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Abstract: e-Navigation is a recent initiative aimed at moving traditional maritime navigation towards a connected digital environment. Defined by the International Maritime Organization (IMO) as "*the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance birth-to-birth navigation and related services, for safety and security at sea and protection of the marine environment*", e-Navigation is not a new system of equipment but more an operational concept. Three significant outcomes are envisioned:

1) Shipboard navigation systems will benefit from the integration of own ship sensors, supporting information, standard user interface, and a comprehensive system for managing guard zones and alerts. Core elements include high-integrity electronic positioning, use of ENCs, and an analysis capability to reduce human error.

2) The management of vessel traffic and related services from ashore will be enhanced through better provision, coordination, and exchange of comprehensive data in formats that will be more easily understood and utilized.

3) A communications infrastructure designed to enable authorised seamless information transfer onboard ship, between ships, between ship and shore and between shore authorities. This paper discusses the main hydrographic-related components, implications for further standards development, some challenges/opportunities, and the role that IHO and others in the hydrographic community should play to facilitate the development and implementation of e-Navigation.

Introduction

E-Navigation is the latest "buzzword" for maritime navigation transitioning into the digital era. Defined by the International Maritime Organization (IMO) as "… *the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance birth-to-birth navigation and related services, for safety and security at sea and protection of the marine environment*" [1], e-Navigation is not a new system but a concept of operation.

First proposed in 2005, IMO recently agreed on an overall development and implementation strategy [2 & 3]. Three significant outcomes are envisioned:

> *1) Shipboard navigation systems will benefit from the integration of own ship sensors, supporting information, standard user interface, and a comprehensive system for managing guard zones and alerts. Core elements include high-integrity electronic positioning,* ***use of Electronic Navigational Charts****, and an analysis capability to reduce human error. This should occur by actively engaging the mariner in the process of navigation while preventing distraction and overburdening.*
>
> *2) The management of vessel traffic and related services from ashore will be enhanced through better provision, coordination, and exchange of* ***comprehensive data in formats that will be more easily understood and utilized****.*
>
> *3) A communications infrastructure designed to enable* ***authorised seamless information transfer*** *onboard ship, between ships, between ship and shore and between shore authorities.*

The broad implications are that e-Navigation will lead to significant changes in terms of how mariners receive, interpret and use navigation-related data, systems and services – including electronic charts.

To date, the primary focus of the International Hydrographic Organization (IHO) and its Member States in support of the e-Navigation concept of operation has been to complete ENC coverage for international shipping routes. ENC data and associated services (e.g., the means and processes for updating) will be a fundamental component of e-Navigation because much of the non-chart information available in an e-Navigation environment will be referenced directly or indirectly against charts or other forms of related charting or hydrographic information.

In 2007, the IHO reported to the IMO Subcommittee on Safety of Navigation (NAV) that ENC coverage was steadily increasing and that there would be an adequate coverage of consistent ENCs by the time mandatory ECDIS carriage requirements would be adopted by the IMO. It was stated that "ENC production, consistency, and availability are constantly increasing, and that major trading routes and ports will be covered by 2010" [4]. In 2008, the IHO reported on the status of a "Comprehensive online catalogue of available official charts" that would show, in a graphical manner, the coverage of all ENCs that were currently available, worldwide [5]. In 2009, the IHO confirmed to IMO that ENC production and availability continues to increase [6]. This July (2010) the IHO will report to IMO that the world's major trading routes and ports are now almost completely covered" [7].

Clearly, the IHO through its national hydrographic offices (HOs) has made a concerted effort to facilitate ENC production, worldwide. However, in addition to ensuring comprehensive ENC coverage for vessels at sea, e-Navigation has other implications for HOs and the broader hydrographic community.

Main Components of e-Navigation

A frequently asked question about e-Navigation is: *What are (or will be) e-Navigation equipment, systems and services?* Alternatively, *What will not be included*? While these may appear as straight-forward questions, at this stage in the process there is no clear answer. Logically, it is likely to be a subset of what is currently being used, or be something that will evolve in the future.

In 2008, a Proposed Strategy for the Development and Implementation of e-Navigation was discussed at the 54th meeting of IMO NAV (NAV54). It included a listing of existing components and "potential building blocks" as a starting point for e-Navigation [8]. The list included:

Radar
ECDIS/IBS
Electronic Navigational Charts (ENCs)
Communications
Positioning, Navigation and Timing
Situational Awareness
Maritime Information Systems
Human Factors

Notably, ECDIS was not listed separately, but along with Integrated Bridge System (IBS). Apparently this was done since, under Regulation 10 of chapter V of the Convention on the Safety of Life at Sea (SOLAS V/19) [9], IBS shall be arranged such that the failure of one sub-system is brought to the attention of the watch officer. Further, it must be possible to operate each individual item of equipment or part of the systems separately. The implication is that in the context of e-Navigation, ECDIS is not being considered as a stand-alone system, but part of an IBS. For ENCs, it was stated that "ENCs conformant with IMO requirements and produced to IHO standards will form the backdrop of navigational chart information within ECDIS" [8].

Clearly, hydrographic information and ECDIS technology, particularly ENCs, are a fundamental starting point for the successful implementation of the e-Navigation concept. At sea, ECDIS is likely to become the focal information point on the bridges of ships. Although not all e-Navigation information streams can or need be displayed on the ECDIS display, critical navigation-safety information will benefit from being cross-referenced with other chart-related information available through ECDIS. This includes AIS Application-Specific Messages and Marine Information Overlays [10].

Implications of Further Standards Development

In concept, and eventually in practice, e-Navigation can be thought of as the "maritime intranet." Ideally, there will be an infrastructure that enables all those in the maritime domain that require information to have access to it in an efficient and timely way. Further, it is envisioned that mariners will be able to use and interpret it in an intuitive and methodical fashion without duplication or inconsistency. To achieve this implies that all information be available in digital

form. In addition, that its encapsulation is standardized in a consistent manner. This does not mean that only one standard must be used; however, encapsulating the same information under a variety of different standards is wasteful, and can only lead to duplication and inconsistency. Similarly, there is no need for a single transmission or presentation format, as long as all the relevant receivers of the information can read the data format and interpret it according to their needs. However, the greater number formats, the more likely there will be complications. The internet and the ever-expanding capabilities of the World-Wide Web are illustrative in this context. A danger will be to try and over-specify the requirements of e-Navigation. It should primarily be the description of a vision that all the stakeholders can then work towards, rather than a detailed definition of infrastructure, equipment, methodology, data formats or information portrayal.

Challenges and Opportunities: Some Examples

Most would agree that achieving the e-Navigation concept of operation is a very worthwhile goal. But, making it happen may not be easy. Some of the goals for e-Navigation can also be considered as major challenges. This will be particularly true when ECDIS becomes part of a larger system or concept of operation.

The following are some examples of challenges and opportunities related to the portrayal of e-navigation-related information on ECDIS, Integrated Navigation Systems (INS) or IBS.

1. The stated goal of achieving "harmonized" shipborne and shore-based displays may be easier said than done. What may be considered an appropriate display onboard a ship may be quite different to what is needed ashore at a VTS Centre or Port Authority. Onboard a vessel there are tactical decisions to be made about grounding and collision-avoidance that are influenced by the current situation or task-at hand. Ashore, the focus is more typically on overall situational awareness. It is not that these scenarios are in conflict, but achieving a one-size = fits-all solution for suitable background colour schemes, symbolization, and minimum/maximum levels of information content may be difficult -- and perhaps unnecessary -- to achieve. It may actually be counter-productive to pursue absolute standardization for standardization's sake

2. In May 2010, the 87th Session of the IMO Maritime Safety Committee (MSC87) approved the promulgation of a new Safety of Navigation Circular (SN/Circ.) on "Guidance for the Presentation and Display of AIS Application-Specific Messages (ASMs)" [11]. The Circular was primarily in the form of "guiding principles" that apply to the display of AIS ASM information both for shipborne equipment and systems (e.g., ECDIS, radar, & IBS) and for shore-based systems (e.g., VTS Centre console). Specifically:

1. Use **consistent** symbology across all displays
2. **Uniqueness** – only one possible meaning
3. **Non-ambiguous** – ability to determine differences (i.e. distinct)
4. **Intuitively obvious** – an easily recognized symbol, icon or pattern
5. Have a **basic symbol** for different categories. Further attributes should be enhancements (not changes) to the basic symbol.

While it may be easy to agree on guiding principles, it will be more difficult to reach agreement on what constitutes "appropriate" information portrayal.

3. AIS includes the capability to broadcast information on Aids-to-Navigation (AtoN). AIS Message 21 includes three types of AIS AtoN: real, synthetic and virtual. A virtual AtoN does not physically exist, and is only recognizable on navigational displays (e.g., radar, ECDIS and INS/IBS). Although the symbols used to display AIS AtoN were defined in IMO SN/Circ.243, there is no distinction made between virtual and real or synthetic AtoN. For the forthcoming meeting of IMO NAV 56 in July 2010, Japan has proposed new symbols for virtual AtoN [12]. Japan's proposed symbols are related to but distinguishable from the IHO Chart Symbols – but the potential for confusion by mariners nevertheless may exist. There is also concern as to whether a virtual AtoN should be primarily a temporary measure or could be used for permanent marking in lieu of fixed navigation aids such as buoys and beacons. If so, such permanent virtual AtoN will need to be symbolized and appear on both paper charts and ENCs [13]. This presents yet more challenges in achieving a standardized approach.

IHO Involvement in e-Navigation: Present and Future

It could be asked:

> "*What is (or should be) IHO's level of involvement (or role) as it relates to facilitating the implementation of e-Navigation?"*

The short answer is to ensure that the necessary hydrographic standards, products, and services are in place from the outset to support the implementation of the e-Navigation concept of operation. It is not the role of the IHO to influence the design or to drive e-Navigation. Instead, it will be up to the IMO, equipment manufacturers, service suppliers, and the maritime user community to fulfill the vision of e-Navigation. However, given the fundamental and leading role that ENCs and ECDIS are likely to play in achieving the e-Navigation vision, the IHO must ensure that its underpinning standards not only support but also encourage the development and implementation of e-Navigation. In this regard, the IHO already has preparations well in hand.

The challenge for e-Navigation is to encapsulate and subsequently transfer the many forms of data and information in the maritime domain in a relatively seamless and efficient way. At the moment much of the information currently in the maritime domain is little more than textual-based messaging or verbal communication. This includes vessel radio reporting, NAVTEX, VTMS, and weather reports. By contrast, the introduction of ENCs and ECDIS has already driven the IHO to develop standardized methods of codifying, encapsulating, and subsequently transferring and distributing hydrographic and charting data and information digitally using the S-57 exchange standard and in the future S-100. The recognition by IMO of the use of binary messaging for AIS Application-Specific Messages is another example of the use of codified messaging as a means of exchanging data and information in a truly digital form. The challenge will be to codify and standardize all the other information required in the e-Navigation domain.

The IHO is actively developing its 2nd generation digital data transfer standard, and for several years has been working on updating product specifications for ENCs, digital nautical publications and supporting symbology. These will exist under the IHO's newly introduced S-100 framework and, significantly, will be compatible with other digital geographic data and information standards developed in accordance with the ISO 19100 series of geographic standards [14]. The IHO, through its technical Working Groups is also considering what are the

optimal methods for ensuring the integrity and security of data, currently provided in S-57 based ENCs by the S-63 Data Protection Scheme.

As part of developing compatible standards and ensuring that hydrographic information is as widely accessible as possible, the IHO will be forming a closer than ever relationship with ISO in the near future. Ideally, relevant ISO and IHO standards can be published jointly.

To ensure that its standards are both robust and acceptable, the IHO has an active policy of industry and stakeholder involvement in its working groups. Expert Contributors provide advice, expertise, test-beds and practical experience of the latest developments and the most appropriate technology. Most of the IHO working groups contain a wide representation from industry that works alongside the members who come from national hydrographic offices around the world. The mariner's voice is usually heard through the various accredited Non-Governmental International Organizations (NGIO) such as the International Chamber of Shipping (ICS), the International Maritime Pilots Association (IMPA), and the Cruise Lines International Association (CLIA) who have observer status in the IHO, as well as through direct approaches to national hydrographic offices that are represented in the various IHO bodies.

Because ENCs will form a fundamental part of any e-Navigation environment, improvements in the distribution and availability (e.g., ease of purchase) of ENCs is an obvious requirement – particularly through improved on-line mechanisms. This will require the current distribution and licensing practices of HOs to be adjusted. The IHO WEND Working Group is presently tasked primarily with addressing ENC quality and consistency issues, but may need to turn its attention to harmonized distribution next.

The IHO has been actively involved and provided significant input to the ongoing discussions of e-NAV both in the IMO and in IALA, particularly in relation to the charting and nautical publications component. Most recently, interest has been shown in using the IHO's S-100 framework and the supporting IHO Registry as one mechanism for standardizing the digital encapsulation of some other maritime information that currently has no data standard. The Registry currently contains mostly hydrographic-related elements, but has the capacity and flexibility to be extended to accommodate other related maritime domains. For example, it is already planned that the Registry will support:

- Aids-to-Navigation (AtoN) metadata requirements from IALA
- Extended continental shelf boundary claims from the UN
- Inland ENCs requirements by Inland ENC Harmonization Group
- Sea Ice Coverage MIOs from World Meteorological Organization (WMO).

In these, and any other cases, the various contributing authorities or organizations retain control and responsibility for their components in the Registry. In these cases the role of the IHO is limited to providing its Registry and its facilities. Any standards that are developed from the contents of the Registry are also adopted and maintained by the relevant contributing authority or organization, not the IHO.

Looking Ahead

The IMO has stated that e-Navigation must be implemented by evolution not revolution. There is no thought of introducing stringent compulsory carriage requirements or system requirements. This means that existing equipment and systems must be used and enhanced over time, rather than by re-equipping ships and shore-based installations. ECDIS alone or in combination with INS/IBS is therefore the logical starting point for bringing the e-Navigation concept of operation to ships. Ashore, the relevant e-Navigation information streams will in the first instance be accessed through existing systems – most probably using existing internet/intranet technologies.

This highlights that ECDIS and ENCs are very important pre-cursors to the successful achievement of the e-Navigation vision. However, in the end, these component technologies will be a relatively small, although always an important element of the e-Navigation data environment. In this regard, the IHOs role in the next few years is crucial – because without ECDIS and ENCs, the e-Navigation concept may struggle to operate.

Viewed from a larger perspective, there is a continuing role that IHO and other members of the hydrographic community should play in the development and implementation of e-Navigation. As will be reported by the IMO's e-Navigation Correspondence Group to NAV 56 in July 2010, the conceptual process for e-Navigation includes a number of elements, procedures and services that all must function together [15]. As shown in Figure 1, this includes everything from proper training and procedures by users to the provision of required operational functions and services by providers.

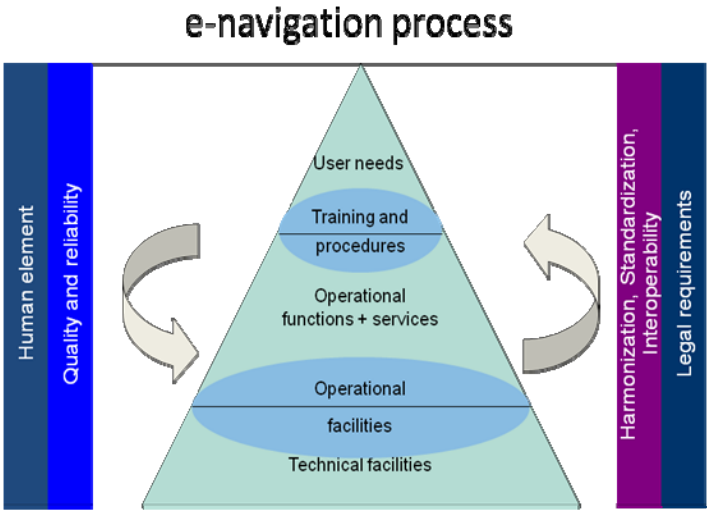

Figure 1 – The conceptual process of e-Navigation (Source: IMO paper NAV 56/8].

Over time, the products and services associated with this process will evolve and change as more experience is gained by both providers and users. Each e-Navigation "stakeholder" has a role and a number of responsibilities to fulfill in order for the process to function. For IHO, national HOs, and other members of the hydrographic community, it will be important to continually

assess what is their role and responsibility under the e-Navigation concept of operation – both for the present and in the future.

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