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Original article

Improving Canada's Marine Navigation System through e-Navigation**Daniel BRETON¹, Jennifer BARRY², Lisa VANDEHEI³*¹ Canadian Coast Guard, Ottawa, Ontario, Canada, Daniel.Breton@dfo-mpo.gc.ca, Author² Canadian Coast Guard, Ottawa, Ontario, Canada, Jennifer.Barry@dfo-mpo.gc.ca, Corresponding Author³ Canadian Coast Guard, Ottawa, Ontario, Canada, Lisa.Vandehai@dfo-mpo.gc.ca**Abstract**

The full application and benefits of e-Navigation, as a whole, cannot yet fully be known. Technological developments will continuously change the course of national and international initiatives in the field, and lead the pace of the evolution. However, how countries govern and support the development of e-Navigation is very much within the realm of control. National-level e-navigation governance structures that are capable of harnessing innovation and supporting the needs of mariners will help ensure that the only limits to the evolution of e-navigation are technological.

The aim of this paper is to describe a model for National-level e-Navigation structures, and to offer the Canadian model as an example for potential replication in other countries. The scope of the paper is limited, providing an account of the steps to implement the e-Navigation model in the Canadian context. The methodology is similarly humble, outlining the framework of the Canadian e-Navigation Concept of Operations, and current e-Navigation priorities. It is the basis for this model that is the keystone to the paper. The Canadian model was developed in a way that ideas, innovation and needs in Canada are not wholly determined by the government, but rather, the government aims to act as a facilitator and guide in bringing together disparate needs and ideas under a harmonized approach.

The conclusion proposed is that on-going work with key partners and stakeholders can be used as the primary mechanism to identify e-Navigation related innovation and needs, and to prioritize next steps. Moving forward in Canada, implementation of new e-navigation services will continue to be stakeholder driven, and used to drive improvements to Canada's marine navigation system.

Keywords: e-Navigation, Canada, marine navigation, SOLAS, Non-SOLAS ships

I. Introduction

The full application and benefits of e-Navigation, as a whole, cannot yet fully be known. Technological developments will continuously change the course of national and international initiatives in the field, and lead the pace of the evolution. However, how countries govern and support the development of e-Navigation is very much within the realm of control. National-level e-navigation governance structures capable of harnessing innovation and supporting the needs of mariners, will help ensure that the only limits to the evolution of e-navigation are technological.

Many e-Navigation initiatives have already been conducted to improve marine safety, security, and efficiency in Canada. Success to date has been due to collaboration and communication with key partners and stakeholders, where on-going consultation is used as the primary mechanism to identify e-Navigation related needs and to prioritize next steps.

As such, the aim of this paper is to describe a model for National-level e-Navigation structures, and to offer the Canadian model as an example for potential replication in other countries. The scope of the paper is limited, providing an account of the steps to implement the e-Navigation model in the Canadian context. The methodology is similarly humble, outlining the framework of the Canadian e-Navigation Concept of Operations, and current e-Navigation priorities. It is the basis for this model that is the keystone to the paper. The Canadian model was developed in a way that ideas, innovation and needs in Canada are not wholly determined by the government, but rather, the government aims to act as a facilitator and guide in bringing together disparate needs and ideas under a harmonized approach.

II. Navigation and Communication System of non-SOLAS Ships

In 2008, Canada focused on the development of a vision and strategy for e-Navigation. As stated in the Canadian Coast Guard e-navigation strategy (2008, p.3), Canada's vision is the widespread use of e-navigation in Canada by mariners and shore authorities for greater marine safety, security, efficiency and environmental protection.

Building on this initial vision, subsequent efforts focused on identification of user-needs through stakeholder consultation, which led to the development of Canada's Required Services Matrix (2011, p.1 - 3). The matrix identified and prioritized various e-Navigation related services for specific waterways and regions across Canada and has become a very important tool for implementation purposes. The matrix clearly identifies the highest priority information and data requested for a given area. Given Canada's diverse geography, coastline and waterway characteristics, high priority required services can vary largely by area. The main categories of information and data that have been prioritized by users include: meteorological and hydrographic services, ice information, navigational charts and bathymetric data, aids to navigation information, restrictions to navigation, vessel traffic services and pilotage related information.

In 2012, further work on Canada's e-Navigation vision and strategy continued between federal partners, including Transport Canada, Environment Canada, the Canadian Hydrographic Service

and the Canadian Coast Guard. The proposed way forward to implement e-Navigation in Canadian waters focused on two main elements:

1. Defining the required guiding principles, which serve as a reference framework for implementation; and,
2. Proposing an implementation roadmap within the broader context of international conventions and other international maritime initiatives.

The Canadian e-Navigation implementation strategy follows, in general, the approach recommended by the International Maritime Organization (IMO) Maritime Safety Committee (MSC). This approach is primarily based on an assessment of the user needs, from which services and technological systems are developed (IMO, 2008). The following five phases frame the approach (IMO, 2008):

Step 1: Identify user needs

Step 2: Define the architecture of the hardware, data, information, communications technology and software

Step 3: Perform a gap analysis of the technical, regulatory, operational and training aspects

Step 4: Perform cost-benefit and risk analyses

Step 5: Implement the concept

III. Canada's e-Navigation Concept of Operations

Building on Canada's high level vision and strategic direction for e-Navigation, the Canadian Concept of Operations (2013) is based on the premise that shore authorities will make data accessible to users via a single, Canadian national e-Navigation Portal, called the Maritime Information Portal. In simple terms, the portal is a website that provides information from recognized sources in a uniform way. The Canadian Coast Guard's role is to maintain and support the Common Maritime Information Infrastructure in collaboration with other Government partners. CCG works to ensure that information is provided in the right format, avoiding duplication of information whenever possible.

The concept is that the data and information will be made available to users and it will continue to be the responsibility of industry to develop the technology and tools to facilitate integration and use by mariners. Information will also be provided through the Automatic Identification System (AIS) Network and other electronic means, such as Very High Frequency Data Exchange (VDE).

The Required Services Matrix was used as the basis for determining what types of information and data would be available to users on the e-Navigation Portal (2011).

3.1. Pre-Voyage Stage

During the pre-voyage stage, mariners prepare for their upcoming voyage by gathering the information relevant to the up-coming trip from the maritime information portal, and then create a voyage plan.

Information that users may gather from the Maritime Information Portal in order to develop their voyage plan includes:

- Predicted meteorological information (such as forecasts of wind speed and direction, visibility, weather conditions, wave height) for the period of the voyage.
- Ice Information (such as ice charts of current conditions, routing advice, forecasts, advisories and bulletins).
- Hydrographical information (such as forecast tides, real-time water levels, predicted water levels, forecast current).
- Aids to navigation information (such as status of existing aids to navigation and related buoy tending information).
- Navigational charts (and updates).
- Restrictions to navigation (such as construction work, temporary restricted areas, harbour closures, etc.).
- Vessel traffic services (such as notices to shipping).

3.2. Voyage Stage

The second phase is the voyage itself where most of the data gathered from the Maritime Information Portal during the first phase (voyage planning) is now used by navigators.

Implementation of e-Navigation services during the voyage stage is allowing users to receive updated information or real-time information via telecommunication means, such as AIS. Further work is underway to determine what real-time data and updated information should be provided to users while at sea. Along these lines, a national user needs survey has been initiated to determine what data is required by users during the voyage stage and at what rate the data should be broadcast. Amongst others, the types of data being considered as part of the survey for voyage stage AIS Application Specific Messages include: vessel traffic services messages; clearance time to enter ports; berthing data; area notices; route information; meteorological and hydrographic information, etc.

3.3. Post-Voyage Stage

The third phase is the post-voyage phase where most of the data is analyzed by navigators and shore-based authorities. Analysis of the information provides validation that the information that was provided during the pre-voyage stage or transmitted during the voyage stage was precise, timely and adequate. Following analysis, reports can be produced and shared between users and shore-based authorities. This phase in the cycle allows the creation of a consolidated maritime picture, providing benefits and opportunities to shore-based authorities and mariners to improve

processes, programs, operations, updates, as well as providing training opportunities for navigators.

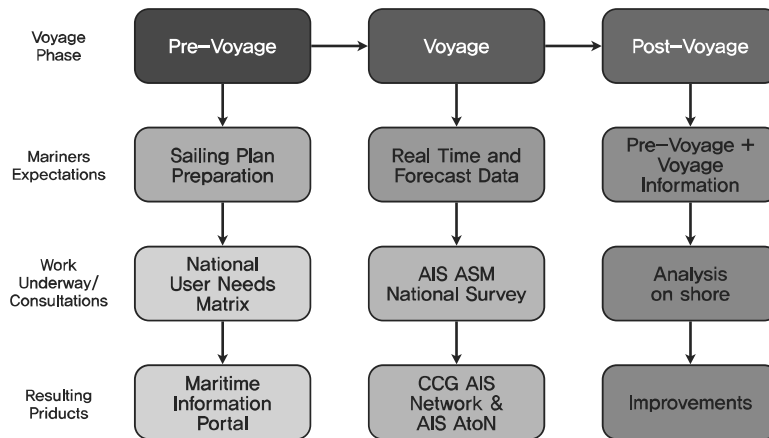


Figure 1: Concept of Operation

IV. Other On-Going e-Navigation Projects

Canada is in the process of conducting a navigational warnings study, which will review systems used to issue navigational warnings at the national and international level. The intent is to review and standardize current procedures and develop operational requirements for a system that will be interoperable with other databases, and will include automatic translation capabilities. Another study underway relates to AIS aids to navigation (AIS AtoN), specifically to: learn from current practices at the international level; identify the conditions where AIS AtoN may enhance the safety to navigation; and conduct a cost-benefit analysis.

Table 1: E-Navigation related Enhancement : Marines-On-Line

Electronic Navigational Charts	Enhanced Electronic Navigational Chart (ENC) coverage for the top 20 ports and waterways that handle oil and gas products. Review work to prepare for the transition to dynamic hydrographic products. Addressing real-time data requirements for next-generation ENCs; supports E-Navigation concept.
Channel Monitoring	More frequent channel bottom monitoring surveys for 47 commercial channels in Canada. CCG issues a Notice to Shipping when new hazards or restrictions to safe navigation are discovered.
Smart Buoys	New smart environmental buoys will be implemented in high risk channels and waterways, providing mariners and the commercial shipping industry with up-to-date and real-time detailed weather and sea-state observations.
Positioning and Timing Solution	Review work to implement a back-up positioning and timing solution for Canada.
e-Navigation Hub	e-Navigation Information Hub to provide reliable, up-to-date and real-time information and data to ships and shore authorities, allowing strategic direction to support continued integration of new and/or enhanced e-Navigation services.

V. Challenges and Opportunities

As is likely the case in many other countries, Canada is facing challenges associated with introducing new, e-Navigation related services, while continuing to provide traditional services. There is also an on-going need to raise the profile of e-Navigation with decision-makers.

5.1. World Class Tanker Safety System Initiative

In 2012, the Government of Canada initiated the *World Class Tanker Safety System Initiative (2012)*, which involved investments in Canada's Ship-Source Spill Prevention and Response Regime, as well as Canada's marine navigation system. Initial drivers for the investments included public concerns over projected increases in oil tanker traffic; increasing expectations regarding Government capacity to prevent and respond to incidents; the Government of Canada priority to increase marine navigation safety; and, the need to enable economic/resource development, while protecting the interests of communities. In essence, this provided a significant opportunity to bring e-Navigation to the forefront in Canada.

World Class Tanker Safety System initiatives fall under three pillars – prevention, preparedness and response, and liability and compensation.

Under the prevention pillar, the *Modern Navigation System* initiative is strengthening Canada's ability to prevent marine incidents, by providing mariners and shore authorities with reliable and real-time information to support decision-making and proactively identify high-risk situations.

The new, prevention-related initiatives take into account international directions, trends and best practices, as well as long-standing requests from industry; they also leverage 'smart' technology, where possible and are empowered by e-Navigation concepts – such as increased access to reliable, up-to-date electronic information and data. It is expected, that over time, these new initiatives will enable economic growth by increasing safety and efficiency for the maritime sector.

5.2. Prevention Pillar - Modern Navigation System Initiative

The *Modern Navigation System* enhancements fall under three themes: *Mariners-On-Line*; *Strengthened Navigational Monitoring*; and, *Modern, Relevant and Innovative Navigational Services*. Expected outcomes for each theme and specific undertakings under each are briefly outlined below.

1. *Mariners-On-Line*: enabling the marine industry to connect to the information they need to plan their voyage, and navigate safely and more efficiently (such as marine weather, tides, currents, hazards, notices, ice conditions, charts and sailing directions, etc).
 - Under this theme, Electronic Navigational Charts (ENCs) will be produced for the highest priority ports and waterways that handle oil and gas products.

- Review work is underway to prepare for the transition to dynamic hydrographic products, effectively addressing Canada's real-time data requirements for next-generation ENC's.
 - Channel bottom monitoring surveys will be conducted more frequently for Canada's commercial channels, allowing the Canadian Coast Guard to issue a Notice to Shipping when new hazards or restrictions to safe navigation are discovered.
 - New smart environmental buoys will be implemented in high risk channels and waterways, providing mariners and the commercial shipping industry with up-to-date and real-time detailed weather and sea-state observations.
 - Review work is underway to identify Canada's requirements to implement a back-up positioning and timing solution.
2. *Strengthened Navigational Monitoring* – enabling future implementation of “SMART vessel traffic services”, to enhance navigational safety oversight, enabling the Canadian Coast Guard to proactively identify high risk situations through real-time and on-going vessel traffic analysis.
- Initial review work is focused on identifying coverage or capacity gaps related to radar, radio communication and the AIS network.
 - In support of enhanced maritime domain awareness, Canada is pursuing expanded AIS carriage requirements to include small commercial vessels. This will be a key enabler for future implementation of SMART vessel traffic services in Canada.
 - Review work is also underway to identify Canada's requirements for the next generation vessel traffic services software. The objective is to provide marine communication and traffic services officers with a more complete operating and environmental picture, automated risk assessment functionality, as well as alerting and options analysis functions.
3. *Modern, Relevant and Innovative Navigational Services* – enabling the Canadian Coast Guard to “right-size” aids to navigation systems.
- Comprehensive aids to navigation system reviews are underway to identify where new or modified aids to navigation are required.
 - Four-season lighted navigational buoys will be deployed in some areas of the St. Lawrence shipping channel.

5.3. Preparedness and Response Pillar

Although not specifically e-Navigation related, the initiatives under the preparedness and response pillar are driving significant change in Canada.

Current enhancements focus on:

1. Establishing new area spill-response planning partnerships in four high-risk regions.

- The new spill-response planning approach takes into account the level and types of risks, including geography, environmental sensitivities and oil tanker traffic volumes.
 - A new program is under development to build capacity for Aboriginal communities to participate more in marine safety and response activities.
2. Implementation of the Incident Command System (ICS), a widely-accepted emergency management system.
 - ICS will increase the Canadian Coast Guard's ability to work with other emergency responders, engage stakeholders in a predictable and structured way; and better enable a coordinated response to complex incidents.
 3. Legislative amendments to permit the authorized use of alternative response measures and scientific research on spill response options.
 - This initiative will consider pre-treatment of heavy oil products at the source, as well as new spill-treating agents.

V. Conclusions

After years of working to implement e-Navigation related services in Canada, it is now at the heart of Canada's agenda to strengthen navigation safety. Canada will continue to implement new approaches to improve marine navigation, and preparedness and response, considering potential e-Navigation related solutions, where appropriate.

Moving forward, the development of e-Navigation services in Canada will continue to be user driven. Working with marine stakeholders and partners to identify and implement high priority e-Navigation services is essential to ensure user requirements and potential impacts for both mariners and shore-side users are adequately considered prior to implementation.

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