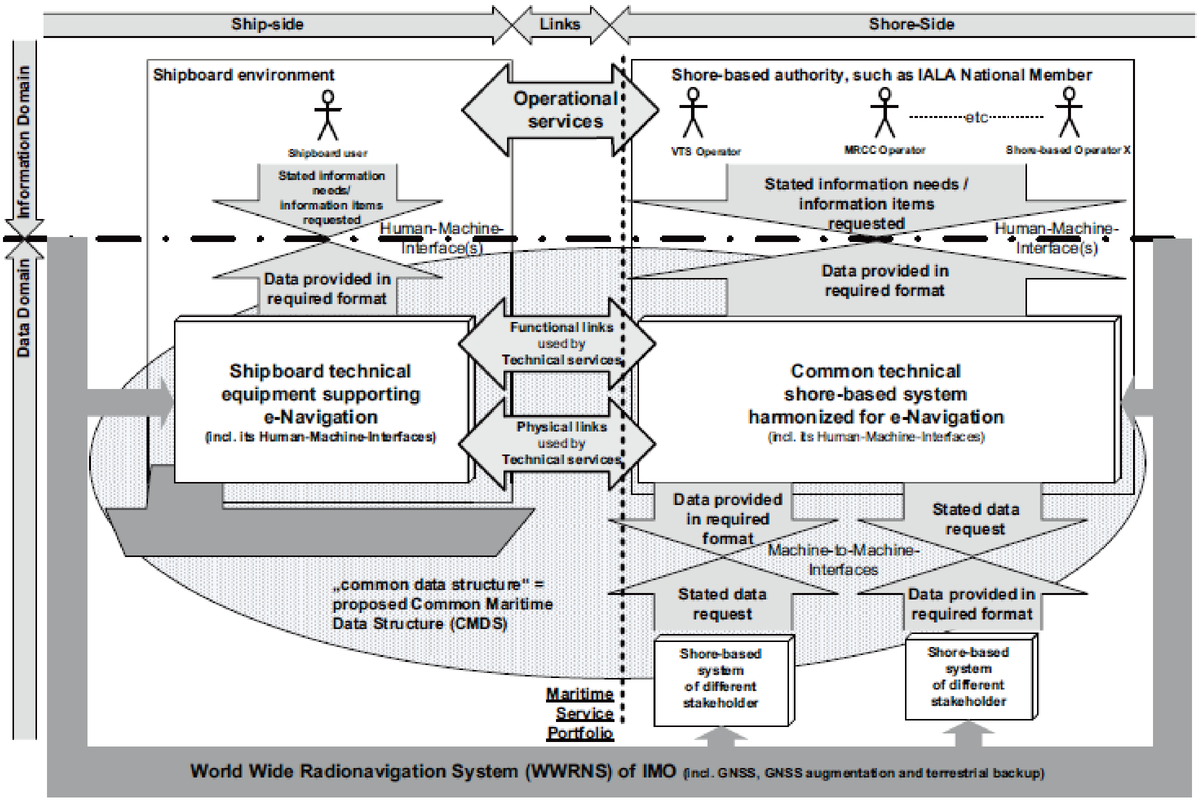

Fig. 2. Overarching e-navigation architecture [3]

The figure shows the complete overarching e-navigation architecture, and defines two additional important features: the Common Maritime Data Structure (CMDS) that spans the whole of the horizontal axis; and the World Wide Radio Navigation System (WWRNS).

The presented architecture also:

1. brings into focus the "operational service" level and the "Functional links used by Technical services" and the "Physical links used by Technical services';
2. highlights the fundamental distinction between information and data domains, explaining the relationship between the user requested information items and introducing the concepts of Operational and Technical Services, as well as Functional and Physical Links into a hierarchical perspective;
3. identifies the concept of "Maritime Service Portfolios";
4. unfolds the relationship of shore-to-shore data exchange.

It is worth emphasizing that the detailed shore and shipside architecture will be further developed in the light of the completion of some of the relevant tasks.

4. Conclusions

As shipping moves into the digital world, the e-navigation system is expected to provide digital information and necessary infrastructure for it. In the above context, we can see that e-navigation project meets the expectations of the present but also the coming times.

Without a doubt, the main benefits of IMO e-navigation project implementation are following:

– improved safety, through promotion of standards in safe navigation,
– better protection of the environment,
– augmented security by enabling silent operation mode for shore-based stakeholders for domain surveillance and monitoring,

– higher efficiency and reduced costs; enabled by:
  – global standardization and type approval of equipment,
  – automated and standardized reporting procedures,
  – improved bridge efficiency,
  – integration of systems,
  – improved human resource management.

It is also worth to emphasize that e-navigation is a development project and it will be a key element of the latest IMO project on Maritime Autonomous Surface Ships (MASS).

According to the author, similar to the presented in the article the e-navigation project will be implemented in the future in other areas of transport such as land or air transport.

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