5-2009

e-Navigation: Challenges and Opportunities

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Proceedings: US Hydrographic Conference 2009, Norfolk, VA, 11-14 May 2009

e-Navigation and Electronic Charting: Implications for Hydrographic Community

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Abstract: e-Navigation is a recent IMO initiative that aims to integrate existing/new shipboard and shore-based navigational tools into an "all embracing" system. 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"

the goal of e-Navigation is to provide an infrastructure that will enable seamless information transfer onboard ship, between ships, ship-to-shore, and between shore authorities. Core elements include high-integrity electronic positioning, electronic navigational charts (ENCs) and improved system functionality towards reducing human error. In particular, this means actively engaging the mariner in the process of navigation while preventing distraction and overburdening. There are two main challenges in going from concept to implementation.

1) Ensuring the availability of all components of the system and using them effectively in order to simplify the display of crucial navigation-related information.

2) Incorporating new technologies in a structured way, while ensuring that their use is compliant with the existing navigational communication technologies and services.

To date, the primary focus of IHO Member States has been to complete ENC coverage for major shipping routes. However, e-Navigation has other implications for the hydrographic community, including:

1) Use of AIS binary messages
2) Standards for Displaying e-Navigation Information
3) Guiding Principles for e-Navigation-related Information

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 an operational concept. Interestingly, the letter "e" is not defined but can be assumed to relate to "electronic" or "enhanced."

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.

To date, the primary focus of the International Hydrographic Organization (IHO) and its Member States has been to complete ENC coverage for major shipping routes. Clearly, ENC data and associated services (e.g., means and process for updating) are major component of e-Navigation. However, in addition to completing adequate ENC coverage for major port and shipping routes, there are other ENC-related matters that will require attention. This includes ENC availability issues related to pricing and security schemes, and providing coordinated ENC updating and paper nautical chart Notice-to-Mariner services. However, e-Navigation has other implications for HOs and the broader hydrographic community.

Use of AIS Binary Messages

Automatic Identification System (AIS) is an autonomous, continuous broadcast system that exchanges maritime safety/security information between participating vessels and shore stations. Chapter V of the 1974 SOLAS Convention [4] requires mandatory carriage of AIS equipment on all SOLAS vessels by 31 December 2004. AIS enables both ships and maritime safety administrations (e.g., U.S. Coast Guard) to effectively track the movement of vessels in coastal waters. In addition, AIS can contribute to safety-of-navigation and protection of the environment by providing additional information in the form of AIS binary messages. This includes meteorological and hydrographic data, carriage of dangerous cargos, safety and security zones, status of aids-to-navigation, and other ports/waterway safety information. This information will be broadcast from shore-side AIS base stations to ships that are underway at-sea or in port.

In May 2004, IMO issued SN/Circ.236 on "Guidance on the Application of AIS binary Messages." [5] SN/Circ.236 contains interim guidelines for the presentation and display of seven (7) types of AIS Binary Message Applications to be tested and evaluated in conjunction with existing shipborne navigation systems. This included the AIS Minimum Keyboard Display (MKD), radar, ECDIS, and Integrated Navigation System (INS) equipment.

As shown in Table 1, the AIS binary message for "Meteorological and Hydrographic data" (Application 1) contains a variety of dynamic, time-varying data/information pertaining to:

- weather (wind speed/direction, air pressure, temperature, etc.)
- hydrological (water level, current flow speed/direction, wave height, etc.)
- oceanographic (sea state, swell height/period, etc.).

Parameter	No. bits	Description
Message ID	6	Identifier for Message 8; always 8
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated.
Source ID	30	MMSI number of source station
Spare	2	Not used. Should be set to zero.
IAI	16	DAC=001; FI=11
Latitude	24	Measuring position, 0 to +/-90 degrees, 1/1000th minute
Longitude	25	Measuring position, 0 to +/-180 degrees, 1/1000th minute
Date and time	16	Time of transmission, Day, hour, minute, (ddhhmm in UTC)
Average wind speed	7	Average of wind speed values for the last 10 minutes
Wind gust	7	Maximum wind speed value reading during the last 10 minutes, 0-120 kts, 1kt
Wind direction	9	0-359, 1 degree
Wind gust direction	9	0-359, 1 degree
Air temperature	11	Dry bulb temperature – 60.0 to +60.0 degrees Celsius, 0.1 of a degree
Relative humidity	7	0-100, 1%
Dew point	10	- 20.0 - + 50.0 degrees, 0.1 degree
Air pressure	9	800-1200 hPa, 1hPa
Air pressure tendency	2	0 = steady, 1 = decreasing, 2 = increasing
Horizontal visibility	8	0-25.0, 0.1 NM
Water level (incl. tide)	9	Deviation from local chart datum, -10.0 to 30.0 m
Water level trend	2	0 = steady, 1 = decreasing, 2 = increasing
Surface current direction	9	0 – 359 degrees, 1 degree
Current speed, #2	8	Current measured at a chosen level below the sea surface, 0.0 – 25.0 kts, 0.1 kt
Current direction, #2	9	0 – 359, 1 degree
Current measuring level #2	5	Measuring level in m below sea surface, 0-30m, 1 m
Current speed, #3	8	0.0 – 25.0 knots, 0.1 knot
Current direction, #3	9	0 – 359 degrees, 1 degree
Current measuring level, #3	5	Measuring level in m below sea surface, 0-30 m, 1 m
Significant wave height	8	0.0 – 25.0 m, 0.1 m
Wave period	6	Period in seconds, 0-60 s, 1 s
Wave direction	9	0-359 degrees, 1 degree
Swell height	8	0.0 – 25.0 m, 0.1 m
Swell period	6	Period in seconds, 0 – 60 s, 1 s
Swell direction	9	0 – 359 degrees, 1 degree
Sea state	4	According to Beaufort scale (manual input?), 0 to 12, 1
Water temperature	10	-10.0 - + 50.0 degrees, 0.1 degree
Precipitation (type)	3	According to WMO
Salinity	9	0.0 – 50.0 0/00, 0.1 0/00
Ice	2	Yes/No
Spare	6	
Total	**352**	**Occupies 2 slots**

Table 1 - IMO Meteorology and Hydrology Message as specified in IMO SN/Circ.236, Annex 2, Application 1. Also described in AIS, Vol. 1, Part 1, Operational Issues, Ed. 1.3. IALA Guideline No 1028, p. 131.

In June 2008, IMO established an Intercessional Correspondence Group to revise the SN/Circ.236 based on experience gained. [6] The terms of reference for the Correspondence Group (CG) were to:

…evaluate the use of binary messages in the trial period as identified in S/N Circ 236, and select and propose a revised set of AIS binary messages for international use. The Correspondence Group should in the selection of messages consider:

.1 the operational need

.2 other/existing methods to fulfil the need

.3 user interface onboard, both for presentation and input of information
.4 the technical limitations
.5 graphical presentation of binary messages

In April 2009, the Correspondence Group submitted a report to IMO that included a description of both revised and new AIS binary message applications. Table 2 provides a comparison of existing applications contained in SN/Circ.236 and the revised/new messages. The clear implication is that the amount and type of information that will be broadcast from AIS Base Stations and displayed on shipborne systems such as ECDIS and INS are increasing.

SN/Circ.236			**Revised/New Messages**	
Appl No.	**Message Name**	**FI**	**Message Name**	**FI**
1	Met/Hydrological	11	Met/Hydrographic	11
2	Dangerous cargo indication	12	Dangerous cargo indication	25
3	Fairway closed	13	---	--
4	Tidal window	14	Tidal window	14
5	Extended ship static and voyage related data	15	Extended ship static and voyage related data	24
6	No. of persons onboard	16	No. of persons onboard	16
7	Pseudo-AIS targets	17	VTS-generated targets	17
			Clearance time to enter port	18
			Marine traffic signal	19
			Berthing data	20
			Weather report from ships	21
			Area Notice - broadcast	22
			Area Notice - addressed	23
			Environmental	26
			Route Information – broadcast	27
			Route Information – addressed	28
			Text Description – broadcast	29
			Text Description – addressed	30

Table 2 - Comparison of existing AIS Binary Message Applications contained in IMO SN/Circ.236 and the revised/new messages proposed by the IMO Intercessional Working Group on AIS Binary Messages.

Clearly, the type and amount of supplementary information that will be displayed on ECDIS, ECS, and INS equipment is increasing. To prevent confusion or and to avoid cluttering the display, the amount of chart-related information being shown in conjunction with the presentation/display of AIS binary messages may need to be reduced.

Standards for Displaying e-Navigation Information

At present, there is no specific guidance or standards related to the presentation/display of AIS Binary messages or other e-Navigation-related information on shipborne equipment/systems. While the Minimum Keyboard Display (MKD) is capable of displaying text messages, it was never intended for the graphical display/presentation of AIS binary message information. Instead, it will be existing shipborne equipment – particularly ECDIS and INS – that will be used.

There are a number of general and equipment-specific international standards that have been adopted by IMO, IHO and IEC that contain specifications and requirements related to the display of navigation related information on shipborne navigation equipment.

General

Performance Standards for the Presentation of Navigation-related Information on Shipborne Navigational Displays, IMO Res. MSC.191(79), 6 December 2004.

Guidelines for the Presentation of Navigation-related Symbols, Terms and Abbreviations, IMO SN/Circ.243, 15 December 2004.

Presentation of Navigation-related Information on Shipborne Navigational Displays – General Requirements, methods of testing, required test requirements. IEC 62288, Edition 1.0, July 2008.

Equipment-Specific

*Revised Performance Standards for **ECDIS**, IMO MSC.232(82), 2006.*

*Specifications for Chart Content and Display Aspects of **ECDIS,*** IHO S-52, Ed. 4.2, March 2004.

IHO S-52, Appendix 2, Colour and Symbol Specifications for **ECDIS**, March 2004.

*Performance Standards for **Radar** Equipment*, IMO MSC.192(79), 2004.

*Performance Standards for a Universal Shipborne Automatic Identification System (**AIS**)*, IMO Res. MSC 74(69), Annex 3, 19 May 1998.

Guidelines for the Onboard Operational Use of Shipborne Automatic Identification Systems (**AIS**), IMO Res. A.917(22), 25 January 2002.

*Display of **AIS** Target Information*, IMO SN/Circ. 217.

*Guidance of the Application of **AIS Binary Messages***, IMO SNCirc.236, 28 May 2004.

Performance Standards for an Integrated navigation System (**INS**), IMO Res. 86(70), Annex 3.

*Integrated Navigation Systems (**INS**) - Operational and performance requirements, methods of testing and required test results.* IEC 61294, Ed. 1,

It should be noted that these were separate standards that were adopted by different organizations (e.g., IMO, IHO, and IEC) for various types of shipborne equipment equipment/systems. Further, most were adopted separately, prior to general standards/guidance being issued. In particular, the ECDIS-related standards associated with chart content and display aspects will need to be "updated" in order to comply with the overall harmonized requirements contained in Res. MSC. 191(79) and IEC 62288. In the interim, there does not appear to be any existing requirement that would preclude the presentation/display of any e-Navigation – related information on shipborne equipment/system that complies with SOLAS V.

At this time, it is premature to propose specific presentation/display standards for shipborne or shore-based e-Navigation equipment/systems. More operational experience is needed. However, both the definition and core objectives that IMO adopted for e-Navigation provide a clear indication of what is desired:

> *… the harmonized collection, integration, exchange, presentation and analysis of marine 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*
>
> *.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;

*(*NAV54/25, Annex 12).

In this regard, IHO should re-examine its ECDIS-related standards/specifications in terms of how they fit into the e-Navigation concept of operations. As a first step, this includes existing standards such as, IHO S-52, IHO S-57, IHO S-61, and IHO S-63. As a second step, it will be important to make sure that the future S-100 family of standards contributes to furthering the goals of e-Navigation. This includes both the planned S-101 ENC Product Specification, and any new "portrayal" guidance/standards under S-100 [7].

Guiding Principles for the e-Navigation–related Information

The overall concept of operation for e-Navigation could be stated as an ideal or goal:

> All shipborne and shore-based equipment/systems/services should provide information to all users (e.g., shipborne and shore-based) in a uniform and consistent manner.

As defined by the IMO's Draft Strategy for the Development and Implementation of e-Navigation, [1], the seven key information components include:

1. Electronic chart and weather information
2. Electronic positioning signals
3. Electronic information on vessel route, course, maneuvering, etc.
4. Transmission of positional and navigational information
5. [Proper] Display of information
6. Information reporting, prioritization and alert capability
7. Transmission of distress alert and maritime safety information

In regard to the use of electronic charting equipment for displaying e-Navigation information, there are some guiding principles that seem to be appropriate:

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.

Both in concept and practice, these should apply to both to shipborne equipment/systems (e.g., ECDIS and INS) and shore-based systems (e.g., VTS Centre console).

Discussion

Most persons feel that achieving the e-Navigation concept of operation would be a desirable outcome. But, making it happen will not be easy. The primary goals for e-Navigation can also be considered major challenges:

1. Ensuring the availability of all components, and using them effectively so as to simplify the display of crucial navigation information.
2. Incorporating new technologies in a structured manner while ensuring that their use is compliant with existing technologies and services.

A major complicating factor is that two main groups are involved, each with a different perspective:

1) Those responsible for providing necessary e-Navigation services
2) Those who will actually use them.

While IMO wants e-Navigation to be "user-driven", most of those currently involved in developing/implementing e-Navigation are from the technology or government sector. Further, it is human nature to resist change. This is particularly true when persons or organizations are sure that they are both knowledgeable about and empowered to decide what needs to be provided. Further, there are differences in opinion between providers and users in terms of the frustration of not having access to critical information vs. being over-burdened with too much that is unnecessary, irrelevant, or confusing. Alternatively, it can be very frustrating when mariners know that crucial information exists, but they cannot get it. This type of information dilemma is not new, and has been previously described as the "The Three Rules of Military Intelligence":

Rule #1 – **What** you need you cannot get (even if you know it exists).
Rule #2 – **If** you get it, you cannot use it (e.g., encrypted data format, wrong type of equipment, out-of-date software, unintelligible display, lack of geo-reference, etc.).
Rule #3 – **When** you can finally use it, the information is now of date (-- back to Rule #1).

The potential of e-Navigation is great, but there could be some undesirable results.

- Integrating more components into a "system" often leads to increased complexity and less reliability.
- With an increasing amount and availability of information, the tendency will be to try and display more – not less -- information.
- The fact that someone else wants to provide what they consider to be "useful" information does not necessarily make it so.
- Trying to integrate "new" technologies into existing equipment, systems or information services often causes more problems than it solves. For example, what will be the impact of e-Navigation on existing Aids-to-Navigation (AtoN) or Vessel Traffic Services (VTS) services? Will it lead to more, less, or "different?" If more, less or different, what will be the impact of the use or reliance on electronic charting systems?

E-Navigation should be regarded as an evolutionary – not revolutionary – change. When change impacts tried-and-true maritime navigational systems or practices, the process may be a bumpy ride. On the other hand, e-Navigation maybe similar to the transition from primarily visual to instrument-qualified flight (VFR and IFR) that occurred in the aviation community. If so, what

will be the implications for those responsible for providing crucial e-navigation related data or services?

- Will mariners be required to take e-Navigation training and become e-Navigation certified?
- Will there be e-Navigation modes of operation whereby vessels are given preferential treatment over those that are not e-Navigation capable? (e.g., under-keel clearance, all-weather navigation, preferred routing/port entry).
- If the HOs have crucial navigation safety-related information, will they take full responsibility to provide it in a timely, reliable manner – and in a format that can be used with existing shipboard navigation systems?

While electronic charts may be considered of foremost importance those in the hydrographic community, under the e-Navigation Concept of Operations they will likely become the background upon which other static and dynamic navigation-related info is displayed.

Some Final Thoughts

In my view, there are three key aspects that will be a crucial determining factor to the success of e-Navigation.

1. Ensuring that the data being provided – and used – is complete, accurate, up-to-date, and suitable for intended use.

This pertains to both chart and navigation-related data. For instance, having complete ENC coverage is just the first step. It must be at the correct scale (i.e., navigational purpose), up-to-date for the intended voyage, and capable of being used with dynamic information required for decision support. Under the e-Navigation concept of operation, there will be a combined display of chart and dynamic water-level information that will be used to make critical under-keel clearance decisions (e.g., how much, when and where) for increasingly large vessels operating in confined ports and waterways.

2. Understanding the capability and limitations of the entire system.

This includes hardware, software, data, sensor inputs, digital communications, electronic positioning, presentation/display, and human-machine interface. Increasingly complex and sophisticated equipment/systems will require more training and understanding by mariners in terms of determining what data is available and how it should be used. In terms of hydrographic data and services, mariners will want to use larger scale, more accurate data that was produced from high-density bathymetric surveys. For some critical waterways and approaches, having to relying on ENC data that was digitized from existing paper charts will no longer be considered suitable.

3. Knowing what information is needed and when it needs to be displayed.

Increasingly, this will become the responsibility of the user, not the provider or regulator. Capt. Jean-Luc Bedard (Port of Montreal) said it best when he remarked during a recent e-Navigation Workshop in Montreal: "*When it comes to e-Navigation, I don't want more information, I want better*." As far as he is concerned, "better information" is that which is required for the current situation or task-at-hand. No more than a person driving a car should be faced with a constant barrage of unnecessary visual or auditory information, a mariner needs to

receive relevant, accurate and up-to-date information clearly presented to meet their current needs. Similar to a heads-up display on a military jet, it may be simple, basic display of critical information rather than a highly detailed, 3-D display that is constantly changing.

Both now and in the future, hydrographic offices will continue to be responsible for determining the type and amount of chart data to be provided in digital charting products/services. However, under the e-Navigation concept of operations, the final decision about what type, how much, or when chart-related information should be displayed on shipborne or shore-based systems will be decided by those who are actually using it – maritime users.

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