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Supporting paper

The presence of the Chilean marine aids to navigation service in routes to the Antarctic territory

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The Presence of the Chilean Marine Aids to Navigation Service in routes to the Antarctic territory

I. Abstract

The Antarctic is a territory of approximately 14.500.000 square kilometers, that is located almost entirely within the Antarctic Polar Circle, bordering with southern waters of the Pacific, the Indian and the Atlantic Oceans. The confluence of three oceans in the area gives to this territory a strategic significance as a communication channel, demonstrated by an increase of 250% in the number of vessels sailing this area since 2007/2008 summer season. The state of Chile, through DIRECTEMAR manages and keeps a network of approximately 72 aids to navigation that contributes to the safety of navigation and protection of this "frozen continent".

II. Principles of the Antarctic Treaty

After World War I, the interest of the countries for the Antarctic as a geostrategic space gradually increased, forcing an international mechanism that harmonizes the various interests involved.

Thus, on December 1rst 1959, Chile participated in the signing of the Antarctic Treaty in Washington which entered into force on June 23rd in 1961, with the aim of explicit recognition of the exclusive use of the Antarctic for peaceful purposes, specifically in the science field.

III. Chile and the Antarctic

Historically, Chilean claims in the Antarctic continent are based on the geographic proximity of the country to this area; on the effective occupation of this territory in 1947, and the legal records that can be traced to 1494, with the Treaty of Tordesillas, signed between Spain and Portugal, that enshrined the legal concept of Uti Possidetis Juris. Since then, the presence of Chilean citizens in the Antarctic continent has continued, increased and becoming stronger, mainly by sea, which has been facilitated by a number of aids to navigation, installed and maintained by the Chilean Navy, through DIRECTEMAR, safely guiding vessels in this area.

Nowadays, Chile has a strong presence in the Antarctic, reaching a total amount of 24 facilities including permanent and summer bases and shelters. As a consequence, there is the need to keep secure communication lines that allow a logistic supply to these bases and at the same time, provide safety to vessels and the marine environment nearby.

IV. The aids to navigation network in the Antarctic territory

Currently the Chilean Aids to Navigation Service manages and maintains 72 aids to navigation in the Antarctic territory, consisted mostly by unlighted beacons, a small number of lighted beacons and 4 racons.

It should be noted that during the last year, DIRECTEMAR has begun a standardization and renovation process of those Antarctic structures that have already achieved their life cycle, for modern metallic structures which will facilitate their viewing and identification to sailors.

Additionally, during the month of November of the present year, the installation of AIS AtoN devices have begun in Bahia Cook area, which will constitute one of the communication lines between the Magellan channels, the port of Punta Arenas and the Antarctic territory. This, in order to increase its availability by monitoring its operation via AIS, the difussion of synthetic and virtual aids to navigation, and also improve the surface pictures controlled by DIRECTEMAR for the execution of maritime search and rescue missions.

V. Conclusions

Because of the need to keep safe and expeditious routes to connect Antarctic national bases and settlements with the continent, and the increase of the number of passenger vessels sailing in the Antarctic territory, DIRECTEMAR, through the Marine Aids to Navigation Service has initiated, in recent years, a standardization and renewal process of Antarctic structures, in order to increase safety levels in authorized sea routes and the dissemination of synthetic and virtual aids to navigation and the monitoring of those by AIS.

Stations according to the following table:

TYPE OF BASE	QUANTITY
Permanent	04
Summer	11
Laboratories	02
Shelters	07
Total	24

Supporting paper

New classification for buoys at the German coasts – Conversion to plastic buoys in Baltic and the North Sea

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IALA·2014·AISM
XVIII Conference · A Coruña · Spain

Floating Aids to Navigation

XVIII IALA Conference 2014

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„New Classification for Buoys at the German Coasts
Conversion to plastic Buoys in Baltic and North Sea“

Introduction

The German Waterways and Shipping Administration (WSV) maintains buoys at about 4.100 positions. Due to historical reasons, there is a huge variety of buoys in 20 different categories with more than 100 different types. As a result of this, it was necessary to keep more than 2000 buoys in reserve. In order to minimize the resulting costs for investment and maintenance, a simplified classification for the type and shape of buoys according to IALA Maritime Buoys System (IALA MBS System A) and national guidelines was established in 2012. The territory covered by the new classification is shown in figure 1.

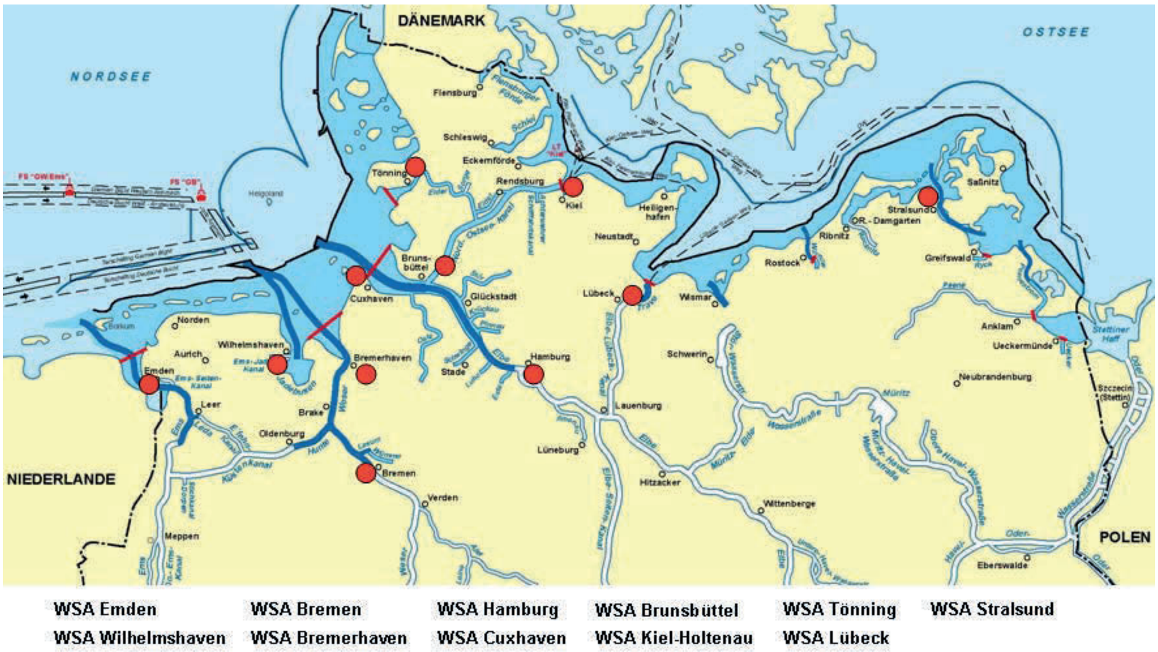


figure 1: territory covered by the new classification and involved water and shipping authorities on the German coast

Classification of buoys

The new system should fulfill several demands. Basically it is necessary to differ between nautical requirements and the geographical and traffic demands.

Regarding the **nautical requirements** mainly questions of disponsability, resistance against collision, swimming stability, visibility at day and at night, radio recognisability and radar reflection as well as RACON/AIS-AtoN were considered and defined. Especially the aspects **visibility at day**, e.g. colour recognisability, writing, height, coloured surface and recognisability of form and **visibility at night**, e.g. night marking, light equipment, height of light underlie a permanent process of optimizing. Therefor the new classification has to be as simple and general as possible, in order to keep enough space for all possible and essential specifications of buoys.

Geographic and traffic demands led to categories of buoys depending on their operation area. The main criteria are the meteorological-hydrological circumstances, traffic frequency and traffic structure, navigation circumstances and meaning and purpose of the buoys. Depending on the operating area the following aspects have to be considered:

- **open sea**: high water depth, few navigation marks
  Buoys should have a very good swimming stability, resistance against ice (especially in Baltic Sea), strong construction and anchorage, big height of buoy body and light, very large coloured surface and be able to sustain RACON and AIS-AtoN
- **coast** (navigable for sea going vessels e.g. Elbe, Kieler Förde, Lübecker Bucht) strong tidal current, heavy traffic, short head sea
  Buoys should have a good swimming stability in tidal current and head sea, resistance against ice, strong attachment for anchor cable, enough height of buoy body and light,
- **estuary**: different water depths, mainly fishing and sporting ships
  Buoys should have good swimming stability in head sea and tidal current, strong attachment for anchor cable, enough height of buoy body and light and be detectable for radar
- **river**
  Buoys should be with good swimming stability in head sea and tidal current, strong attachment for anchor cable, middle height of buoy body and light, detectable for radar
- **shallow water** (e.g. Wadden Sea and Bodden): falls dry, rapid and often ice, often changing of waterways
  Buoys should be of low weight, should bear to fall dry and shpuld be resistant against ice.

Regarding these aspects the new classification simply consists of 5 different categories of buoys. The new categories are:

- Lighted pillar buoys
- Spar buoys
- Conical buoys
- Spars
- Barrels

Can and spherical buoys were regarded as no longer necessary. Dependant on traffic and geographical circumstances 3 different sizes maximum will be put into service (see figure 2).

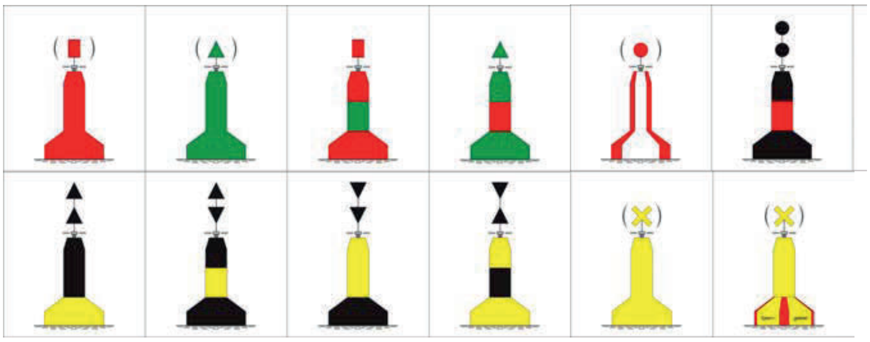
	sea/coast	**coast/estuary**	**river**	**shallow water**
lighted pillar buoys	very large (XL)	large	small	---
spar buoys	large	large	mid-size	small
conical buoys	---	large	mid-size	small
barrels	large	large/small	small	small
spars	unit size	unit size	unit size	unit size

figure 2: classification of all types of buoys

Characteristics of the new Classes

The classification has to be applied for all kinds of lighted and unlighted buoys irrespective of the material (steel, plastic, hybrid). Moreover, all unlighted buoys should be able to withstand the effects of ice (winter or ice buoys). The technical parameters of the new classes as seen in the following figures should be regarded as standard values and should not be changed unless of very rare exceptional reasons.

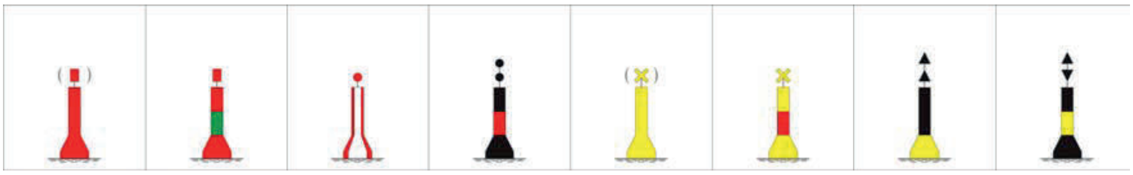
Lighted pillar buoys



	XL LT	large LT	small LT	remarks
visible coloured area (m²)	≥ 5,0	≈ 4,0	≈ 2,0	(projected area)
height above water line (without top mark) (m)	≈ 5,0	≈ 4,0	≈ 2,0	
maximum diameter in waterline (m)	≈ 2,5 (3,0)	≈ 2,5	≈ 1,4	
maximum diameter beacon (m)	≈ 1,0	≈ 0,9	≈ 0,5	
radar reflection area (m²)	≈ 400	≈ 400	≈ 30	

figure 3: parameters and examples of lighted pillar buoys

Spar buoys



	large spar buoys	mid-size spar buoys	small spar buoys	remarks
visible coloured area (m²)	≥ 3,0	≈ 2,0	≈ 1,0	projected area
height above water line (without top mark) (m)	≈ 4,0	≈ 3,0	≈ 2,0	
maximum diameter in waterline (m)	≈ 1,5	≈ 1,0	≈ 0,7	
maximum diameter beacon (m)	≈ 0,6	≈ 0,5	≈ 0,4	
radar reflection area (m²)	≈ 30	≈ 30	≈ 15	
topmark	Class 2	Class 2	Class 2	if any
numbering or lettering (size)	large	mid-size	mid-size	

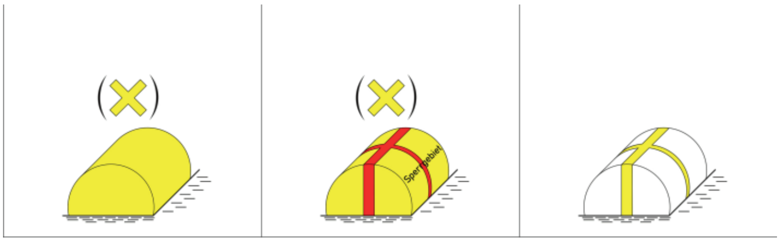
figure 4: parameters and examples of spar buoys

Conical buoys

	large conical buoy	mid-size conical buoy	small conical buoy
visible coloured area (m²)	≥ 3,0	≈ 2,0	≈ 1,0
height above water line (without top mark) (m)	≈ 4,0	≈ 3,0	≈ 2,0
maximum diameter in waterline	≈ 1,5	≈ 1,0	≈ 0,7
radar reflection area (m²)	≈ 30	≈ 30	≈ 15
numbering or lettering (size)	large	mid-size	mid-size

figure 5: parameters and examples of conical buoys

Barrel buoys



	large barrel buoy	small barrel buoy	remarks
visible coloured area (m²)	≈ 3,5	≈ 0,9	projected area, buoy has the shape of a lying barrel
height above water line (without topmark) (m)	≈ 1,2	≈ 0,6	
length (m)	≈ 3	≈ 1,5	
radar reflection area (m²)	≈ 30	≈ 15	
LED-unit	IPSL	./.	Or: if lighted then LT mid
topmark	lying cross	lying cross	if any
numbering or lettering (size)	mid-size	small	

figure 6: parameters and examples of barrel buoys

Spars

	Unit spar
visible coloured area (m²)	≈ 1,5
height above water line (without topmark) (m)	≈ 3,0
diameter (m)	≈ 0,5
radar reflection area (m²)	≈ 30
LED-unit	IPSL
height of light (m)	≈ 3,0
topmark	class 2
numbering or lettering (size)	mid-size

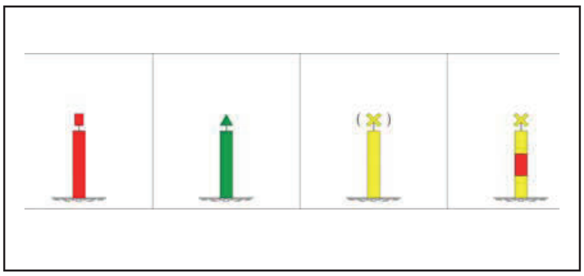


figure 7: parameters and examples of spars

Classification of topmarks

The different classes of topmarks are defined in the following figure.

	cone class 3	cone class 2	cylinder class 3	cylinder class 2	ball class 3	ball class 2
visible coloured area (projected area) (m²)	≈ 0,25	≈ 0,13	≈ 0,38	≈ ,18	≈ 0,28	≈ 0,1
diameter (m)	≈ 0,7	≈ 0,5	≈ 0,5	≈ 0,35	≈ 0,6	≈ 0,35
height (m)	≈ 0,7	≈ 0,5	≈ 0,75	≈ 0,5		

figure 8: classified sizes of topmarks

Conversion to plastic buoys

The continuous process of optimize as well in technical demands as in cost reducing leads to the conversion from steal to plastic buoys under certain circumstances. In order to provoke a high efficiency mainly the following conditions and assumptions have to be observed:

- acquisition of new buoys according to the new classification system
- replacement only of small and mid-sized buoys with diameter less than 2,5 m
- life time of 15 years with none or minimized maintenance and repair
- extension of inspection intervals
- ice resistance
- optimized anchor system

figure 9: plastic buoy in ice

Based on these principles the conversion from steel to plastic will start at the Baltic Sea with small unlighted buoys. A year later the substitution at the North Sea will begin. On the whole about 3.400 buoys (75 % of all) will be bought successively over a period of 8 years. During this time the german “IPSL-standard” for lighted buoys must be integrated into an ice standing design so that finally lighted buoys of medium size can be changed into plastic (see presentation of Peter Schneider “ Conversion of light buoys in the North and Baltic Sea…”).

Supporting paper

The Canadian Coast Guard methodology for the design and review of aids to navigation systems

Scott Windover & John Festarini

Canadian Coast Guard

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Paper Title: The Canadian Coast Guard's Methodology for the Design and Review of Aids to Navigation Systems

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ABSTRACT

The Canadian Coast Guard can trace its roots in the provision of aids to navigation to Louisbourg, Nova Scotia, where the very first lighthouse in Canada was constructed in 1734[1]. The initial plan to build a tower and a light was made after a French ship, Le Profond, nearly met its end in Louisbourg harbour. At the time, it was marked only by a navigational cross and periodically by a bonfire.

For the two and a half centuries following the construction of the Louisbourg Lighthouse, aids to navigation were traditionally provided on a 'user-demand' basis in Canada. Requests for new aids to navigation would be made at the local level and the regional officers would evaluate the requirements based on their navigational knowledge and experience. This practice laid the foundation for the Canadian Coast Guard's Methodology for the Design and Review of Aids to Navigation Systems. The Methodology is a disciplined approach which identifies and assesses the level of risk in a navigable waterway and then ascertains the appropriate combination of aids to navigation to mitigate the risks.

Since the Methodology was first implemented in the late 1980's, there have been significant increases in the use and availability of technology in the field of marine navigation. These advances have provided

[1] http://www.nslps.com/light-detail.aspx?ID=216&M=IP&N=2

mariners with improved situational awareness and underscored a need to modernize the Methodology to better reflect today's marine navigation environment. As a result, the Canadian Coast Guard initiated the Methodology Modernization project in 2011.

BACKGROUND

At 243 000 km, Canada's shoreline is the longest in the world.[2] Add to this about 3000 km of navigable inland routes and the result is a significant area which requires marking to facilitate safe marine navigation. Canada's extensive shoreline is even further complicated by extreme variations in environmental conditions and local geography. This can range from the temperate deep waters of southern British Columbia, to ice covered Arctic waterways and rapidly changing sandy shores of Prince Edward Island.

Brunswick Point, British Columbia (West Coast)

Frobisher Bay, Nunavut (Arctic)

Covehead Harbour, Prince Edward Island (East Coast)

These conditions exacerbate the difficulties related to the shear expanse of the country in providing consistent and equitable aids to navigation systems.

Traditionally, aids to navigation were placed at the discretion of regional officers usually as a result of a request from mariners. The process was heavily dependent on individual knowledge and local navigational practices. This created inconsistencies in the provision of aids to navigation across the country and reinforced a reactionary style of validating and improving the broader aids to navigation system. Services were provided or enhanced based on public requests with little to no consultation with mariners to confirm the needs based on identified threats or risks.

[2] http://www.nrcan.gc.ca/earth-sciences/geography-boundary/coastal-research/about-canada-coastline/8504

In 1983, a report from the Auditor General of Canada found that the services provided by the Canadian Coast Guard varied significantly across the country. Specifically, there was a lack of consistency in the way that aids to navigation were provided and evaluated. In response to these findings, the Canadian Coast Guard developed a risk-based methodology known as the Design and Review of Aids to Navigation Systems. The Methodology is a disciplined approach which identifies and assesses the level of risk in a navigable waterway and then ascertains the appropriate combination of aids to navigation to mitigate the risks. The original guide was created by Canadian Coast Guard personnel in collaboration with professional mariners and Academia in 1989 followed by marginal updates in 1993 and 2001.

The Methodology's foundation is based upon three types of analysis:

1. **SITE ANALYSIS:** The collection of data and information about mariners, vessel characteristics, traffic patterns, environmental conditions, oceanography and geography to identify navigational risks.

2. **NEEDS ANALYSIS:** The interaction of the identified risks are evaluated and rated in order to better understand their effects on navigation and ultimately the requirements of mariners.

3. **OPERATIONAL ANALYSIS:** The assessment and determination of an appropriate combination of aids to navigation to meet the requirements of mariners and mitigate navigational risks.

METHODOLOGY MODERNIZATION

Since the Methodology was first implemented in the late 1980's, there have been significant increases in the use and availability of technology in the field of marine navigation. These advances have provided mariners with improved situational awareness and underscored a need to modernize the Methodology to better reflect today's marine navigation environment. As a result, the Canadian Coast Guard initiated the Methodology Modernization project in 2011.

The objective of the project is to complete a thorough review and update of the Methodology in order to modernize the content, incorporate national and international best practices, as well as better reflect the challenges facing modern marine navigation. This modernization project is being completed by a team of subject matter experts and was a collaborative effort between regional and headquarter personnel.

The Methodology will capture the advances in marine navigation and the effect that technology has had on integrating and enhancing information across all types of users. The prevalence of satellite navigation, electronic charting and information systems, in addition to radar and automatic identification systems are now important considerations when evaluating risks and determining the appropriate combination of aids to navigation.

KEY IMPROVEMENTS

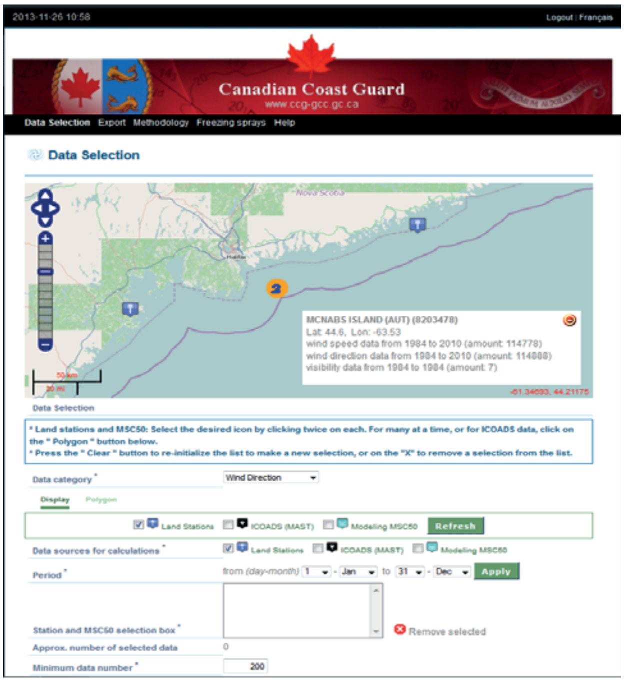
Preliminary Threat Assessment

The Methodology Modernization project seeks to build on the identification of preliminary threats that are evaluated through the loose grouping of size and type of vessel that navigate the waterway in question. Threats were initially ranked based on threshold values designating them as significant or highly significant risks and included:

- Distance from hazard
- Distance from other hazard when passing
- Minimum channel width
- Angle of turn in the channel
- Wind speed
- Wave height
- Current speed (Along and Cross Track)
- Visibility

The analysis, though adequate at the time, was found to be over-simplistic and in some instances led to the possible misrepresentation of the risks identified within waterways. For example, the relationship between the distance to hazard and the channel width often allows for the channel to be an acceptable width however the need to mark the edge as a hazard remains. The new methodology addresses this issue by using mathematical formulas to provide more specific distances based on hydrodynamic effects and maneuvering requirements in the identified conditions.

Atmospheric and Environmental Conditions



At the time the Methodology was originally introduced, weather information was collected by using readily available information provided by Environment Canada's Atmospheric Environment Services for a general location. Due to changing user requirements, Environment Canada discontinued the provision of the information in this format and moved to a new system of hindcast forecasting for environmental information.

A Climatological Data Processing and Analysis Module was developed by a project team to provide more recent and accurate information for the design and review process and is being incorporated into the new methodology. In addition to prescribed elements of visibility, wind, wave and freezing spray, the addition of wave period and wind direction were identified as requirements. These new elements will greatly enhance the identification and evaluation of environmental conditions in a given waterway.

Empirical Data

In order to further refine the identification of risks and improve the design and review process, more accurate and supplementary empirical data was needed. The need to collect information on the channel and vessel characteristics in an effort to properly address the impact of the resulting hydrodynamic effects was deemed essential. This information will be used to properly ascertain and evaluate the level of risks in a waterway. As such, the following information on the least maneuverable vessel in each category and the channel routes to be marked will be collected and analysed:

Vessel Information

- Vessel Type
- Length
- Speed
- Draft
- Beam
- Maneuverability Factor
- Loading Conditions (if applicable)
- On-board Electronic Navigational Equipment

Channel Information

- Width
- Depth within Channel
- Depth outside of Channel
- Bottom Type
- Bank Slope

Through the collection of this information and using the revised methodology, the Canadian Coast Guard will be able to accurately determine the required safety margins by evaluating the interaction and effect between the ships and the channel as part of the composite risks

Composite Risks

The Needs Analysis was previously based on the combination of risk factors where the degree of risk was categorized and evaluated based on their composite risk. As a critical component of the design and review process, this portion of the Methodology is seeing the most drastic improvements. The original ten composite risks have been replaced with the following three over-arching risk themes:

1. Lack of Space
2. Complexity of Manoeuvres
3. Lack of Situational Awareness

Given the sophistication of the proposed changes involved, the Methodology Modernization project team engaged subject matter experts at Canada's National Research Council. The Council's solution to address Lack of Space and Complexity of Manoeuvres is by creating a custom made application that uses the vessel, channel and meteorological data collected in the Site Analysis to provide safety margins specific to the waterway being evaluated providing a more accurate identification of risk. The application further expands on the risk themes by providing safe distances for the following:

Lack of Space

- Minimum Depth Allowance
- Limiting Channel Width
  - One way traffic
  - Two way traffic
  - Overtaking traffic

Complexity of Manoeuvres

- Minimum Settle up Distance
- Radius of Turn and Advance and Transfer

These features ensure that the right amount of space required by a vessel is precisely identified, based on the prevailing conditions, and allows the Canadian Coast Guard to mark the waterway appropriately.

The evaluation of the Lack of Situational Awareness will be heavily influenced by client engagement and fact finding such as the inspections of the charts in comparison with the conspicuousness of the physical features and the prevailing visibility conditions in the area observed and or verified during physical site visits. In addition, the electronic capabilities of the vessels that use the waterway will be considered and the application of radial error or of harbour identifiers will then be adjusted accordingly.

Operational Analysis

The Operational Analysis continues to build on the Needs Analysis by facilitating the selection of the correct aid(s) to mitigate the risks identified in the waterway. This is achieved through a more comprehensive set of guidelines that better correlates the strengths and weaknesses of the various aids to navigation in mitigating the risks present in the system. The design and review process ensures that practical options are brought forward and are accompanied by a rationale for each individual aid to navigation proposed and their relation to other aids to navigation. The narrative will provide a detailed explanation as to why specific aids to navigation were selected and justifies the retention of any existing aids to navigation that were left unchanged. This degree of knowledge retention will enhance future reviews by capturing the fundamental requirements for the placement of an aid to navigation.

Cost-Effectiveness

Like most Aids to Navigation Authorities, the Canadian Coast Guard is asked to provide aids to navigation where the volume of traffic justifies and the degree of risk requires in a cost-effective manner. With that in mind, the Methodology Modernization introduces an additional phase in the design and review process that evaluates the costs and benefits of a recommended system, including the comparison of various elements of options within the recommendations. Technical expertise is engaged to provide full implementation and lifecycle costs in order to better inform the decision making process.

Prioritization of System Reviews

After an aids to navigation system is put into place, it is important to return periodically to review its effectiveness and relevance. The Canadian Coast Guard strives to review each of its 17 000 aids to navigation once every five years. Nevertheless, competing priorities and areas of growth requiring new designs can make that objective a challenge. In response, the concept of prioritizing the various aids to navigation systems will be implemented. Essentially, systems are prioritized based on the rate and magnitude of change within a system which often translates to changing aids to navigation requirements within the system. In order to drive consistency within the prioritization process, the following considerations must be evaluated and rated:

- Period Since Last Review
- Under Keel Clearance
- Category of Vessel and Cargo
- Sea Floor Type
- Width of Channel
- Request for Aids to Navigation and Mariner Input
- National Refurbishment / Replacement Plan
- Economic Benefit
- Service Delivery
- Other Governmental Organization Investment
- Economic Growth / Industrial Boom
- System Reliability
- Obsolete Equipment Replacement
- Harbour Closed or Severe Reduction in Use

These criteria are scored based on a pre-determined set of guidelines and are intended to assist regional personnel in the creation of their annual work plans.

Client Engagement

Since the implementation of the Methodology, the Canadian Coast Guard always included a client engagement component. The purpose of the engagement was primarily fact finding in support of the design and review process, but also served as a direct way to communicate changes to users. The Methodology Modernization introduces structure around the client engagement process and places a renewed emphasis on the verification process of site and user specific information. This was identified as a critical step as industry witnesses a gradual shift from traditional navigation techniques to ones that rely more heavily on electronic equipment and information. This allows the Canadian Coast Guard to better understand the capabilities of mariners as well as their degree of on board navigational aids and ensure that aids to navigation systems respond to the requirements of mariners in that area. The client engagement sessions also serve as a unique opportunity to better understand vessel traffic types, sizes and patterns and the rate at which mariners are adopting new technology.

<u>Conclusion</u>

The Canadian Coast Guard is committed to providing reliable marine navigation systems which supports a safe, accessible, and efficient environment for the commercial marine transportation sector, fishers and pleasure craft operators. The application of the Methodology will facilitate a consistent and rational placement of aids to navigation and will provide mariners with a standard level of service that they can expect from the Canadian Coast Guard. Additionally, the Methodology will further support the concept of providing aids to navigation where the volume of traffic justifies and the degree of risk requires in a cost-effective manner.

The Methodology Modernization will position the Canadian Coast Guard to continue to deliver relevant services that respond to today's user requirements and to maintain safe and efficient waterways for generations to come.

Supporting paper

e–Navigation in Canada
Vision and strategy

André Châteauvert & Natacha Riendeau

Canadian Coast Guard

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Paper Title: E-Navigation in Canada – Vision and Strategy

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Abstract

In the mid 1990's, Canada began looking at better ways of communicating and integrating navigational information for the benefit of mariners and shore-based authorities. Pilot projects have allowed the country to identify and to address many important issues such as the way information is collected and exchanged as well as how the information is transmitted and displayed. The success of these projects was due in great part to the close collaboration among mariners, pilots and authorities responsible for collecting and providing data and information.

In 2012, a national Vision for the implementation of e-Navigation in Canada was officially approved. In August 2013, a paper describing the Concept of operation in Canadian waters was completed providing additional details on how e-Navigation information may be accessed and exchanged. The aim of this paper is to provide a status update on the implementation of the Canadian concept of operations for e-Navigation.

E-Navigation in Canada – Vision and Strategy

This paper provides a status update on the implementation of the Canadian concept of operations for e-Navigation. Based on Canada's Vision for e-Navigation, it provides details on how e-Navigation information may be accessed and exchanged in Canada.

Background

In the mid 1990's, the Canadian Coast Guard (CCG) began looking at better ways of communicating and integrating navigational information for the benefit of both mariners and shore-based authorities. Since then, test bed projects have enabled Canada to identify and to address many important issues, such as the way information can be collected, exchanged, transmitted and displayed. The success of these projects was due in great part to the close collaboration among mariners, pilots and the governmental organizations responsible for collecting and providing data and information. Marine pilots have played a key role as well in test beds, either in supplying computerized devices on-board (Portable Pilot Units) which allow displaying information and traffic, or by collectively working for the transmission of environmental data (e.g. wave height, currents, etc.) from 'smart buoys', web portals, and AIS base stations.

A national Vision

In August 2012, a national Vision for implementing e-Navigation in Canada was officially approved by all contributing governmental organizations. Based on comprehensive users' needs, this national document describes the Canadian Vision for e-Navigation, its guiding principles, objectives and the implementation strategy that Canada has been following, and will continue to follow over the coming years. In concrete terms, this Vision is guiding stakeholders in sharing and communicating the required data/information services through the use of a national portal and other communication means such as the AIS network. These services have been identified and are continually validated through comprehensive interactions with users and reflected in a Required Services Matrix, as presented in Annex A.

The vision for e-Navigation in Canada is:

> *Widespread use of e-navigation in Canada by mariners and shore authorities for greater marine safety, security, efficiency and environmental protection.*

The following principles were defined in the Vision document to ensure the effective implementation of e-Navigation:

1) *Safety of Life, Property, and the Protection of Marine Environment.*
E-navigation is to contribute to the safety of life, property and the protection of marine environment by improving navigation decision-making and reducing the risk of human error as the cause of a marine incident.

2) *Applicability to All Categories of Users.*

Development of navigational system and services will need to consider all categories of users (e.g., commercial, fishing and recreational mariners, pilots, ship owners and operators, shore authorities including Harbour Authorities, Regulators, etc.).

3) *Cooperation with the International Community.*
E-navigation shall facilitate global coverage, consistent standards and arrangements, and mutual compatibility and interoperability of equipment, systems, symbology and operational procedures, so as to avoid potential conflicts between users[1]. The implementation of e-navigation in Canadian waters will need to be consistent with adopted international regulations, standards, guidelines and procedures.

4) *Contribution to Marine Transportation Efficiency.*
E-navigation should contribute to marine transportation efficiency and effectiveness through better voyage planning, respect of schedule, and a reduction of emissions by using optimum routes and speeds. In this respect, the provision and exchange of authoritative, accurate and reliable information in a timely manner is essential. Information should be made available 24 hours per day, 7 days per week (24/7).

5) *User Consultation.*
E-navigation development will need to be validated through a robust procedure before being implemented, including involving consultations with users.

6) *Interdepartmental Coordination.*
E-navigation will require close coordination between contributing departments, and other organizations, and need to take into account each department and organization's mandate and available resources.

Concept of Operations
Following the publication of the Vision, the Canadian Coast Guard worked on defining the overall concept of operations for e-Navigation in Canada. In brief, the concept calls for shore authorities to make data and services accessible to mariners on a Common Maritime Information Infrastructure which can be accessed in many ways while mariners are planning their voyage, navigating and/or analysing their voyage once at destination.

The CCG's role is to maintain and support the Common Maritime Information Infrastructure in collaboration with other Government partners who maintain responsibility for the data. CCG will work to ensure information is provided in the right format while avoiding duplication of information whenever possible. The overall concept is that necessary data and information will be made available to users. However, it will be the responsibility of the industry to develop the technology and tools to facilitate its access and integration, subject to international regulations. In addition to the Maritime Information Portal, other information updates or notification of new information will also be provided through the AIS Network and other electronic means, such as

1 International Maritime Organization. 2009. Report of the Maritime Safety Committee on Its Eighty-Fifth Session. MSC 85/26/Add.1.

Very High Frequency Data Exchange (VDE). Figure 1 below provides additional details on the Canadian concept of Operations for implementing e-Navigation.

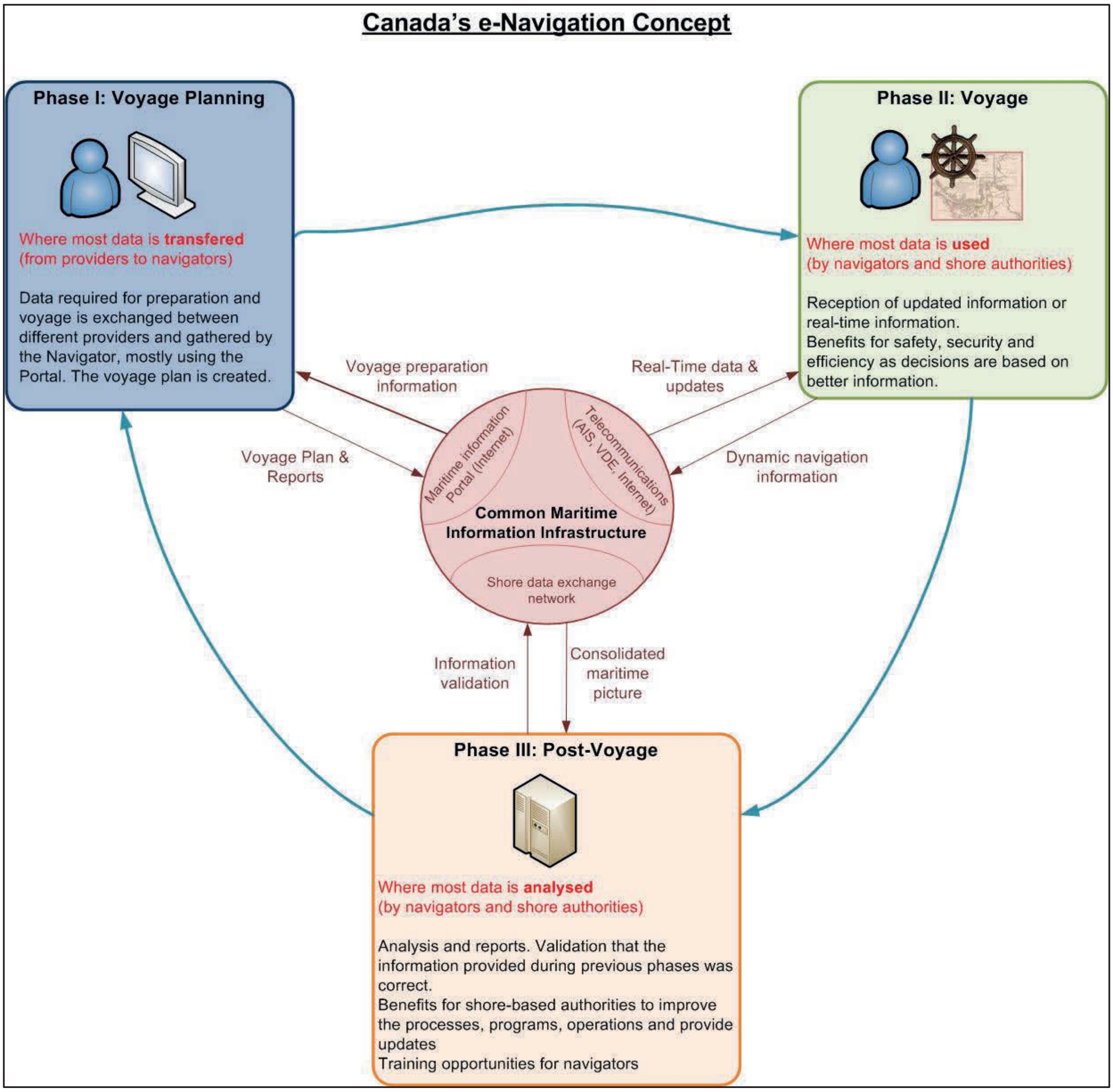

Figure 1 – Concept of Operation for E-Navigation in Canada

Phase I, Voyage Planning

This is the beginning of the journey where mariners will prepare for their upcoming voyage by gathering the information relevant to the upcoming trip from the Maritime Information Portal, and then creating a voyage plan.

Regulation 34 of Chapter V of the *Convention for the Safety of Life at Sea* (SOLAS), the *Canada Shipping Act 2001* and the *Charts and Nautical Publications Regulations*, 1995 require masters to ensure the intended voyage has been adequately planned. The degree of voyage planning depends upon the size of the vessel, its crew and the length of the voyage.

Voyage planning, as set out in IMO's Guidelines for Voyage Planning, involves four distinct stages:

- Appraisal – Gathering the information relevant to the coming trip;
- Planning – Preparing a detailed plan of the expected trip and alternate plans; this includes establishing waypoints, identifying hazards, setting the times for passing certain landmarks and decision points where the mariner must decide to proceed or engage alternate plans;
- Execution – Implementing the plan and making the necessary decisions and, if necessary, implementing alternate plans;
- Monitoring – Keeping an eye on your progress and the effectiveness of the plan's execution.

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

- Meteorological Information (e.g., wind speed, visibility, weather conditions, wave height and direction, air and water temperature, atmospheric pressure, and related weather warnings);
- Ice Information (e.g., ice charts, routing advice, forecasts, advisories and bulletins);
- Hydrographical Information (e.g., forecast tides, real-time water levels, predicted water levels, forecast current);
- Aids to Navigation Information (e.g., status of existing aids to navigation and related buoy tending information);
- Navigational Charts (and updates);
- Restrictions to Navigation (e.g., construction work, temporary restricted areas, harbour closures, etc.);
- Vessel Traffic Services (e.g. notices to shipping)

A voyage or sail plan includes the travel route and basic details about the vessel.
Once the user prepares a voyage plan, using information downloaded from the Maritime Information Portal, mariners may share the plan with a responsible person on shore, or one of CCG's Marine Communications and Traffic Services (MCTS) Centres.

Phase II, Voyage

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. Navigators will have planned their voyage based on updated nautical charts, forecast weather conditions and warnings, ice information and routing advice, predicted water levels, forecasted currents, etc., taking care to review any applicable notices to shipping or relevant status updates for aids to navigation. However, once at sea, conditions may change and navigators are required to make decisions and implement alternate voyage plans based on current or real-time information.

Implementation of e-Navigation in Canada will allow users to receive updated information or real-time information via telecommunication means, such as AIS, Very High Frequency Data Exchange (VDE) or the internet, when available.

Providing updated and real-time information to users will have clear benefits for safety, security and efficiency, as decisions will be based on better, more reliable information. For example, real-time navigational buoy status may be transmitted to users via AIS. This means that navigators will be able to confirm the exact location of the buoy and status of its light, allowing navigators to rely upon the navigational mark and avoid marked hazards. Similarly, available water depths (real-time and forecasted) may be transmitted to users. This will provide mariners with up-to-date information on the actual and forecasted availability of the water column to ensure they optimize their cargo to a safe level and to avoid potential groundings.

Phase III, Post-Voyage
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 Phase I (voyage planning) or transmitted during Phase II (voyage) was precise, timely, and fit for purpose. 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.

Maritime Information Portal
As part of the concept of operations, CCG is currently working on its Maritime Information Portal. This involves data formatting, services standards (reliability, availability) and the IALA Common Shore-based System Architecture.

Under the current definition, access to information and data will be available via four (4) different means:

1- Navigation by Location: where users will have on-screen access to information of the available data of different maritime service portfolios.
2- Download Datasets: where users will have the opportunity to download datasets directly from the portal's extensive data catalogue.
3- Connect to Services: where users will make a direct and permanent connection to the dataset, mainly using Geospatial software and Web Map Services protocols.
4- View Interactive Map: where users will interact and visualize maritime service portfolios on an interactive map.

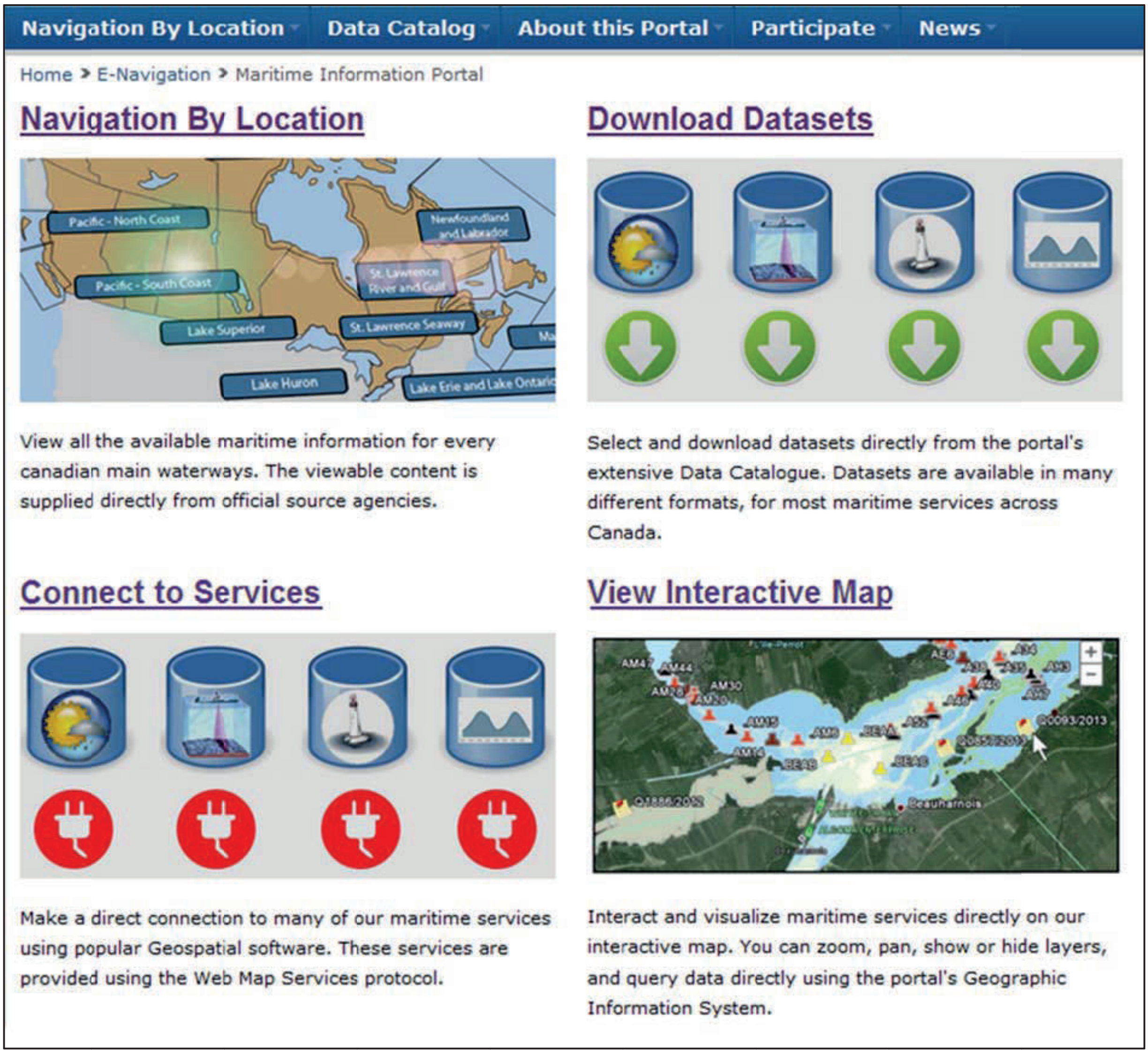

Figure 2 - Proposed Canadian e-Navigation Maritime Information Portal

This portal is currently under development (as of November 2013) and it is expected that a first version will be up and running by the end of March 2014. Based on the prioritization results from the Required Services Matrix as presented in Annex A, the following maritime service portfolios have been identified as the priorities for first phase deployment within the portal. These are meteorological information (wind, wave, air and water temperature, atmospheric pressure), ice charts, hydrographical information (real-time and forecasted water levels), status of aids to navigation and GPS/DGPS, restrictions on navigation (newly discovered hazards, shoals, wrecks or dangers, as well as bridge air gap) and vessel traffic services (notices to shipping) information.

As improvements will be made, the end goal is to make all services identified in the Required Services Matrix available. On-going resources will be used to monitor and maintain the website, for on-going data / information management and integration needs.

Conclusion
The implementation of the Canadian Concept of Operations represents one step further toward the implementation of e-Navigation. Nevertheless, it is understood that e-Navigation will never be considered fully implemented, as technology will continue to evolve and users's needs will also change, making e-Navigation a direction, not a destination.

Moving forward, the development of e-Navigation in Canada will continue to be user-driven, taking into consideration user requirements, as well as national and international directions, guidelines, recommendations and regulations.

Annex A – Required Services Matrix

		Navigational Areas →		Atlantic		St.Lawrence Gulf		St.Lawrence River			Great Lakes			Pacific			Arctic	
		Sub-Areas →		Coastal Area	Major Ports	From Cabot Strait to Les Escoumins	Major Ports	From les Escoumins to Québec City	From Québec City to Montréal	Major Ports	Seaway	Lakes	Major Ports	Coastal Areas	Interior Waters (see note 1)	Major Ports	≤ 75º North (See note 2)	> 75º North
Navigation Safety Services	**Category**	**Data to be available electronically**	**Survey Item #**															
Environmental Information	Meteorological (Observation and Forecast data)	Wind (speed & Direction)	2.1	M	H3	M	H3	M	M	M	H2	H	H1	H1	H2	H3	H	H
		Visibility	2.1	M	H2	H	M	L	M	L	H2	M	H1	M	H	H1	M-H	L
		Weather (e.g.fog, rain,snow)	2.1	M	M-H	M	M	L	L-M	L	H2	M	H1	L	H	M-H	M-H	L
		Wave (height & direction)	2.1	H	H3	M	H3	L	L-M	L	M	M	M	H	M	M	H	H
		Air temperature	2.1	H	H	L	M	L	L-M	L	M	M-H	L	L	L	L	H	M
		Water temperature	2.1	H	H	L	M	L	L-M	L	L	L	L	L	L	L	L	L
		Atmospheric pressure	2.1	H	M-H	L	M	L	L-M	L	L	L	L	L	L	L	L-M	M
		Weather warnings (e.g. gale, storm, hurricane, tsunami, freezing spray)	2.1	H	H	H	M	L	L-M	M	M-H	L	M	H1	H2	H3	H	H
		METAREAS		L	H	L	M	L	L	L				N/A	N/A	N/A		
	Ice	Ice charts	2.1	H3	H3	H	H3	M	M	L-M	M	H	M	N/A	N/A	N/A	H	H
		Ice forecasts	2.1	H	H	H	H3	M	M	L-M	M	H	M	N/A	N/A	N/A	H	H
		Ice advisories	2.1	H	H	H	H2	M	M	L-M	M	H	M	N/A	N/A	N/A	H	H
		Ice Routing	2.1	H	H	M	H3	M	M	L-M	M	H	M	N/A	N/A	N/A	H	H
		Ice webcams	2.1	H	H	H	H3	H1	H	M	M	H	M	N/A	N/A	N/A	H	H
		Ice Bulletins	2.1	H	H	M	H2	L-M	L-M	L-M	M	H	M	N/A	N/A	N/A	H	H
		Iceberg Bulletins	2.1	H	H3	N/A	L	N/A	N/A	N/A	M	H	M	N/A	N/A	N/A	H	H
	Hydrographical	Real-time tide	2.1	L	H3	H	H3	H1	H1	L-H	N/A	N/A	n/a	L	M	H	M-H	H
		Forecast tide	2.1	L	H3	H	H2	H1	H1	M-H	N/A	N/A	n/a	L	M	H	H	H
		Real-time water level	2.1	L	H3	M	H3	H1	H1	M-H	H	M-H	H	L	M	H	M	L
		Forecast water level	2.1	L	H3	M	H1	H1	H1	H1	H	H	H	L	L	H	M-H	L
		Predicted water level		L	H3	M	H1							TBD	TBD	TBD		
		Real-time current (speed & direction)	2.1	L	H3	H	H3	H	M-H	L-H	M	H	M	L	H	H1	M	
		Forecast current (speed & direction)	2.1	L	H3	H	H3	H	H1	H	M	H	M	L	H	H	M	L
		Predicted current		L	H3	H	H2	L	L	L				TBD	TBD	TBD		
Waterways Management	Aids to navigation	Status of aids to navigation	2.1	H	H3	H	H3	M	M-H	L-M	H2	M	H2	L	H1	H2	M-H	L-M
		Buoy tending (winter vs summer buoys)		L	M-H	M	TBD	H	H	H	H2	M	H2	N/A	N/A	N/A	L	L
		Status of GPS & DGPS	2.1	M	H3	M	TBD	H	H	M-H	M-H	M-H	M-H	H	H	H	H	M-H
	Charts	Electronic Charts		H	H3	H	H3	H	H	H				M	H	H1		
		Charts updates		H	H3	H	H3	L	L-H	L-M	M	M	M	L	L	H	H	M-H
		Sailing Directions updates		L	H	H	H1	L	L	L	L-M	L-M	L-M	L	L	L	M	M-H
	Restrictions on navigation	Construction works (bridge, dredging, hydro)	2.1	L	H3	H	H3	L	M-H	M	M-H	M	M-H	L	L	L	L	L
		Temporary restricted areas (marine events, regattas)	2.1	L	H	H	H3	L	M-H	M-H	M-H	M-H	M-H	L	L	H	L	
		Channel Bottom monitoring H/D bathy		L	H	M	M	H	H	H	H	L-M	H	L	L-M	H	L	
		Newly discovered hazards, shoals, wrecks or dangers		H	H	H	M	H1	H1	H	H	H	H	H	H	H	H	H
		Bridge & Cables air gap	2.1	L	H	M	N/A	H1	H2	H2	M-H	L-M	M-H	N/A	H	H	L	
		Bridge open / closed	2.1	L	H	M	N/A	N/A	N/A		H1	M	H1	L	L	H	L	
		Fairway closed	2.1	L	H	M	N/A		L-H	L-M	M	L-M	M	L	L	L	L	L
		Harbour closed	2.1	L	H	M	H3		L-H	L-H	M	L-M	M	L	L	L	L	L
		Security operations		L	H	M	H3	L	L-H	L	M	L-M	M	TBD	TBD	TBD	L	L
	Vessel Traffic Services	Anchorage assignment	2.1	L	M-H	L	H1	L	L-M	L-M	L-M	L	L-M	L	L	L	L	L
		Berthing assignment	2.1	L	H	N/A	M	L	L-M	L	L-M	L	L-M	L	L	L	L	
		Lock order	2.1	L	M	N/A	TBD	L	L-M	L-M	H1	N/A	N/A	N/A	N/A	N/A	L	
		Very large / special vessel movements	3.2	H	M-H	M	M	L	L-H	L-H	M	M	M	L	L	L	L	
		Vessel meeting / passing	3.2	L	H	M	M	L	L	L-H	M	L	M	L	L	L	L	
		Route advisories	2.1	L	M-H	M	N/A	L	L	L-M	L	M	L-M	L	L	L	L	L
		Navarea messages		L	M	M	M	L	L	L	L	L	L	L	L	L	M-H	H
		Navtex messages		L	M	H	M	L	L	L	L	L	L	L	L	L	M-H	H
		Notice to shipping		M	H3	H	H3	L	L	L-M	H	H	H	L	H	H	M-H	H
		Auto Reporting		L	H	TBD	TBD	N/A	N/A	N/A				TBD	TBD	TBD		
		Security level		L	L	TBD	TBD	L	L	L-M	L	H	L-M	L	L	L	L	L
	Pilotage	Pilot stations	2.1	H	H	M	H3	L	L-M	L	M	M	M	N/A	N/A	N/A	L	
		Procession order	2.1	L	TBD	L	TBD	L	L-M	L	M	M	M	N/A	N/A	N/A	L	
Emergency	Search & Rescue	SAR Operations	2.1	M	TBD	M	TBD	L	L-M	L	H	H	H	M	M	M	M-H	L-M
	Environmental Response	Environmental Response Ops		L	TBD	M	H2	L	L-M	L	H	H	H	M	M	M	M	L

Rating→ H - High, M - Medium, L - Low, N/A - not applicable, TBD - unknown/more information needed

Ranking→ ascendent H→ H1→ H2→ H3 (Highest H3)

Supporting paper

Decision support tool
Useful or additional burden?

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"Decision Support Tool – Useful or Additional Burden?"

Abstract

The decision support tool (DST) assists the VTS operator (VTSO) in his current tasks to take a timely and profound decision by synthesizing multiple pieces of data in order to produce valid information. Basic functions of the DST are prediction, summary and compilation of data in a comprehensible order.
DST- applications which have become a kind of standard in VTS-centres are CPA and TCPA prediction. They will give a short term forecast of the vessel´s movement. The report will focus on the more sophisticated tools. These tools will give a long term forecast in order to support the VTSO in the traffic organisation task. Multiple traffic influencing factors like vessels behaviour, met-hydro and fairway condition and various scenarios have to be taken into account. Difficult to predict are bad-case scenarios, but they are of particular importance for the decision making.
Therefore, DST must contain wide expert knowledge and must model the local conditions. Such a customised tool cannot be bought off the shelf and therefore will be costly. In addition, such a tool must be fed with a lot of high quality data from sensors and other sources. Also parameter input by the VTSO may be required.
How much input must the VTSO give to the tool to get a valid result? How far can the VTSO trust and rely on the proposed decision he cannot retrace?
The report will highlight how much support a Decision Support Tool needs rather to help in the day to day work of the VTS centre than to become an additional burden or even risk to the VTS.

1 Introduction

On the 17th IALA Conference/Cape Town and on the12th VTS-Symposium/Istanbul several presentations dealt with the decision support tools (DST) in VTS [1], [2]. Obviously there is a need for the decision support tools. The conclusion found at the VTS Symposium was *´Risk management and decision support tools enable VTS to be proactive mitigating risk and improving logistics´* [3]. The VTS Committee has added the task *´Produce a Guideline on the use of decision support tools in VTS´* to its 2014-18 work program [4]. Although or better because only a preliminary definition of DST is available the paper highlights pro and cons for the use of a DST in VTS operations. This may support the ongoing task in IALA to prepare recommendations and guidelines for the DST and its operational use.

2 Need for DST

DST or what is currently assumed to be a DST function is currently installed in many Vessel Traffic Centres. And, of course there is a need for DST. The drivers to use DST are the increasing complexity in the maritime transport. Not only navigational and environmental situation must be considered. The indirect and interactive factors become more important today like slot management, navigable space management , link to the transport chain in the port and ashore, physical or legal fairway limits, legal restrictions, security, CO2-footprint, ballast water treatment etc. The factors are interactive and they are not a mariners traditional business at all. Therefore the operators in the VTC needs support to manage the heterogeneous demands for the traffic.
We created computers and numerous sensors that provide the operator with data in real time he can´t capture in real time due to his cognitive limits. The task right now is to let the machine reduce the data and only present the needed information.
This is an application for a DST.

3 Definition

Before asking the question of the usability of the DST, a definition on "What is a DST?" is necessary. In the working paper of the IALA´s VTS Committee on ´A guideline on the use of DST for VTS personnel´ [5] a preliminary definition for DST is made as "A tool to assist the VTS personnel for supporting decision making". For the technical DST-System the definition found is "An information system to assist a decision- maker at an operational, planning and management level".
The purpose of all human machine interface (HMI) in the vessel traffic centre (VTC) is that the user can derive information from it. And all information should help to make decisions. The operational VTS task is a continuous decision process. E.g. the presentation of vessel static or voyage related data may lead to the decision to ask the vessel or VTC data base to verify the data. The traffic image may the VTS operator let decide that currently no action is required.

This paper refers to the cooperative and active tools as preliminary defined in the draft IALA guideline on DST. These more sophisticated tools have features like to

- to organise the input data from different sources and quality
- to assess the data in respect to their impact on traffic or risk
- to provide a variety of possible decisions
- to predict and simulate
- to record data and make an adaptive prediction

3.1 Types of DST

According to the definition the variety of DST is large. Therefore no general answer can be given to the question whether a DST is helpful or a burden to the VTSO.

The operator should be in the focus of the development of really supportive DST. Therefor the different tasks of the operator have to be considered and to be supported by different types of DST.

DST for information management

The operators have to cope with a lot of data, not only directly linked to traffic and navigation but also legal, administrative, organisational or neighboured processes like logistics. Where is the level of the cognitive capabilities of the operator? The VTS-authority should be proactive before the human factor becomes critical. In is respect the DST can help. The technology today can easily deal with manifold data and formats to reduce the amount of data or to present it an ergonomic way. Possible DST function are listed below.

- filter redundant data
- fuse data
- resent data in sorted format
- classify data in respect to quality, actuality

A known application in respect to filter and data reduction is the fusion in multisensory trackers which inhere highly complex track and fuse algorithm. The use is common today and not really questioned and trusted in the engineers expertise. So why not use system to filter and fuse data other than target position data.

This type of tools are not cooperative or active tools that support the decision making progress by proposing solutions to prevent critical situations or predicting scenarios. But the tools paves the way for the decision making as it provide the information for decision making in a proper way.

DST for time critical decision support in tactical scenarios

This type of DST can be useful for more complex situations with many interactive effects. In this kind of situations third parties might be involved. Without decision support the operator has to predict the manifold impact on the traffic alone. For routine procedures the scenarios can be analysed before, the prediction and weighting process can be translated into software and the information for the decision provided. The scenarios must be analysed und modelled beforehand together with the operator anyhow. Why not using the operators training to determine the scenarios and to derive the specification for the DST? The advantages are :

- User driven design
- The operator has already trained the scenario before it occurs.
- The operator can define at what stage in the scenario support is needed.
- The operator tells what kind of support he needs.

During the time of the critical process the operator should not be loaded with the machine´s request for input. Manuel input takes time and inhere the risk of type in errors. The presentation of the DST results should not distract the operator from his permanent monitoring of the traffic image.

The routine scenarios can be covered by the model and prediction in the DST. However, to find and to model bad cases is a real challenge. But just in critical scenarios the decision support is needed. History shows, that in complex and critical situations the human factor very often makes the right decision due to the skill, experience or just intuitive.

DST for traffic organisation and planning :

The current development in the maritime transport shows increasing traffic, larger and extraordinary vessels, less space of navigable waters and more traffic restrictions. Other drivers like CO2 footprint, security, shore based logistics have impact on the traffic, although they are not the traditional business of the mariner. The consideration of those factors does not only require navigational skills. Therefore the VTS operator should get support in future traffic organisation and vessel traffic management.
These not time-critical traffic planning scenarios are perfect applications for a DST. The DST can do what a machine perhaps can do better than a human:

- do extrapolation of vessel movement
- forecast environmental situations
- manage numerous routes und schedule of different vessels
- combine interfering processes and drivers

With the data storing capacity the tool can playback true scenarios or even learn for it. Advanced system may include risk assessment. This kind of tool would support the user, mainly because of the combination and prediction capabilities of the software. In addition it reduces the information load because there is no need any more to display numerous schedules, regulations and forecasts separately at the VTSO ´s workstation or combine them manually.

DST for strategic planning:

The DST could be used for long-term planning not only in the VTC but also in the NCA or VTS management. The DST could can get access to data bases with previously recorded historical data from different fields like vessels movement and environmental occasions.
The prognosis for future port, traffic, waterways infrastructure, legislation and even politics may be considered and could provide the parameters for the traffic planning and basis for VTS– / NCA management decision and measures as a benefit .

4 Usability of DST

The previous chapter may conclude that the VTS authorities should immediately install and use DST, if they not already did. But as stated in [5] a DST should be “robust, consistent, tested, proven and approved by the VTS-authority”. This statement is valid for any equipment used in the VTS. But for the DST it deserves closer attention because the system is not only sophisticated in a technical way. Due to its

a) broad bandwidth of functions
b) with interdisciplinary characteristics
c) prior knowledge of the variety of processes translated into a software model
d) the diversity of connected sensors and data sources
e) the diversity data quality
f) the interaction with the user(s)

The DST will not only need simple test of each function for approval. Instead the processes presented in the model must be tested by performing the scenarios the DST shall give decision support.

a) The model programmed in the DST processes various inputs and provides proposed decision including prediction or simulation features. It is a task for the VTS-authority to provide all the input and to define a proper model together with manufacturer and other experts in this discipline. The knowledge of the operators and experts in the various fields have to be implemented in the model. This is a organisational, personnel and expensive effort. The more sophisticated the tool should be, the more it must be adopted to specific to local conditions and to scenarios that may occur. A high level VTS tool cannot be bought off the shelf. Definition and standardization may help to find some common functions and reduce costs.

b) The DST algorithms depend on data input. The operator's manual input or dialog with the machine should be minimized in order not to burden the operator. Pressing buttons hinders the decision process and distracts from the ongoing monitoring task in the VTC. It is a human factor that we can only concentrate on one thing at a time.

c) When electronic data is processed in the system the quality (integrity, accuracy,…) must be known for the automated assessment. The quality can only be determined if the entire information/ data flow from the source to the DST is analysed before.

d) Liability issues have to be considered in cases of technical failures and inconstant quality. In cases of an incident the investigators will ask in detail for the quality of the data presented at the operators workstation. It will be an effort to prove the liability or quality of the presented output of the DST, when it is computed from numerous data sources in an iterative algorithm. Extensive tests for different scenarios and use cases should be performed beforehand.

e) The DST will have a HMI to present its calculated result in an alphanumerical or graphical way. In case of an interactive DST (dialog function) it needs the operator´s input to proceed with the calculation. In other cases parameter input may be required from the operator for further prediction calculation or simulation. In all cases the operator gets additional information or is bound to the HMI waiting for input.

f) The more complex the model is, the less the user can estimate whether the calculated result or recommended decision is plausible. What happens if the machine recommends another solution than the operators found based on his experience? That will complicate the decision process rather than support it.

g) In addition the VTSO will not be able to fully saturate the model with its manifold weighting, estimation or iteration procedures. And if he could follow the computer's results it would be time consuming and compensate the DST´s support.

5 Conclusion

The previous chapter may conclude, that a VTS-Authority better not decide for a DST. But the most cons mostly can be in an administrative, technical or organisational way and have minor impact on the VTS operation.

In many field like road, railway and air traffic or military tactics and strategy DST are used. Also in the maritime domain should use DST to manage complex scenarios.

As long as some criteria are considered the DST will provide more more benefit then burden.

- The task to be supported and the workflow to manage scenarios should be considered when introducing a DST. The scenarios should be modelled in the DST.
- DST for ad hoc decision or tactical planning should not require addition manual input from the operator. The DST presentation should be integrated into the traffic image. The assessment in time critical processes should not be too complex. The operator should be able to track the presented solution in short time.
- A DST should indicate when there is a development towards a critical situation. To prevent too late or too early alarms the in detail knowledge of the participating objects and their dynamics respectively the process run times is necessary. If the DST is not correctly adapted to the true behaviour of the relevant objects it easily becomes a burden or perhaps a liability issue because the alarm functions are turned off.
- Bad case scenarios are mostly unique and therefore are very hard to implement into a model. DST in this respect needs extensive investigation.
- The processes for the tasks traffic planning and traffic management are the best to be supported by DST. Long term prediction, combination and simulation a computer can do better than a human.
- With the development of shore based data networks and the measures of e-Navigation allow to integrate additional processes in the maritime domain to loop of decision making.
- On a management level a DST for strategic maritime planning may be recommended. The benefit is the documentation for the management decision and definition of the steering parameter for the traffic organisation service.
- The usability of a DST is more a national competent authority (NCA) or VTS-management issue than an operational. The usability depends on the proper modelling of traffic scenarios and interfering processes. Therefore it is preparatory investment to analyse the operational, organisational, legislative parameters in decisions process beforehand and to translate it into a computer logic.
- Because sophisticated DST depend on the scenarios and the modelling they are unique for the specific VTS. Therefore the costs not only for the hard – and software but also for the preparatory investigation should be considered.

- Decision Support in a VTS is proving the right information to make decisions. The engineers have been able to create systems that can present any data at the VTS´s workstation without the user´s help . They will also be able to create systems that reduce the data so that operator can retrieve the information he needs for the decision. But in this case the user must tell what he needs.

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Supporting paper

Implementing virtual AtoNs

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Implementing Virtual AtoNs

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BIOGRAPHIES

Mr. Jan Šafář is a Research & Development Engineer with the Research and Radionavigation Directorate of The General Lighthouse Authorities of the United Kingdom and Ireland. He holds an MEng equivalent degree from the Czech Technical University, Prague and is currently finishing his PhD at the same university. His area of expertise includes GNSS, eLoran, radar and AIS. He is a Member of the Royal Institute of Navigation (RIN) and the U.S. Institute of Navigation (ION).

Dr. Alan Grant is a Principal Development Engineer for the Research and Radionavigation Directorate of the General Lighthouse Authorities of the UK and Ireland. He is the technical lead and project manager for all GNSS projects within the directorate. He received the degrees of BSc and PhD from Staffordshire University and the University of Wales respectively. He is a Fellow of the Royal Institute of Navigation and a member of Council for the Institute of Navigation.

Dr. Nick Ward is Research Director of the General Lighthouse Authorities of the UK and Ireland, with responsibility for strategy & planning of research & development. His area of specialisation is in radio-navigation and communications, including Automatic Identification Systems (AIS). He is currently vice chairman of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) e-Navigation committee. He is a Chartered Engineer, a Fellow of the Royal Institute of Navigation and a Member of ION.

ABSTRACT

The purpose of the Virtual Aids-to-Navigation (AtoN) System is to provide a near-instantaneous warning to the mariner of a new danger, such as a wreck, obstruction or floating debris. This warning must be provided in a form that can be received, interpreted and displayed by any class of vessel in the required operational area and carrying appropriate equipment.

The ability to provide Virtual AtoNs could be one of the most significant technical developments for lighthouse authorities in the short to medium term and is an important application of e-Navigation. This development has become possible through the deployment of networks of AIS base stations and the installation of onboard equipment with the capability of displaying the Virtual AtoN symbols. Such networks are generally provided and operated by coast guard services and these may or may not be the same authorities that provide AtoNs. Agreements may be necessary on the use and service levels of these networks for providing Virtual AtoNs. However, because such agreements may not cover all situations and locations, some alternative delivery methods have also been explored.

One alternative is to install AIS AtoN units on lighthouse service vessels, so that they can transmit Virtual AtoNs and can be deployed to the area of an incident. The second option is to install AIS AtoN units permanently on shore stations, such as lighthouses, in critical locations. Another possibility is to deploy transportable units by land vehicle, boat or helicopter. The last option may have licensing complications, which are currently being investigated.

Trials have been carried out with the first two options and the results are reported in this paper, together with recommendations on further deployments and procedures for use.

INTRODUCTION

The General Lighthouse Authorities of the United Kingdom and Ireland (GLA) comprise Trinity House, The Commissioners of Irish Lights and The Northern Lighthouse Board. Between them, they have the statutory responsibility to provide marine AtoNs around the coast of England and Wales, all of Ireland and Scotland, respectively. AtoNs take many forms, including the more traditional buoys and lighthouses, radio navigation systems, and recently also Virtual AtoNs.

The ability to provide Virtual AtoNs could be one of the most significant technical developments for lighthouse authorities in the short to medium term and is an important application of e-Navigation. This paper reports on development work towards the establishment of the GLA Virtual AtoN System. Background information is given about Virtual AtoNs, and the benefits, limitations and risks associated with their use are discussed. The paper then goes on to describe the development of operational procedures and hardware for the future system. Results of trials with AIS AtoN units installed on a ship and on a lighthouse are then reported and discussed, and recommendations on further deployments are suggested.

BACKGROUND

Definition

IALA defines a Virtual AtoN as: “a digital information object promulgated by an authorised service provider that may be presented on navigational systems” [1].

There are many possible approaches to providing Virtual AtoNs, but the use of AIS broadcasts is the one which has attracted most attention. It has long been recognised that AIS had the potential to present a “virtual” aid to navigation on an electronic display, where no physical AtoN exists. The AIS AtoN Report (Message 21) includes a Real/Virtual flag [2] and symbols for AIS AtoNs, including Virtual AtoNs, are included in the current IEC Performance and Test Specifications for Radars (IEC 62388) and Navigation Displays (IEC 62288). At IMO NAV 59 a Report was approved on Policy and Symbols for AIS AtoNs [3]. Examples of the symbols proposed in that report are shown in Figure 1 below.

Figure 1: Real (left) and Virtual (right) AIS AtoN symbols for an Emergency Wreck Mark, as proposed in IMO NAV 59/7.

Use of Virtual AtoNs

The primary purpose of a Virtual AtoN is to provide a near-instantaneous warning to the mariner of a new danger, such as a wreck, obstruction or floating debris. It is hoped that Virtual AtoNs could reduce the risk of other vessels running into a new wreck, as happened with the Tricolor [4]. Virtual AtoNs are particularly useful in situations where navigational conditions change frequently or in applications where the use of physical aids is not practical or possible. However, it should be noted that Virtual AtoNs are not, in general, intended to replace physical AtoNs.

Specific applications of Virtual AtoNs are described in IALA Guideline No. 1081 [5].

Benefits

One of the key benefits of this emerging technology is the ability to precisely target where this information is delivered, as it can be limited to the affected area and can be presented directly on navigation displays; with low deployment and maintenance costs.

Limitations & Risks

As mentioned, the development of Virtual AtoN systems has become possible through the deployment of AIS infrastructure. Such infrastructure is generally provided and operated by coast guard services and these may or may not be the same authorities that provide AtoNs. Agreements may be necessary on the use and service levels of these networks for providing Virtual AtoNs. However, because such agreements may not cover all situations and locations, it may also be necessary to develop some alternative delivery methods. The GLA have explored several such methods. The options explored are briefly described in the following section and two of the alternatives are discussed in detail in this paper.

A major obstacle to immediate application of Virtual AtoNs is that the IEC standards pertaining to the display of AIS AtoNs were introduced in 2008, and equipment that meets these specifications is not yet fitted on the majority of vessels. As a result, Virtual AtoNs may not be visible on the displays of some ships, or the symbols may differ between displays. At the current rate of fitting new equipment, 10 – 15 years appears to be a realistic timescale for the majority of ships to benefit from the provision of Virtual AtoNs [5]. It should also be noted that display of AIS AtoNs by Class B equipment is optional.

Authorities and users should be aware that Virtual AIS AtoN transmissions (as any other AIS transmissions) are susceptible to interference, whether caused by natural events or intentional jamming and spoofing. Jamming could block the reception of Virtual AtoN data, but would only be limited to a certain geographic area determined by the propagation characteristics of the VHF signal. Spoofing could have more serious consequences, but can be detected through careful monitoring of the transmission channel (see [5]).

GNSS vulnerability may also be a concern. The delivery of the Virtual AtoN should not be directly affected by a short-term loss of GNSS signals as the position information included in the transmitted message is fixed and independent of GNSS. A long-term GNSS outage could, however, negatively affect the synchronisation of AIS transmissions, unless backup timing references are provided, potentially leading to reduced effectiveness of the Virtual AtoN service.

Alternative Delivery Methods

As explained above, lighthouse authorities may need to develop alternative ways of delivering Virtual AtoNs to mariners using their own assets. One alternative may be to install AIS AtoN units on lighthouse service vessels, so that they can transmit Virtual AtoNs and can be deployed to the area of an incident. Suitable AIS units are readily available and therefore this option can be implemented relatively easily and at low cost. It is, however, necessary to develop and implement appropriate operational procedures, and provide adequate training to ensure the correct configuration and operation of the AIS AtoN unit by the vessel crew. The 'Development: Procedures' section of this paper outlines the key points that need to be considered when developing such procedures.

The second option is to install AIS AtoN units permanently on shore stations, such as lighthouses, in critical locations. Since such stations would normally be unmanned, this option requires that the AIS units can be controlled and configured remotely. Existing AIS AtoN units generally do not provide this capability and some development is required to make these units suitable for the application described in this paper. The 'Development: Hardware' section below describes an approach taken by the GLA.

Another possibility is to deploy transportable units by land vehicle, boat or helicopter.

Trials have been carried out with the first two options and the results are reported later in this paper.

DEVELOPMENT: PROCEDURES

In order to provide Virtual AtoNs effectively the information they provide must be robust and have integrity. As such, a formal process is required that ensures Virtual AtoNs are deployed with the correct information at the correct time. This section describes the fundamental elements required in a Virtual AtoN System and outlines the key points that need to be considered when developing operational procedures for the provision of Virtual AtoNs.

Elements of System

It is envisaged that a Virtual AtoN System should comprise the following elements:

1. Reception point for information on hazards
2. Analysis & decision making function
3. Means of sending request to deploying agency
4. Procedure for monitoring correct deployment and continued correct deployment
5. Procedure for confirming correct cessation

Process

The process by which the Virtual AtoN System carries out its function can be broken down into the following components:

1. Receive information on hazard
2. Determine action to be taken (Virtual AtoN or not)
3. If Virtual AtoN appropriate, pass on request and necessary information to activating agency (including period for which required, if appropriate)
4. Confirm Virtual AtoN provided and that information is correct
5. Monitor integrity
6. Request cessation of provision
7. Confirm cessation at end of required period

When deploying a Virtual AtoN, the activating agency also needs to assign an MMSI (Maritime Mobile Service Identity) number to the AtoN. The MMSI is a unique identifier issued by the appropriate national authority. MMSI numbers used for Virtual AtoNs should follow the format described in IALA Recommendation A-126 [6].

Effectiveness

The effectiveness of the Virtual AtoN System can be measured by:

1. Time taken to deploy and discontinue
2. Availability and continuity during deployment (determined by broadcasting system parameters)

3. Accuracy and Integrity of broadcast information (as required for conventional AtoNs)
4. Cessation at correct time (dependent on communications and adherence to procedures).
5. Coverage area, number of base stations needed (determined by method of transmission and broadcast parameters)

DEVELOPMENT: HARDWARE

This section describes the development work that was undertaken to add the remote control capability to commercially available AIS AtoN units. This development was necessary in order to enable deployment at remote, unmanned locations, such as lighthouses or light vessels.

Requirements for Communications Interface

AIS AtoN units are normally configured locally using a serial interface connection to a PC. However, one of the main reasons for using Virtual AtoNs is speed of deployment and in many situations this can best be achieved by remote configuration of a unit already in an appropriate location. In order to enable remote configuration and control over a telecommunications network, an additional interface needed to be developed. This interface required the following features:

- The interface needed to be compatible with a wide range of communication technologies, such as PSTN (Public Switched Telephone Network), mobile networks, satellite modem links, etc. as it was recognised that remote locations could be outside the coverage area of traditional communication networks.
- The interface required some form of authentication to prevent unauthorised use of the AtoN units. False or misleading Virtual AtoNs could be a serious hazard in themselves and therefore attention had to be paid to the security of the system.
- The interface was to be capable of operating from a DC power supply to ensure compatibility with battery systems typically used at remote sites, and designed for deployment in harsh environments (appropriate ingress and lightning protection to be provided, with a watchdog timer to monitor proper functioning).
- There could also be a need for remote power-cycling of the AIS AtoN unit, to ensure the successful reconfiguration of the unit.

GLA Prototype Communications Interface Unit

The GLA developed a prototype communications interface unit that met most of the above requirements. The solution was based around a commercially available AIS AtoN unit and allowed the unit to be remotely reconfigured and controlled via PSTN.

The solution is comprised of four main hardware components: a PC (located at the control site); Communications unit; Lightning protection unit; and the AIS AtoN unit with associated antennas. A schematic diagram of the solution is shown in Figure 2.

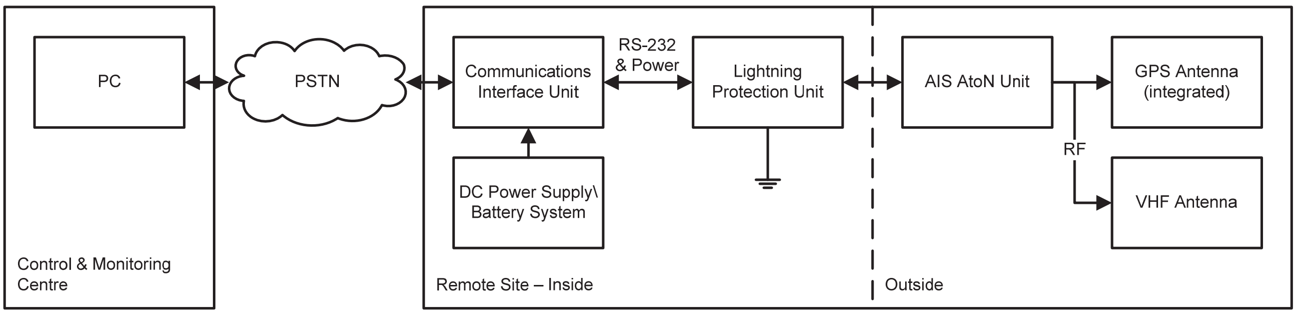

Figure 2: Overview of the implemented solution.

Ongoing Development

Collaboration is ongoing with the manufacturer of the AIS AtoN unit with the aim to commercialise the GLA prototype interface unit. At the time of writing, the unit is being integrated with PSTN and GSM modems. The ultimate goal is to develop a generic interface to enable communication using any Hayes-compatible modems [7]. This would facilitate integration of the AtoN unit into the GLA outstation monitoring and control systems and make the solution applicable to a wider market.

TRIALS AND RESULTS

Installation on Vessel

An AIS AtoN unit was installed on THV Alert (see Figure 3 and Figure 4) and tests were carried out by transmitting a Virtual AtoN from the vessel alongside Trinity Pier in Harwich, Essex, on to Stream Moorings No. 1 about half a mile to the North-East. Figure 5 and Figure 6 show the Virtual AtoN, displayed as a diamond with a V superimposed inside it on the ECDIS of THV Alert. This is in accordance with the current IEC specification for Navigation Displays (IEC 62288).

In this experiment, the AtoN unit was controlled by GLA personnel directly from an onboard PC.

Figure 3: THV Alert – the AIS AtoN unit was installed above the wheel-house.

Figure 4: Close-up of the AIS AtoN installation on THV Alert.

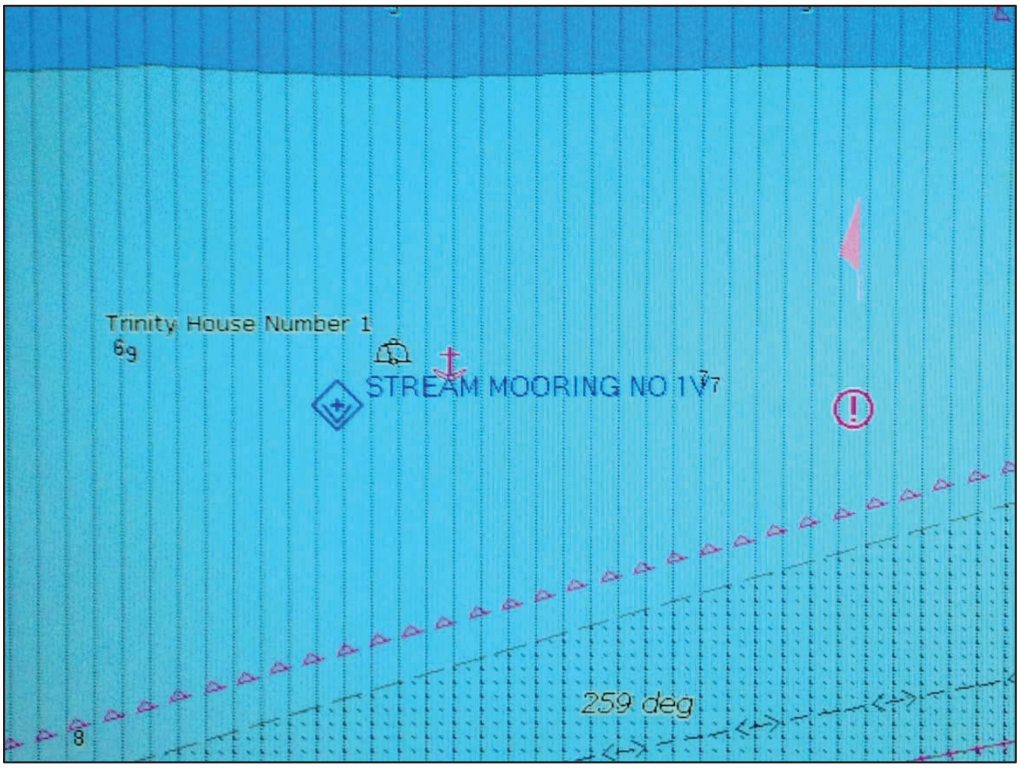

Figure 5: ECDIS showing Virtual AtoN transmitted by THV Alert on to Stream Mooring No. 1.

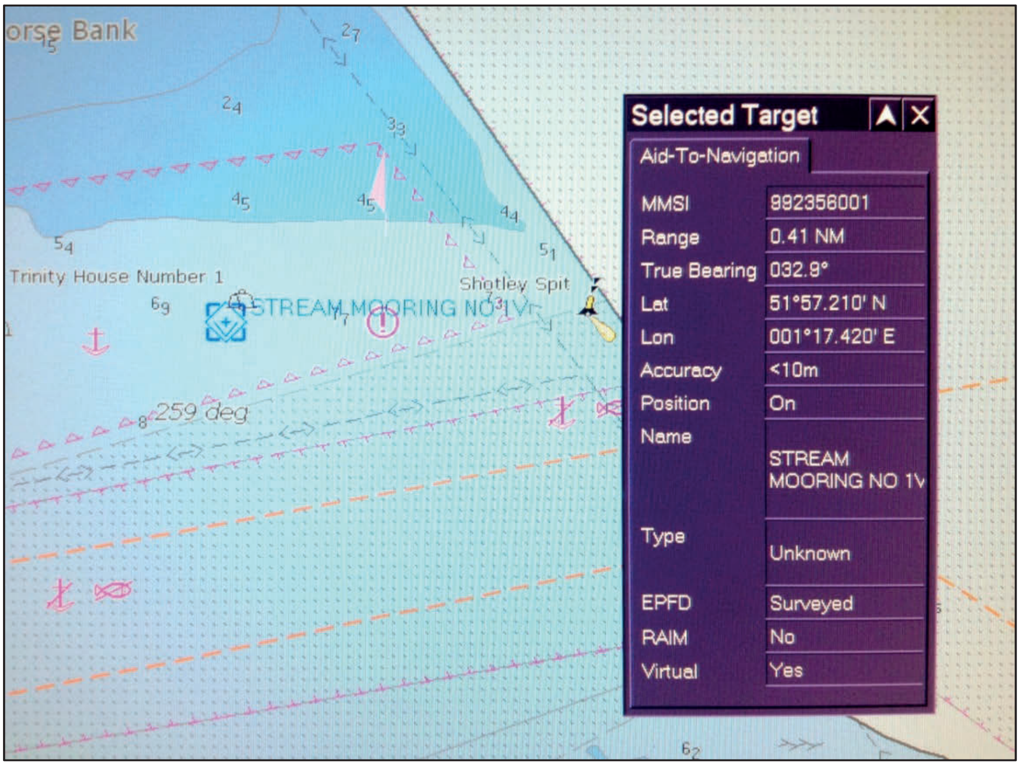

Figure 6: ECDIS showing Virtual AtoN transmitted by THV Alert on to Stream Mooring No. 1.

Installation on Lighthouse

An AIS AtoN unit was also installed on Dungeness Lighthouse, Kent. In this test, the unit was configured and controlled from Trinity House Depot in Harwich, Essex, using the prototype GLA communications interface described earlier in this paper. The result is shown in Figure 7 taken from a display in the Trinity House Control and Monitoring Centre in Harwich and

Figure 8 – taken from the MarineTraffic.com website. In this case the Virtual AtoN flag was set in the message, but only a diamond is shown on the displays. This is a function of the display software, not the AIS unit.

Figure 9 shows the estimated coverage area for an AIS AtoN transmitted from the lighthouse. This is defined as the geographical area within which the received power exceeds -107 dBm [6]. It can be seen from Figure 9 that the maximum range is predicted to be approximately 60 km (32 NM), which is in line with observations. The plot was generated using the Signal Propagation, Loss, And Terrain (SPLAT) analysis tool [8].

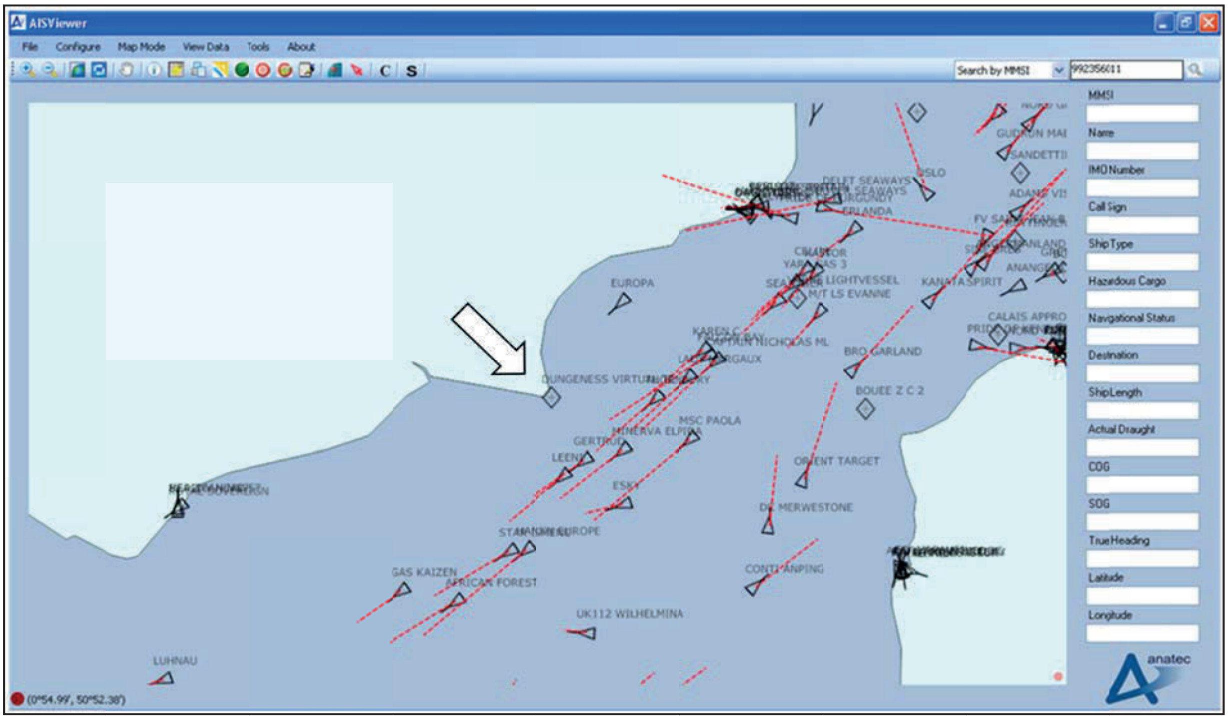

Figure 7: Dungeness Virtual AtoN shown on a display in the Trinity House Control and Monitoring Centre.

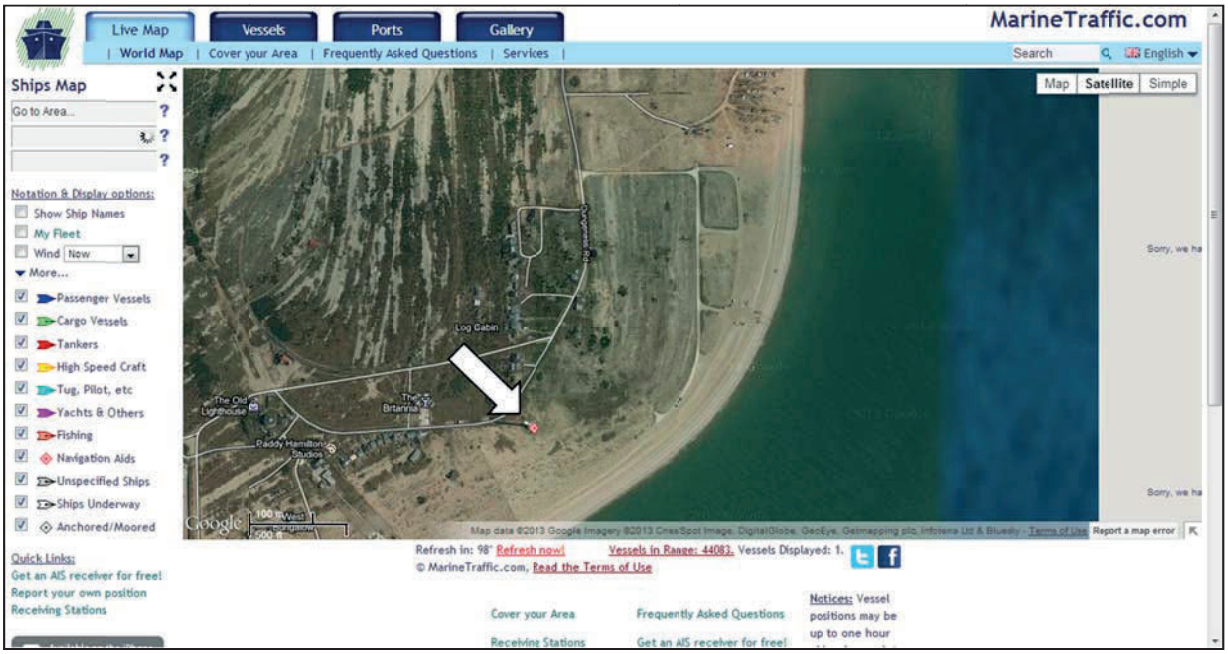

Figure 8: Dungeness Virtual AtoN on MarineTraffic website.

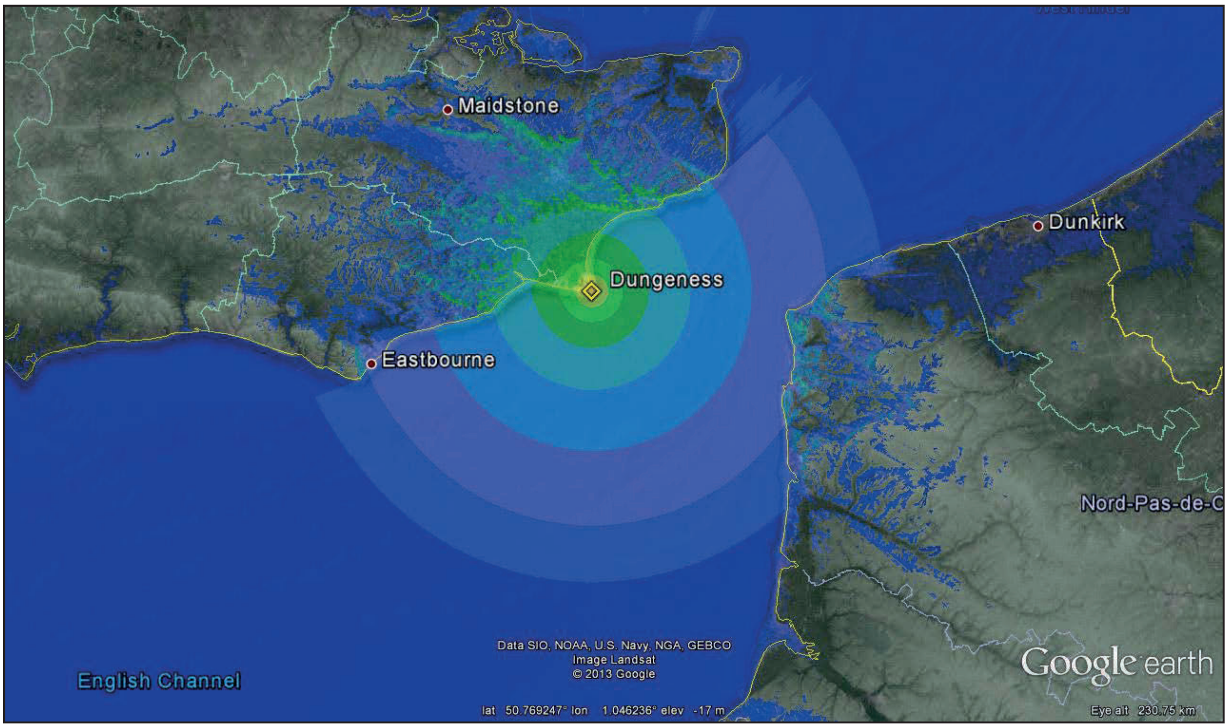

Figure 9: Estimated coverage area for an AIS AtoN transmitted from the Dungeness Lighthouse, assuming transmitter power of 12.5 W, transmitting antenna height of 40 m and receiving antenna height of 10 m.

DISCUSSION

It has been successfully demonstrated that AIS AtoNs can be set up and transmitted for chosen locations from a vessel and from a lighthouse. These options provide lighthouse authorities with an effective way of marking new hazards rapidly and this method could now be implemented operationally.

The symbols shown are determined by the display software. In these tests the symbol presented on the ship's ECDIS was a diamond with a V superimposed inside it, which is in accordance with the current IEC specification for navigation displays. Other displays presented a plain diamond symbol as specified in the relevant IEC document for real AIS AtoNs, without the distinction defined for Virtual AtoNs.

The symbols to be used have now been agreed in IMO, based on the Report of the Correspondence Group set up by the Safety of Navigation Sub Committee [3].

It should be noted that it will take some time for suitable display equipment to become available and some years before it is fitted in a significant number of ships. However, further tests would be appropriate with such equipment to ensure that the correct symbols are presented.

CONCLUSIONS

Lighthouse authorities can provide the capability to deploy Virtual AtoNs using their own assets, by installing suitable AIS AtoN units on lighthouse service vessels and at shore-stations, where justified by the risk.

Appropriate operational and technical procedures would need to be adopted for the safe and efficient deployment of Virtual AtoNs.

ACKNOWLEDGMENTS

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Supporting paper

Vessel traffic services

Emerging needs and developments

What are the challenges and how do we address them?

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IALA·2014·AISM

XVIII Conference · A Coruña · Spain

Australian Government
Australian Maritime Safety Authority

Vessel Traffic Services

Emerging needs and developments – What are the challenges and how do we address them?

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ABSTRACT

Although a relative newcomer in the maritime world, and at times considered a controversial one, there are now well over 500 vessel traffic services operating worldwide (IALA VTS Manual 2012).

The realities of modern shipping with larger, faster and often less manoeuvrable ships, increasing maritime traffic congestion and increases in competition for water space has resulted in an increased number and type of services being delivered throughout the world.

One of the major contributing factors in the increasing number of VTS is that these services provide a mechanism to mitigate risks where passive traffic management measures alone (e.g. improvements to visual and radio aids to navigation, routeing measures, etc) are considered inadequate to attain the desired level of safety and efficiency of the maritime traffic.

In addition to providing information and data in a timely manner to assist on board decision making VTS provides a 'human element' whereby the VTSO has the capability to interact with ships crews, respond to traffic situations developing in the area, and monitor its effect.

This paper aims to:

- *Examine the growth and achievements of VTS since the emergence of the international framework for the delivery of VTS under the International Convention for the Safety of Life at Sea (SOLAS)*
- *Identify key emerging developments, trends and needs associated with the delivery of VTS in a rapidly changing world, and*
- *Provide an appraisal of the IALA VTS Strategy Paper - Delivery of VTS in a rapidly changing world currently being developed.*

1 INTRODUCTION

The world's first harbour surveillance radar was inaugurated in Liverpool, England, in July 1948. In 1950, a radar surveillance system was established at Long Beach, in the United States. The ability of the coastal authority to keep track of shipping traffic by radar, combined with the facility to transmit messages concerning navigation to those ships by radio, therefore constituted the forerunner to what we know today as VTS.

Other countries quickly followed Liverpool and Long Beach utilising a combination of radar and radio to achieve the capability to have a traffic surveillance system and real time information exchange between the shore and ships. These systems initially had a focus on safety and efficiency but in more recent times protection of the environment has also emerged as an important parameter, and in some instances provides the driving force.

By 1999 there were 250 vessel traffic services (Boisson, 1999). Reasons attributed to this rapid expansion include:

- Multiplying dangers with the increase in the size and speed of ships.
- Increasing concentration of maritime traffic in certain zones, such as the approaches to ports, straits and narrow or shallow shipping lanes.
- Increasing public anxiety associated with the growth in transport of dangerous goods by sea and the need to protect the environment.

By 2012, there were over 500 services operating worldwide (IALA VTS Manual 2012) and evidence suggests that the number is growing rapidly, both in the developed and developing world.

Most services are operated under domestic law within the territorial seas however VTS is increasingly being adopted beyond the territorial sea to address issues related to the safety and efficiency of navigation and protection of the environment. The IALA Guideline 1071 on *Establishment of a Vessel Traffic Service beyond Territorial Seas* provides five examples of where a VTS manages a Ship Reporting System or monitors a Traffic Separation Scheme, approved by IMO and that is operating partially or solely beyond territorial seas or in an international strait. These include:

- Great Belt VTS (Denmark)
- Sound VTS (Denmark/Sweden)
- Turkish Straits VTS
- Off the coast of Portugal VTS (Roca Control), and
- Vardoe VTS (Norway)

This guideline clearly articulates that authorities identifying the need to establish, or extend a VTS beyond territorial seas, either individually or on a multi-national basis, should note that this can only be achieved under current regulation through:

- The establishment of voluntary use of VTS.
- Approval under the provision of SOLAS Chapter V/11 (Ship Reporting System).
- Approval under the provision of SOLAS Chapter V/10 (Ships' Routeing).

2 BENEFITS OF VTS

A VTS provides essential and timely information to assist the on-board decision making process. This is achieved by maintaining a traffic image of ships transiting the VTS area and interacting with individual ships to provide information such as reports on the position, identity and intentions of other traffic, weather, hazards and other factors that may influence a ship's transit.

The benefits of implementing a VTS include the identification and monitoring of vessels, strategic planning of vessel movements and provision of navigational information and assistance. It can also assist in the prevention of pollution and co-ordination of pollution and or emergency response.

The efficiency of a VTS will depend on the reliability and continuity of communications and on its ability to provide accurate and unambiguous information. The quality of accident-prevention measures will depend on the system's capability of detecting a developing dangerous situation and the ability to provide timely warning of such dangers. In particular, a VTS can contribute to:

- Preventing incidents from developing
- Preventing incidents from developing into accidents
- Preventing accidents from developing into disasters

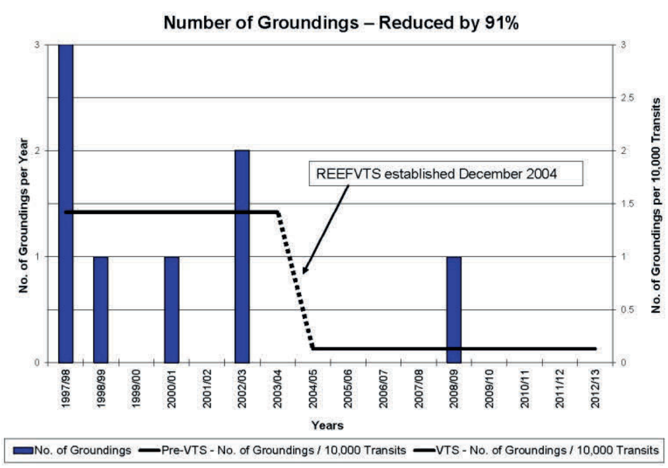
Unlike other aids to navigation, VTS provides a human element in that VTSO’s have the capability to interact and influence the decision-making process on board the vessel. For example, where information available to the VTS suggests a potential developing situation, such as a ship approaching shallow water, is deviating from a recommended route or does not alter course at a critical waypoint, the VTS operator may initiate interaction to confirm the ship’s intentions, or in situations where the ship is approaching danger, to provide assistance to avert an incident.

As approximately 80 percent of all accidents at sea are attributed to human factors (Nautical Institute, 2003) there is considerable value-adding through the involvement of and interaction with the VTS as an additional safeguard.

While several examples could be quoted to highlight the effectiveness of VTS recent statistics released by the Great Barrier Reef and Torres Strait Vessel Traffic Service (REEFVTS) clearly shows the effectiveness of interaction between the shore and the ship. Introduced in 2004, the objectives of the VTS are to:

- Enhance navigational safety in Torres Strait and inner route of the Great Barrier Reef by interacting with shipping to provide information on potential traffic conflicts and other navigational information;
- Minimise the risk of a maritime accident and consequential ship sourced pollution and damage to the marine environment in the Torres Strait and Great Barrier Reef region; and
- Provide an ability to respond more quickly in the event of any safety or pollution incident.

Since its introduction the average number of groundings in the Great Barrier Reef and Torres Strait has declined from 1.42 per 10,000 transits to 0.14 per 10,000 transits per year, a reduction of over 90%.



This reduction is attributed to the interaction between VTS operators and the ship to provide timely and accurate information to assist on-board decision making, and helping to prevent situations before they became critical.

2.1 Accident Zero Campaign

The contribution of VTS to the safety of life at sea, safety and efficiency of navigation and protection of the marine environment is a key component of the IMO/IALA Award for Accident Zero Campaign. The purpose of this award is to provide international recognition for established Vessel Traffic Services which provide shipmasters and others with the information necessary to enter a VTS area and subsequently to comply with its requirements, thereby optimising efficiency and enhancing safety. The basic requirements for nominating a VTS include, amongst other things, that:

- the objectives of the VTS were set and it could be demonstrated that they were being met
- the VTS Authority should retain accident and near-miss records and statistics for the VTS area

In addition to the basic requirements, the following elements may be taken into consideration by the Panel when nominating a VTS for the Award:

- any documented near-miss situation that may demonstrate a positive contribution by the interaction of the VTS that avoids the adverse effects of maritime traffic or marine environment
- any history of an improving safety record, culture and continual procedural developments as a result of VTS performance monitoring

3 DEVELOPMENTS, TRENDS AND NEEDS

Developments, trends and needs commonly identified as impacting on VTS include:

- Increasing public perceptions, including:
  - The desire to enhance the safety and efficiency of navigation, safety of life at sea and the protection of the marine environment,
  - The necessity to provide a mitigation tool to assist in the prevention of catastrophic events that could endanger coastal populations or the marine environment in waters where they have sovereign rights, and
  - Recognition that maritime safety and the protection of the environment often has trans-boundary implications.
- Environmental concerns from the public and future regulatory requirements that are expected to continue to gain ever-higher importance;
- An increasing demand by coastal states to seek more information from vessels transiting waters under their jurisdiction, adjacent waters and beyond, to manage the risks they pose and to have a positive means of communicating with them;
- An increasing tendency by port and coastal states to implement more rules/requirements for vessels arriving in and/or transiting waters within their jurisdiction;
- An increasing need for mandatory training requirements for VTSOs;
- An increasing tendency between coastal states for regional co-operation;
- An increasing importance being placed on shipping routes in polar regions;

- Changing traffic conditions and increased risk posed by faster and larger vessels;
- Emerging concepts such as the IMO led e-Navigation concept, Sea Traffic Management (STM) and the Motorways and Electronic Navigation by Intelligence at Sea (MONALISA) to further contribute to maritime transport in terms of contributing to safety, efficiency and environmental protection. (These all involve similar goals to VTS, that is, safe, secure and efficient maritime traffic and the protection of the marine environment);
- The rapid development of new technologies in recent years (such as AIS, LRIT, AIS via Satellite technologies) which are providing coastal states with the opportunity to maintain an accurate and real time traffic image of shipping well beyond their territorial sea;
- The development of the slot management concept to improve efficiency within the maritime sector as pioneered by the Turkish Straits and Newcastle Port (Australia);
- Concerns over security and the impact on maritime and other modes of transport;
- Acknowledgement that crew competency and the skill sets of maritime personnel will continue to vary;
- An increasing demand for rapid and predictable transportation and cargo handling schedules;
- Competition for the use of navigable waters (high seas, coastal, etc) which continues to increase (e.g. High Speed Craft, larger and faster commercial ships, recreational vessels, offshore structures, and renewable energy systems).

4 INTERNATIONAL FRAMEWORK FOR VTS

The value of the "VTS like" systems developed during the 1950s and 1960s was recognised by the IMO in 1968 with adoption of Resolution A.158 (ES.IV) Recommendation on Port Advisory Systems adopted. It was not until 1985, however, with the adoption of IMO Resolution A.578(14) Guidelines for Vessel Traffic Services, that VTS became a defined and recognised service. Resolution A.578(14) defined a VTS as:

> *"any service implemented by a competent authority, designed to improve safety and efficiency of traffic and protection of the environment."*

Further, Resolution A.578(14) highlighted that:

- VTS was particularly appropriate in the approaches and access channels of a port and in areas having high traffic density, movements of noxious or dangerous cargoes, navigational difficulties, narrow channels, or environmental sensitivity.
- Decisions concerning effective navigation and manoeuvring of the vessel remained with the ship's master, and
- The importance of pilotage in a VTS and reporting procedures for ships.

Revised Guidelines for vessel traffic services, including Guidelines on Recruitment, Qualifications and Training of VTS Operators, were adopted as Assembly Resolution A.857(20) in November 1997. This Resolution has not been reviewed or amended since 1997.

4.1 VTS and SOLAS

Vessel Traffic Services were not recognised in the International Convention for the Safety of Life at Sea (SOLAS) 1974 until the adoption of Regulation 8.2 Vessel Traffic Services in 1997. In a revised SOLAS Chapter V on Safety of Navigation (adopted in December 2000) this became Regulation 12. Amongst other things, Regulation 12 states that:

> *"Vessel Traffic Services (VTS) contribute to safety of life at sea, safety and efficiency of navigation and protection of the marine environment, adjacent shore areas, work sites and offshore installations from possible adverse effects of maritime traffic."*
>
> *"Contracting Governments undertake to arrange for the establishment of VTS where, in their opinion, the volume of traffic or the degree of risk justifies such services."*

4.2 VTS and UNCLOS

The United Nations Convention on the Law of the Sea (UNCLOS) is 'silent' on VTS. That is, it does not explicitly provide for, nor does it exclude, the establishment of VTS for each of the maritime areas.

5 IALA VTS STRATEGY PAPER - DELIVERY OF VTS IN A RAPIDLY CHANGING WORLD

In progressing its 2010-14 Work Programme Tasks the IALA VTS Committee identified possible shortcomings and differing interpretations about the delivery of VTS in a rapidly changing world. In considering these the Committee identified the need for a high-level policy document describing the objectives for VTS to meet the emerging needs of and developments within the maritime domain and the adequacy of the existing international framework for VTS.

Key components of this task include:

- Developing an IALA VTS Strategy with regards to the delivery of VTS in a rapidly changing world, and
- Identifying and documenting:
    - the strengths and weaknesses of IMO Resolution A.857(20) in setting the framework for the delivery of VTS;
    - developments in VTS since the existing Resolution was agreed and emerging trends that may be anticipated over the next 10-20 years;
    - possible limitations to addressing the emerging needs and developments for VTS within the existing provisions of IMO Resolution A.857(20).

The IALA VTS Strategy Paper - Delivery of VTS in a rapidly changing world is due to be completed in 2015 and it is anticipated that it will provide a significant document for IALA, the future of VTS globally and the maritime world.

The possible need to review existing frameworks relating to maritime safety and protection of the environment was discussed recently at the IMO Symposium on the Future of Ship Safety (10 and 11 June 2013). In particular, the Statement of the Participants from the IMO Symposium on the Future of Ship Safety (2013) made five recommendations to the Maritime Safety Committee. Recommendation 5 was that the Committee:

> *"consider undertaking a long-term comprehensive review of the existing safety regulatory framework with a view to ensuring that it will meet the future challenges associated with*

the application of new technologies, the human element, the needs of the maritime industry and the expectations of society, taking into account the ever-increasing pace of change and technological advancements made since the 1974 SOLAS and the International Load Lines Conventions were adopted"

6 WHERE TO FROM HERE

The increasing number of VTS being implementation throughout the world (both within and beyond territorial seas) highlights an emerging need for greater clarity and certainty with respect to the international framework for VTS. Public awareness is heightened and there are growing expectations with regards to the capabilities for VTS to monitor and communicate with vessels beyond port and coastal areas. The future implementation of developing concepts such as e-Navigation and STM also need to be considered.

Issues associated with the international framework facing both VTS beyond its traditional boundaries and emerging "VTS like" systems seeking to introduce requirements (such as notification and reporting requirements, and increasing interaction from the shore) achieve greater clarity and certainty are fundamental principles such as:

- freedom of navigation
- flag state sovereignty over its vessels under UNCLOS and the challenges this may create for coastal states imposing notification and reporting requirements
- decisions on navigation are the responsibility of the shipmaster, and that the shipmaster has full legal and financial responsibilities for the conduct of a ship

It is becoming increasingly evident that this clarity is required to address emerging concerns such as:

- The status and validity of services in some areas (e.g. beyond territorial seas) is currently viewed as questionable by some contracting governments and some quarters of the maritime sector.
- The lack of clarity/certainty may lead to confusion on the part of the mariner as to their obligations while navigating in these areas and their expectations as to what services, if any, to expect from the shore-side authority.
- Contracting Governments may not be meeting their international obligations for planning and establishing a VTS. For example, IMO Resolution A.857(20) states that, in planning and establishing a VTS, the Contracting Government or Governments or the competent authority should, amongst other things, *"ensure that a legal basis for the operation of a VTS is provided for and that the VTS is operated in accordance with national and international law"*.

7 CONCLUSIONS

The increasing implementation of VTS throughout the world and rapidly emerging developments, trends and needs associated with the delivery of VTS and "VTS like" services is increasingly highlighting a need to review the existing international framework.

This is particularly important to avoid the development of disparate systems and situations that may lead to confusion on the part of the mariner as to their obligations while navigating in these areas and their expectations as to what services to expect from the shore-side authority. Coordination, integration and the adoption of international standards and frameworks is required.

The IALA VTS Strategy Paper - Delivery of VTS in a Rapidly Changing World will provide a significant contribution to this and it may also provide input the recommendation to the Maritime Safety Committee in the Statement of the Participants from the IMO Symposium on the Future of Ship Safety undertake a long-term comprehensive review of the existing safety regulatory framework with a view to ensuring that it will meet the future challenges associated with the application of new technologies, the human element, the needs of the maritime industry and the expectations of society.

The combination of the development of the IALA VTS Strategy Paper and the recommendation to the Maritime Safety Committee may provide an opportunity to embrace the need for clarity with regards to VTS and "VTS like" systems within the international framework in a holistic and inclusive manner. Should the Maritime Safety Committee determine to undertake a long-term comprehensive review of the existing safety regulatory framework as recommended, close liaison between IALA and the IMO is to be encouraged in progressing the Strategic Paper, given its emphasis on IMO Resolution A.857(20) Guidelines for Vessel Traffic Services.

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Supporting paper

Enhanced safety through the use of real time dynamic charts overlays

Jonathon Pearce

OMC International, Australia

IALA·2014·AISM

XVIII Conference · A Coruña · Spain

ENHANCED SAFETY THROUGH THE USE OF REAL-TIME DYNAMIC CHARTS OVERLAYS

by Captain Jonathon Pearce, Senior Pilotage Advisor, OMC International

Abstract

In today's economic climate, ports need to maximise their efficiency while ensuring safety of passage. As vessels increase in size, the dilemma facing many ports is that their existing static underkeel clearance (UKC) rules are inflexible, thus deeper vessels cannot transit without compromising safety.

As static rules do not change with the environmental conditions, the actual clearance and the potential of vessel grounding varies on any given day; for this reason static rules need to be conservative.

In contrast, dynamic UKC systems, calculate the required UKC depending on the prevailing environmental and vessel conditions; this ensures every transit satisfies appropriate risk standards. With safety assured, economic and efficiency benefits are realised when conditions allow deeper draughts and/or extended tidal windows.

This dynamic information can now be relayed to the pilot, via a chart overlay, to provide real-time 3D displays of the safe navigational areas, thereby ensuring continued safety of navigation.

Static v Dynamic Systems

The majority of authorities' in the world use static rules to determine the safe underkeel clearance of a vessel. These static rules often use the vessel's draught as the baseline to determine the underkeel clearance; however it is contended that this method can be erroneous as they are based on the assumption that this clearance is sufficient regardless of the prevailing environmental conditions.

In practise, the actual safety clearance is determined by the conditions on the day, and under static rules, the clearance for a vessel varies for every transit. Most of the time the static rules will be conservative, but evidence shows that up to five percent of transits are marginal, even unsafe[1].

By contrast, a dynamic under keel clearance system (DUKC®)[2] calculates real time under-keel clearances in ports and shallow waterways to maximise channel safety and also productivity. The DUKC® considers all factors that affect the UKC of a vessel transiting a channel to determine the minimum safe UKC requirements. The system does not use the vessels draught as the baseline, but a pre-determined safety limit which must not be breached; added to this limit are the vessel's dynamic movements which are modelled using the predicted environmental conditions and this gives the minimum water level that is required to ensure safety at all times throughout a planned transit.

[1] *OMC's historical records show approximately 95% of vessels are conservative, 4% marginal and 1% potentially unsafe*
[2] *DUKC® is the trademarked product of OMC International to determine dynamic underkeel clearances*

The methodology behind dynamic underkeel clearance has been internationally recognised, and the improved certainty and information that dynamic systems can deliver, has seen regulatory bodies, i.e. IALA and PIANC[3], regarding such systems as an essential Aid to Navigation (AToN).

These bodies are now developing standards for dynamic underkeel clearance systems because of the significant benefits, which dynamic determination of underkeel clearance provides, as a risk mitigation tool. They have identified DUKC® as a core e-Navigation concept, which is available and operational today. For the same reasons many authorities' have become increasingly interested in installing DUKC® for safety and risk management purposes.

However, DUKC® systems have also been widely recognised for the enormous economic benefits provided to waterway owners and users by reducing the inefficiencies inherent in the static rules, which is a result of the conservatism, when allowed; Therefore benefits can be realised when environmental conditions allow, and safe transits outside the restrictive static rule boundary can be undertaken.

Static Rules

Traditionally, authorities' have utilised static rules to govern the minimum under keel clearance (UKC) to ensure the safe transit of a vessel. These static rules were devised when vessels were smaller, their speeds lower, ship/shore communications poor and technology generally unavailable to determine ship motions accurately.

Therefore, there needed to be a simple method of calculating a safe underkeel clearance, and the accepted practise, was/is to calculate the underkeel clearance as a proportion of the vessels draught. The most common clearance ratio is "ten percent of draught", which is unfortunate as the PIANC[4] guidelines state that this is a minimum suggested safety clearance and is *for calm waters only*, and that twenty, even fifty, percent may be better, especially for areas that are subjected to wave motions, but this fact is often forgotten.

The static rule tries to capture all anticipated factors[5] in a single allowance. Essentially the only controllable factors are the tide height (and therefore transit time) and speed (which determines the amount of squat[6]). Therefore, where depths are critical and conditions more variable, there may be times when the allowance is marginal.

It could be suggested that the **"static rule" approach is a "top-down" approach**, where the gross clearance is determined from the draught and the actual net underkeel clearance is unknown.

Some ports do try to assess some of the factors, and this could be viewed as an advanced static rule. But whilst some of these factors can be pre-calculated, predicted wave response (in real time) is impossible to calculate without significant processing power and access to environmental data; so in practical terms wave motions are undeterminable once a transit commences. To address this issue,

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[3] *International Association of Lighthouse Authorities and Permanent International Association of Navigation Congresses*
[4] *Underkeel clearance for large ships in maritime fairways with hard bottom; Supplement to Bulletin No51 (1985);*
[5] *Factors include: Tidal residual (difference between predicted and actual tides); Tidal change during transit; Allowance for unfavourable metrological conditions; Water density; Squat (from ship speed); Wave response; Sounding errors; Sedimentation, Localised phenomena such as standing waves.*
[6] *Squat is a hydrodynamic phenomenon by which a vessel moving through water creates a localised area of lowered pressure that causes the vessel to "apparently increase in draught" and be closer to the seabed than would otherwise be expected. It is approximately proportional to the square of the speed of the ship. http://en.wikipedia.org/wiki/Squat_effect*

these ports apply a pre-determined roll/pitch angle to give the ship-handler an indication of loss of underkeel clearance due to wave motion[7].

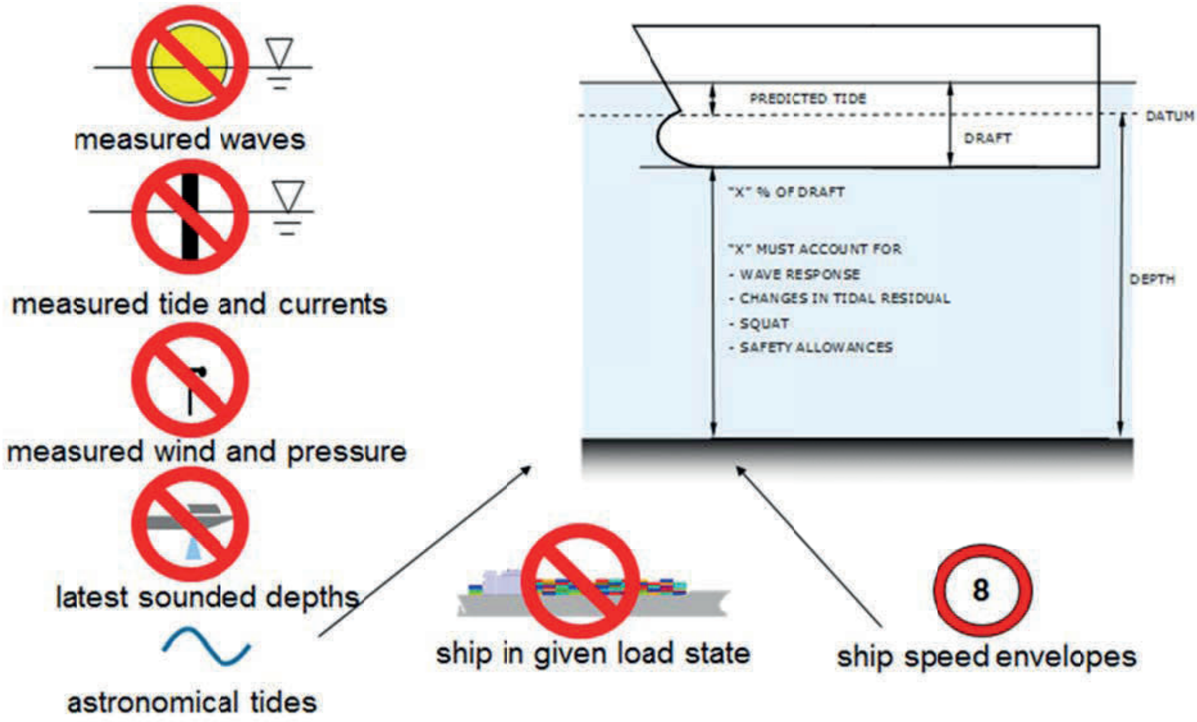

Figure 1 Static Rule components

Speed is an absolutely critical element in maintaining safe UKC. Evidence has shown that vessels' do not always maintain the planned, or proceed at an appropriate speed for the transit. If the transit is too fast, the ship will squat, and heel, in excess of the predicted amounts; both effects are approximately proportional to the square of the speed. By contrast if the vessel transits slower than planned, it will not reach way points at required times and, in tidal waterways, may have less water than predicted and the transit may now be unsafe.

Once underway these elements can be difficult to assess and can often be overlooked. Most authorities' use a single squat formula, but there are many formulae in existence and the most appropriate formula will depend on the bathymetry, channel design and the type of vessel. Often the navigator will calculate the squat for a single critical point, but in practise the vessels squat is continually changing throughout the entire length of the transit.

The biggest drawback with static rules is that the actual clearance is wholly reliant on the environmental conditions. If they are too optimistic, safety could be jeopardised; too conservative, and they become uneconomic; so they are blunt compromise, and for safety reasons need to be derived for the worst case scenario[8]. The actual net clearance is proportional to the environmental and transit conditions, but at the same time unresponsive to change; this means an authority cannot maximise efficiency when conditions allow. More worryingly, an authority will not be aware when

[7] *Loss of UKC = Tan Roll * Beam. However it should be remembered that two vessels, of the same dimensions, but with differing stability will react differently in the same environmental conditions*

[8] *The probability that ship-bottom contact in the long term results in the loss of a ship, or large contamination of the marine environment or the beaches, should be virtually zero. PIANC (1985)*
The chance that a vessel touches the channel bottom during its transit must always be less than 1% for all (weather) conditions (Savenije RPhAC 1996. Probabilistic admittance policy deep-draught vessels))
PIANC (1997) grounding probability studies show risk of grounding is in region of $3x10^{-5}$ (one ship per 33000 movements)

conditions are actually unsafe[9], because when static rules are used, the level of risk is variable and the net underkeel clearance on any particular transit is unknown.

Dynamic Allowance

By contrast, dynamic underkeel clearances are determined based on the actual vessel and its stability parameters, real-time met-ocean conditions (wave height, period and direction, water levels, currents, tidal plane, wind), vessel transit speed and waterway configuration, including detailed bathymetry, at the time of sailing.

Wave spectra, ship speed and water depths vary along the transit and the effect of these variations is computed by the numerical ship motion model used in each DUKC® system. In addition, wave spectra and tidal residuals will change over time, and these effects are accounted for the system.

With respect to squat, individual ships and the pertinent characteristics of the complete approach channel are modelled in each dynamic system, using the most appropriate squat formula, and include the effect of temporal and spatial variation of tidal currents during the transit.

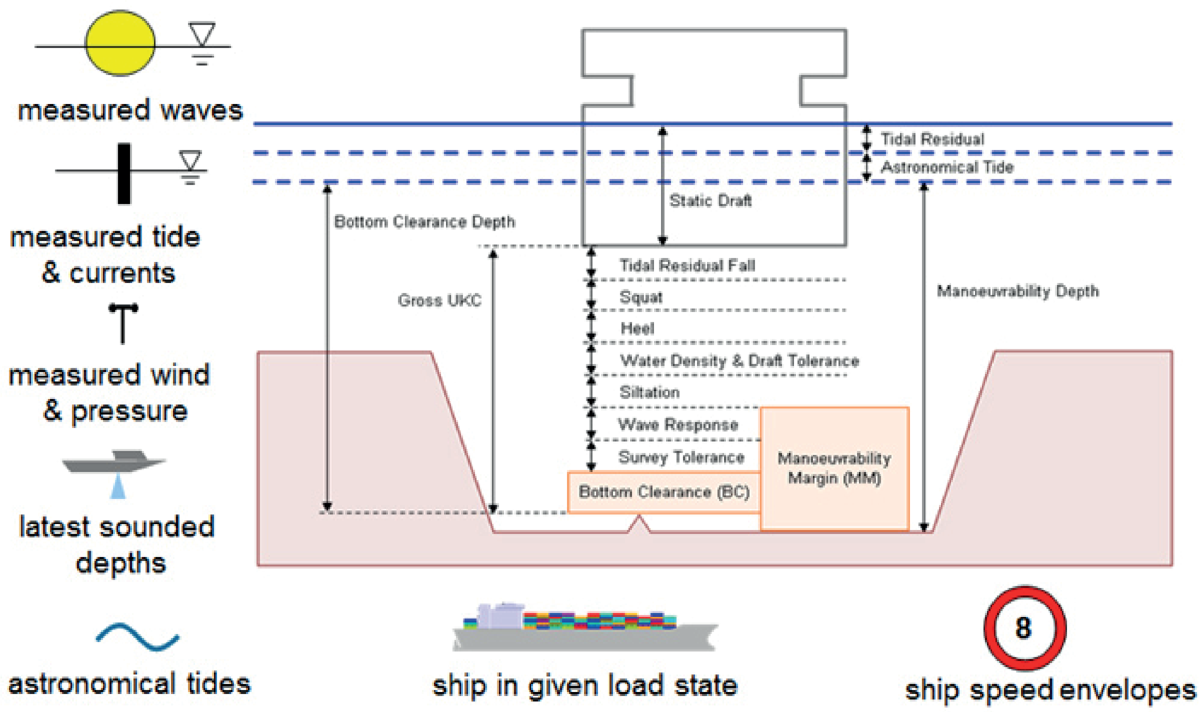

Figure 2 Dynamic Allowance components

Dynamic systems can be considered as a **"bottom up" approach** and the system has, at its core, minimum limits[10] that must not be breached. Each of the factors are computed in real time, and then added until the minimum tide height is found that ensures a safe transit. Thus when the conditions are favourable vessels may have greater tidal windows and/or can sail with a deeper draught; but when conditions are not then tidal windows are reduced, and may even be closed, or a vessel may be able to proceed but with a reduced draught.

[9] *Whangarei, 2003. Two vessels "Capella Voyager' and 'Eastern Honour' ground under existing static rules, which were considered safe.*

[10] *The limit/s can be found in PIANC, 1985 (Underkeel Clearance for Large Ships in Maritime Fairways with Hard Bottom. Report of a Working Group of the Permanent Technical Committee II. Supplement to Bulletin No. 51 (1985)). The limits used in a dynamic system are the PIANC's Bottom Clearance and Manoeuvring Margin limits, but any stipulated minimum limit could be used.*

The systems are predictive, so if a navigator wishes to adapt his transit plan (especially the transit leg speeds), or if there is an unforeseen event (e.g. an engine issue or berth congestion), or there is a change in the environmental conditions the system will automatically update the safe transit windows.

Integration of the sophisticated numerical calculations (the "engine") with real time environmental data (wave, current and tide) ensures integrity and quality at the critical interface between the UKCM system and the dynamic data. Validated accurate numerical models[11] are used to ensure accurate vertical displacements for any vessel type, size and stability condition and vessel speed, in any channel width, configuration, lengths and wave condition, tidal regime and current speed. Each installation is customised using these numerical models to calculate the UKC requirements of the particular ship sailing in the particular waterway in the environmental conditions at the particular time. For this reason a dynamic system satisfy and often exceeds the internationally-accepted levels of risk for safely managing the UKC of vessel transits[12].

By conducting extensive comprehensive geospatial analysis of raw sounding data[13] the system can accurately quantify minimum depths and manoeuvrability depths on a much finer resolution than a standard DUKC calculation. High resolution multi-beam survey data is primarily used to describe the sea bed in much greater detail than is typically available from a standard ENC or navigational chart.

This allows vessels to load deeper when performing dynamic passage planning analyses based upon actual channel depths derived from raw sounding data rather than from a usually conservative estimate of channel depths. For channels that have major siltation issues and require regular sounding, these can now be readily input the DUKC® as soon as they are made available. The DUKC® is therefore always operating on the latest available hydrographic depths, with an allowance for siltation where appropriate from the date of the latest survey.

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[11] *Accurate, and validated, numerical models are fundamental to the assured safety of a DUKC® system. This is done through full-scale measurements of vessel speed, track and vertical displacements, using survey grade DPGS units. OMC has undertaken on more than 300 ship transits in a wide variety of channel widths, configurations and lengths, vessel types, sizes and stability conditions, vessel speeds, wave conditions, tidal regimes and current speeds.*

[12] *The system has also been rigorously and independently tested by specialist risk management consultants to ensure that it satisfies internationally-accepted levels of risk for safely managing the UKC of vessel transits. The Port of Melbourne also undertook two independent risk assessment studies and these extensive risk management studies concluded that the full complement of DUKC® software would significantly reduce the risk of large vessels grounding in port approach channels.*

[13] *El Mejoramiento De La Seguridad De La Navegacíon Utilizando El Sistema Dukc®, M.R. Turner , M.A. Villella and P. W. O'Brien, VI Congreso Argentino de Ingeniería Portuaria Seminario Latinoamericano " Desarrollo Sustentable de la Infraestructura Portuaria Marítima y Fluvial en América Latina.*

Dynamic Underkeel Clearance Systems (DUKC®)

DUKC® is a proven safety and risk management technology and is a recognised core e-Navigation concept, which is available and operational today. OMC, the developers, created the first DUKC® system for Hay Point coal terminal in 1993. The technology has now been installed in over 20 ports and has ensured the safety of over 100,000 transits to date and ***the day-to-day operation of DUKC®, in preference to static rules for UKC, has moved the system from academic theory into a best practice in the real world.***

The system is customised for every port and implements the "dynamic allowances" mentioned above. The core functions of DUKC® systems have always been to provide ports and users with dynamic passage planning advice on:

- maximum draft for tides
- earliest and latest sailing times (tidal windows)
- UKC for specific transits

The system provides comprehensive reports for ports and pilot's which improves the decision making process and enhances the master pilot information exchange. It also serves as a historical database for auditing and risk analysis purposes. The system is now at Version 5 and is a fully interactive cross-platform web based system.

Examples of the information from the voyage planning service, which provides advice and maximum draughts and tidal windows, can be seen in Figure 3, and the transit planning service which allows for speed (squat) adjustment and information on calculated keel elevations in Figure 4.

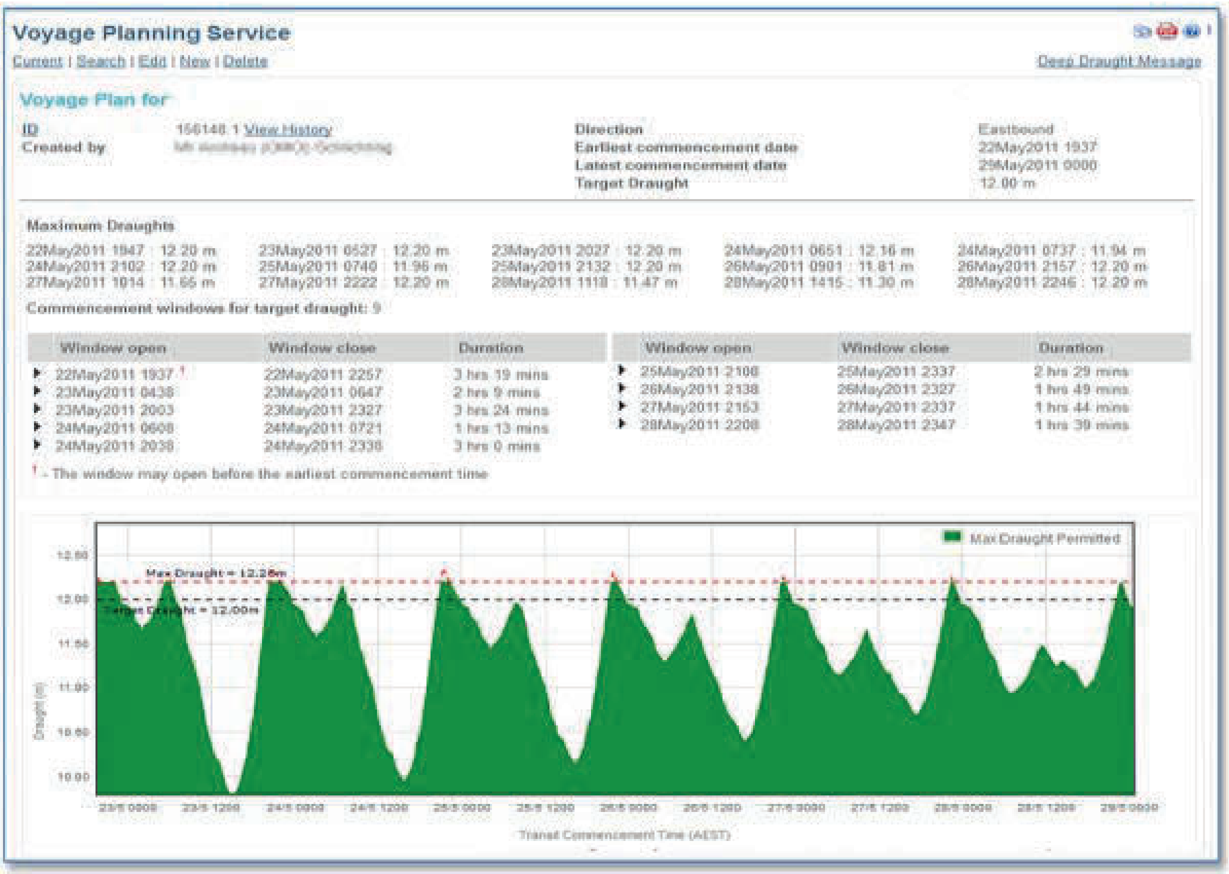

Figure 3 Voyage Planning Service - Max draughts and Tidal Windows

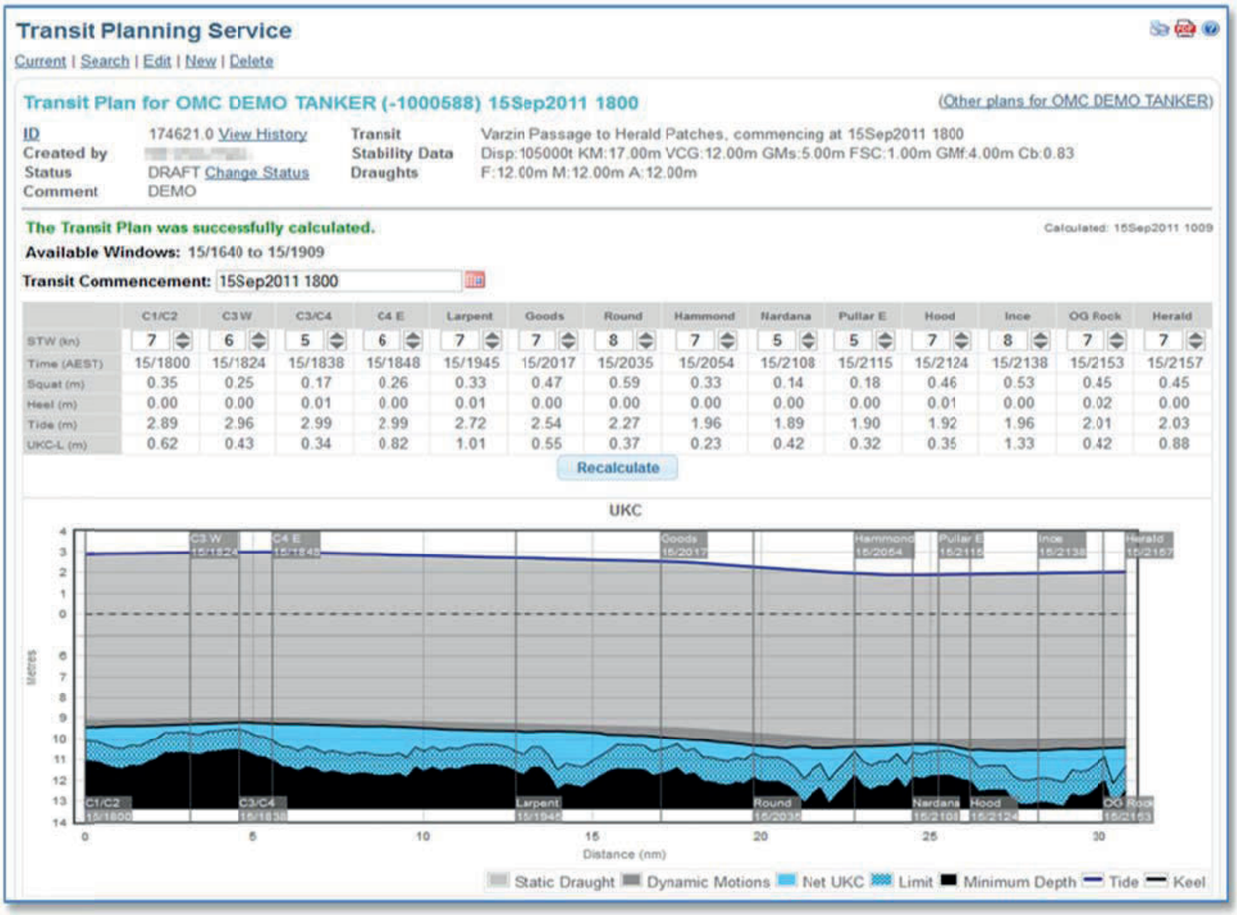

Figure 4 Transit Planning Service - Transit and Speed Assessment

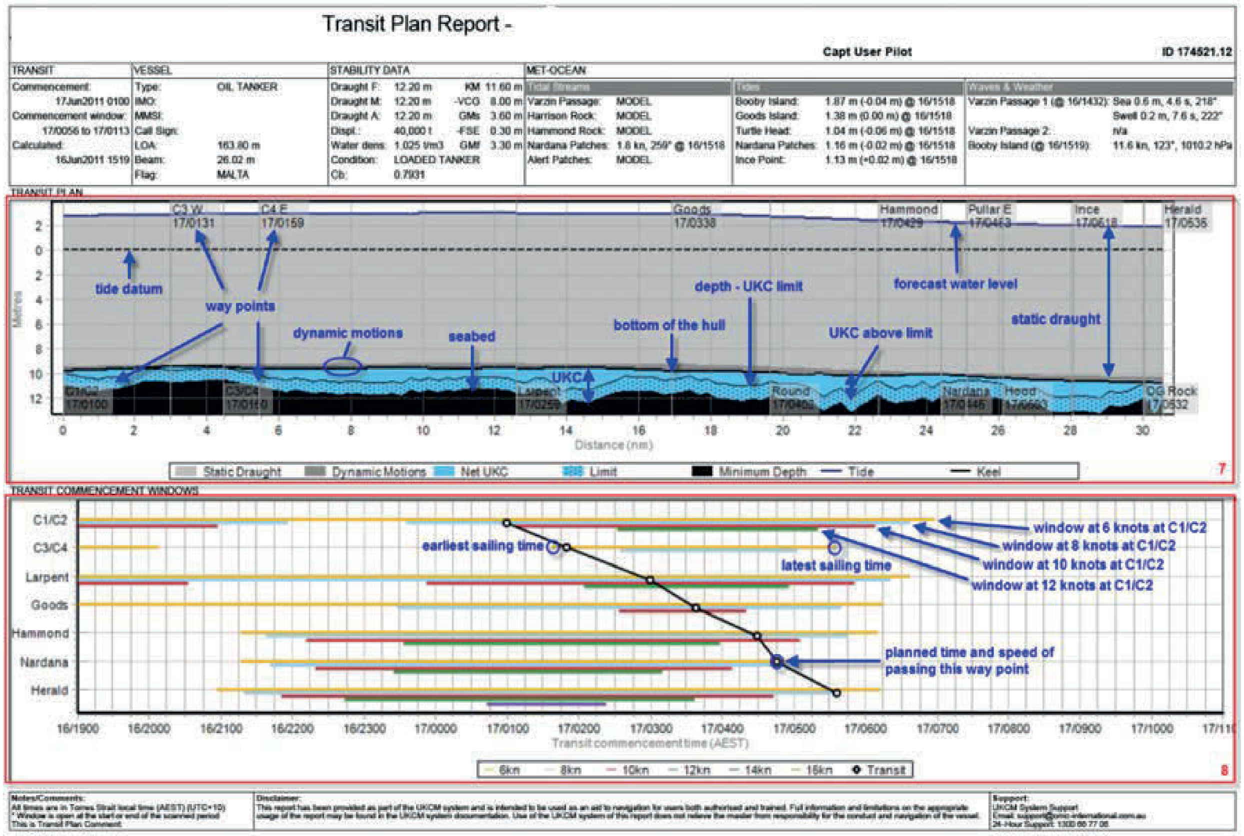

Figure 5 Overview of transit information report

Whilst these functionalities remain at the core of the DUKC system, specific user needs and how they want their results computed and delivered often drive new developments, which have universal application for all waterways. One such development was the delivery of dynamic information to the pilot (and vessel), in a format that is readily understandable, and did not interfere with primary requirement of navigation. Chart overlays were identified as the most appropriate method, which can be readily incorporated into the pilots' portable pilotage unit (PPU). Chart overlays present a simple visual indication on which areas meet UKC limits, and are safe for traversing, and which areas do not meet UKC limits, and should be avoided.

Essential to any implementation of chart overlays is the availability of promulgating the raw sounding data, as previously mentioned. This data is required to be up to date, and in recent years, survey techniques, data processing and computing power have progressed to the point where detailed electronic sounding data can be readily analysed and quickly, provided to users.

Chart Overlays

DUKC® Chart Overlay was specifically designed for pilots and mariners and displays under keel clearance information geospatially through a Marine Information Overlay (MIO) on a compatible Electronic Charting System (ECS) such as one running on a Portable Pilot Unit (PPU) carried on board to monitor the passage in real time. In parallel, the overlays can be displayed on the web within the DUKC portal, allowing a shore station to view the same dynamic overlay that the pilot is viewing.

As every vessel has a unique dynamic UKC plan each overlay is vessel dependant; this is different to a tidal or weather overlay that is generic to all vessels. Thus there may be numerous vessel specific chart-overlays in existence at any one time.

The overlay is based on the latest available high-resolution bathymetry data, prediction of tidal and non-tidal water levels, waves and currents, knowledge of the recorded vessel load state (draft, trim, and stability), the pilot's submitted passage plan (speeds and expected times at waypoints) and predictions of the associated dynamic vessel motions (squat, heel, and wave response). DUKC® overlays are also predictive in nature, therefore tide heights, currents and environmental conditions are being predicted for the actual time of transit (i.e. at a waypoint) which makes DUKC overlays unique when compared to other products.

An example of the chart overlay is displayed in Figure 6. The simple presentation of predicted Go / No Go areas for the time of the vessel arrival in those areas allows the pilot to anticipate required deviations from the transit plan. This anticipation allows time for various options to be considered and enables proactive rather than reactive navigations.

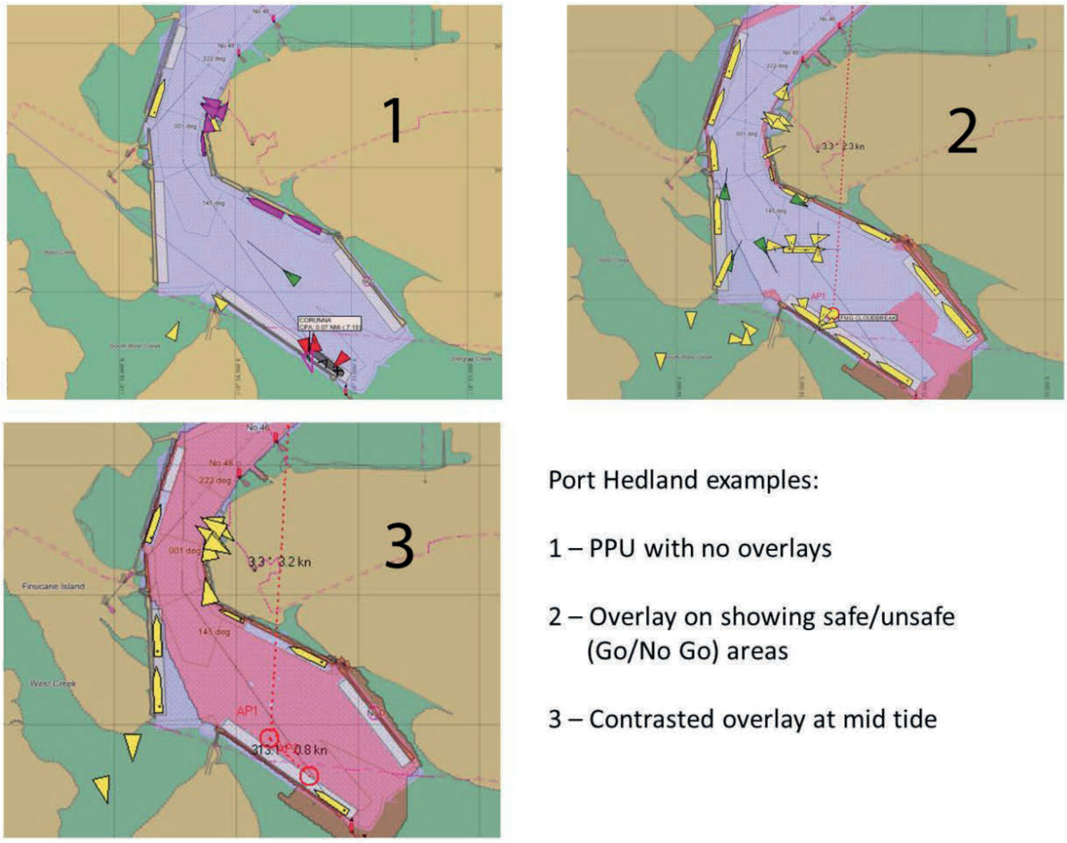

Figure 6 Actual PPU displays with overlays on/off and differing tidal conditions

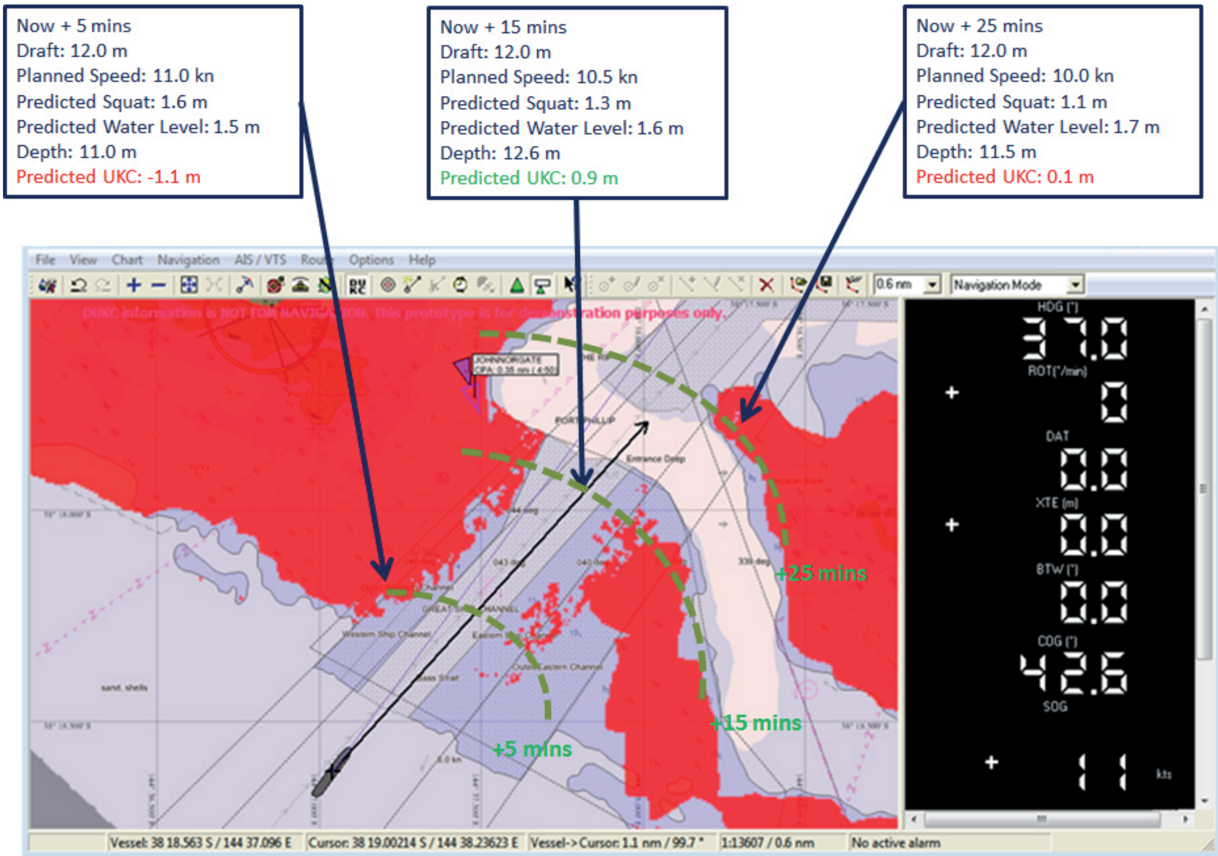

Figure 7 Overlays are predictive as well as dynamic (overlay colour transparency reduced for clarity only)

Key Benefits and Features

Dynamic UKC chart overlays, and the predictive capabilities, have a number of key benefits over existing navigational systems.

- It allows rapid identification of channel (or adjacent) areas that must be avoided and allows identification of potential UKC hazards at the passage planning stage.
- It allows pilots and masters to make informed tactical navigational decisions about the vessels route which can be adjusted to ensure safety of navigation is maintained.
- It offers optional fine-tuning and optimising of passage plans for long or complex passages while underway.
- In emergency conditions it offers informed escape options and lowers the risk of channel blockage. As the same overlay is available to the port user, it allows the Harbour Master (or similar) to assess the situation in parallel. This benefits the pilot/master whose primary priority is to stabilise the situation, whilst contingency plans are assessed.

The key features of the system are:

- Display of safe and unsafe transits (go/no-go areas) at the passage planning stage and whilst underway.
- Updates go/no-go areas automatically based on the latest available met-ocean conditions and actual vessel speed and position (AIS).
- Go/no-go areas are based on dynamic under keel clearance calculations and include the impact of dynamic ship motions on navigational safety.
- Go/no-go areas are computed on-shore by powerful computers and are transmitted to the vessel, allowing relatively lightweight and low spec on-board devices.
- The go/no go areas are predictive, i.e. predicts the conditions ahead of the time of arrival.
- The go/no-go areas can be displayed within compatible ECSs.

Chart Overlay Delivery

The delivery of a chart overlay to a pilot required a number of technologies to be integrated. The concept of overlays is not new, but dynamic and predictive UKC content, delivered in real-time, is a world first and true e-Navigation solution. The first live application is at Port Hedland, Australia, and involved three[14] principal companies, these were:

- OMC International: DUKC® system delivering dynamic chart overlays in real-time.
- QPS BV: Received the chart overlay, interpret the data and deliver to the PPU via their Qastor Connect server.
- Navicom Dynamics: PPU manufacturers running Qastor navigation software which receives the Qastor Connect data and displays on the PPU.

[14] *A fourth company, Telstra, was used for dedicated 3G broadband but newer technologies like marine broadband VDES could be used when available.*

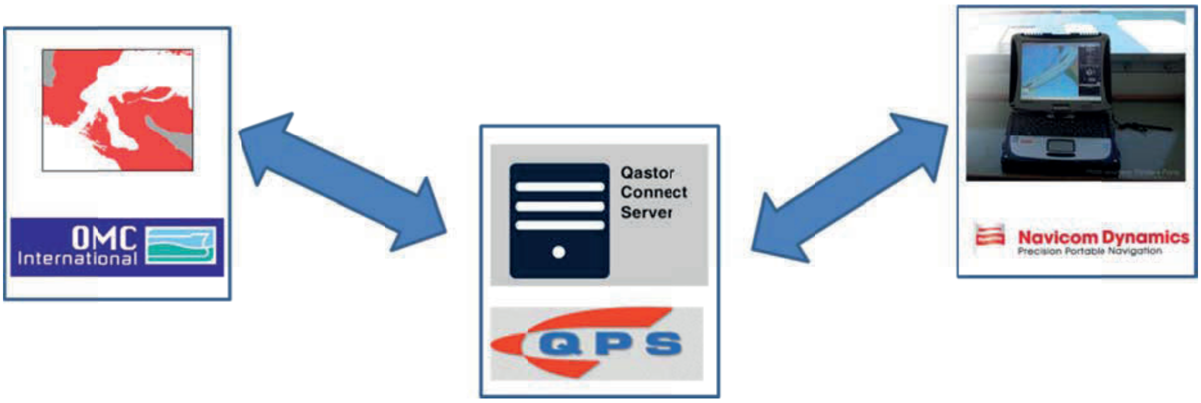

Figure 8 : Overview of the Chart Overlay delivery

The key steps to producing an overlay are:

1. At the planning stage, prior to the transit, the administrator calculates a safe transit window for the vessel and the time of sailing, based on a default speed profile, and promulgates this to the pilot organisation. The pilot can then interact with the system (via the web) and customise the transit. In essence this means the pilot can optimise/adjust the speed profile, to match the vessels manoeuvring characteristics and any changes that negatively impact on the safety are visually[15] apparent to avoid unsafe transits.
2. When a DUKC calculation is performed the results are spatially combined with the high resolution bathy grid (as described earlier) and areas of Go/No Go are determined. This data are stored as a single band geotif, and are vessel and transit specific i.e. customised for each vessel using the system.
3. The computed geotifs are placed on a local file server. The chart overlays are now ready for display. For passage planning where pilot has ready broadband access (before departure on land) overlays can be displayed on map server within DUKC® system.
4. The overlays are continually updated and file sizes are reduced by splitting transit into tiles and only updating the required tiles by overwriting. Once a transit commences historical tiles are not recalculated, thus reducing file sizes further (and this significantly reduces data transfer costs).
   Once transit has commenced the other Chart Overlay partner companies take over.
5. Qastor Connect server regularly pole the OMC file server for new chart overlays. These are pulled down from the local server, interpreted and broadcasted via a dedicated communications channel to a receiver running the Qastor software, normally being the pilot's PPU.
6. The Qastor navigation software has been modified to allow the pilot to load the applicable transit from the server. Once loaded the software continually downloads the revised chart overlays (updated tiles) and these are displayed as a layer on the PPU display by over laying the standard ENCs and other layers used. The chart overlay is on by default but can be turned off if the full chart needs to be viewed.

[15] *At the planning stage, the transit is displayed as a vertical graph of the water column taking into account the dynamic components for the whole transit. See Figure 4.*

Future Developments

Chart overlays will be an important component of any eNavigation system as it will deliver navigational and safety information in formats that will be readily understandable. The type of data that could be communicated is diverse, and it is probable that it will revolutionise today's navigational practices.

Dynamic UKC chart overlays are already well established, and whilst they are presently being delivered by geotifs via 3G, any recognised overlay format and communication channel could be implemented. Implementation of the S100 standard is very likely to benefit the delivery of this information to a ship's ECDIS, or other navigational systems, rather than just the pilot's PPU, and the proposed VHF Data Exchange System (VDES) will also be an important/necessary development as data requirements increase.

Conclusion

The use of static rules at many ports needs serious consideration about whether they are suitable, and if all factors are understood. The paradox of the static rules is that without an incident a port's static rules may appear validated and considered safe. In reality, where underkeel limits are critical and conditions variable, there may be times when the clearance is marginal and the port has experienced an unknown "near miss".

Dynamic underkeel clearance systems ensure safety through accurate planning and continual monitoring of the UKC of large vessels during transit along shallow waterways. These decision support tools, and the integration into navigation systems, such as a pilot's PPU, also allow the effect of alternative speed/sailing options on UKC to be quickly investigated by pilots and masters in situation where the passage does not proceed as planned. The information that is now available from a dynamic system enhances the decision making processes of all users, and complements the master/pilot information exchange, and the availability of results to both vessel and shore, in real time, also enhances contingency planning in the event of an unforeseen incident.

Dynamic underkeel clearance systems have a proven track record and its use will only increase throughout the maritime industry. As the methodology builds on the concept of a minimum clearance limits that must not be breached, dynamic underkeel clearance systems effectively controls the risk of a touch-bottom/grounding incident. This level of risk cannot be achieved with static rules because the clearances vary and are determined by the environment present on the day.

Dynamic UKC chart overlays are an evolutionary step in delivering UKC information to the navigator in a visually understandable format. It is an operational and proven eNavigation solution that can only increase the safety of vessels.

Supporting paper

Resilient PNT for e-Navigation

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The General Lighthouse Authorities,
United Kingdom and Ireland

IALA·2014·AISM
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Resilient PNT for e-Navigation

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BIOGRAPHIES

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ABSTRACT

The IMO has stated that positioning systems for e-Navigation: "should be resilient …. robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems should be considered".

GPS has become the primary source of positioning for mariners; but no Global Navigation Satellite System (GNSS) alone can provide resilient Position, Navigation and Timing (PNT). GNSS, including GPS, GLONASS, Compass-Beidou, QZSS and Galileo, is vulnerable to deliberate, accidental or natural radio interference. Despite these weaknesses, GPS has become a crucial element not only of maritime navigation, but also of critical national infrastructure, often without any backup being provided. A complementary system, compatible with GNSS but independent of it, is essential to achieving the resilient PNT required for e-Navigation; it is also essential for supporting a wide range of national and international critical infrastructure systems.

For many applications, the ideal backup to GNSS is eLoran, a modern low-frequency (100 kHz) radionavigation system that uses high-power, long-range, transmitters to provide accurate positioning for all modes of transport plus precise timing for telecommunications and other systems.

The UK, as one of the initiators of the e-Navigation project, has put forward this position at IMO, supported by evidence from a trial eLoran system. It has taken the lead in raising awareness of the vulnerability of GNSS and the need for a backup. The prototype eLoran service provided by the UK, in cooperation with France and Norway, employs signals broadcast from the UK, France, Norway, Germany and the Faeroe Islands and has been available in the UK for several years. It has played an important role in demonstrating the case for a terrestrial backup in Europe and so contributing to a future European Radio Navigation Plan (ERNP). It is also becoming well-known to the international maritime community through IALA.

The GLA are now implementing maritime eLoran Initial Operational Capability (IOC) on the east coast of the UK, with completion in 2014. This will support demonstrations for mariners and manufacturers provide a development test-bed for the GLA to gain operational experience, and encourage take-up of the service. Adding a simple eLoran unit integrated within a maritime GNSS receiver will mitigate GNSS vulnerabilities at minimal extra cost to the user.

INTRODUCTION

Today, the primary means of Positioning, Navigation and Timing (PNT) employed at sea is GPS, whether stand-alone or augmented. The dependence on, and vulnerabilities of, GPS and its augmentations are well known [1].

This paper will explain the need for resilient PNT as well as discussing the various options available to achieve it. The paper will also introduce trials that have demonstrated the benefit of having resilient PNT information available on a typical vessel.

This work was conducted as part of GLA involvement in the ACCSEAS project [2]. ACCSEAS aims to develop an e-Navigation test bed within the North Sea Region (NSR). It is being undertaken as a collaboration by 11 partners from across the NSR, which includes service providers, industry and academia.

The paper concludes with an update on the GLA eLoran programme.

NEED FOR RESILIENT PNT

The ACCSEAS project is investigating future navigation issues that will affect shipping in the NSR [2]. The project has highlighted the fact that shipping densities are set to increase with more, bigger, vessels leading to reduced manoeuvrability. The navigable area of the North Sea will be reduced in size by the growth in offshore installations such as oil and gas platforms and off-shore renewable energy infrastructure (OREI). As a result, the risk of an incident or accident occurring will increase, particularly at pinch points on the approaches to major ports such as Rotterdam or Dover and on inland waterways like the Kiel Canal in Germany.

In this context, the project recognises that GPS has become the principal source of maritime PNT, primarily because it is freely available and provides excellent performance. As a result, the number of GPS receivers installed on the bridges of vessels is increasing and GPS data is fed to a large number of the bridge systems, including some which mariners may not realise use GPS. These systems include: ECDIS, AIS, GMDSS, satellite communications, depth-sounder and elements of the radar and gyro-compass. Even the ship's clocks may depend on GPS!

GNSS Vulnerabilities

It is well known that GPS, and GNSS in the broader sense, are vulnerable to system failures and to intentional and unintentional interference [3].

An example of natural interference was observed in 2006, when the Earth was exposed to the most intense solar radio burst ever recorded. GPS reception was affected over the entire sunlit side of the Earth: in Figure 1 the green dots indicate receivers that continued to track 4 or more satellites and provide a position fix; the red dots show those that could no longer track sufficient satellites because of solar noise. At some stations GPS was unavailable for some 30 minutes.

The use of GPS signal jammers can produce similar effects, albeit on a more local scale. Jamming does occur and evidence suggests is that it is on the increase. Some interference comes from accidental sources such as the military jamming unit operated inadvertently at San Diego harbour in 2007 or that at Newark Airport, where a prototype landing systems was intermittently jammed over many months by a passing vehicle-borne "personal privacy" device [5].

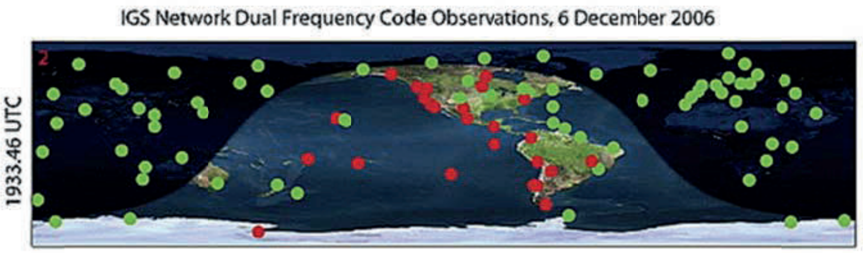

Figure 1: Map of GPS receivers affected by the radio blackout. Green dots are stations that could track 4 or more satellites. Red dots are stations that lost GPS [4].

Even more significant events occurred in 2012 when on more than one occasion North Korea intentionally jammed GPS over large areas of the Republic of Korea, affecting military and civilian users alike. There are reports of large numbers of aircraft, ships and land vehicles losing navigational information and of cell-phone networks losing timing [6].

Such issues affect not only GPS but all Global Navigation Satellite Systems (GNSS). Signals broadcast by GNSS satellites are very low-powered and all GNSS systems share frequency bands, something which aids interoperability. As a result, a single commercial jammer can block all frequency bands of all GNSS systems in an area simultaneously. Jammers designed to do so are readily available and being detected by law enforcement agencies.

E-NAVIGATION

Within the definition of e-Navigation, the IMO has acknowledged the need for resilient PNT and explicitly require it:

> "e-Navigation systems should be resilient …. robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems should be considered" [7].

In order to achieve resilient PNT a second or even a third PNT system may be added to the primary source, GNSS. Any additional system needs to have dissimilar failure modes to GNSS, otherwise it will be affected by the same vulnerabilities. Simply adding more receivers, or using different satellite systems that employ the same band of frequencies, are not solutions.

One of the aims of the ACCSEAS project, therefore, is to consider the question of which system, or systems, can deliver resilient PNT and to demonstrate how they might be used within future e-Navigation services.

RESILIENT PNT OPTIONS

When developing resilient PNT, one must ask: how the candidate systems differ from GNSS; how they can be integrated with GNSS; their expected availability in respect of e-Navigation; and, of course, their cost. The range of options includes complementary inertial devices, alternative radionavigation systems and the possible hardening of GNSS receivers and systems.

Each of these options has been considered by the GLA in a Business Case prepared using rigorous UK Treasury *Green Book* methods. Inertial technology for maritime applications appeared relatively immature and its high costs may be prohibitive. While GNSS hardening options exist, either they are mainly for military use or their development time means that they will not be available for the anticipated introduction of e-Navigation.

The ACCSEAS project is considering a selection of alternative radionavigation systems including:

- R-mode
- Radar absolute positioning
- eLoran

R-Mode

R-Mode, or "Ranging Mode", is effected by adding a navigation ranging signal to the broadcasts from an existing network of marine radiobeacon DGPS stations or AIS base stations.

Radiobeacon DGPS operates in the Medium Frequency band (around 300 kHz), so the signal propagates from the transmitters to the mariners' receivers as a groundwave over the surface of the earth. AIS operates in the VHF band (at approximately 160MHz), and so its signals propagate from transmitters to receivers along line-of-sight paths.

Each ranging signal would require: synchronising to UTC, or another common system time; a suitable signal structure for tracking purposes; and propagation effects to be taken into account. R-mode is being developed as part of the ACCSEAS project.

Radar Absolute Positioning

Radar is normally used for *relative* positioning; it determines the ranges and bearings from a vessel of other ships and structures. Over the last five years the concept of *absolute* positioning using radar has been investigated. Modern radars, with their high stability and resolution, can interrogate active “enhanced” radar aids-to-navigation which transmit their identities and location coordinates as part of their responses. Using this information, the radar computes its own position. In ACCSEAS project trials during 2013, two such radar beacons (or “racons”) were installed at lighthouses on the east coast of England. A vessel carrying a solid-state radar, with an additional absolute positioning processing unit demonstrated positioning accuracies comparable with those of GNSS at ranges up to 10 Nautical Miles from the coast [8]. Although this demonstration showed that absolute radar positioning is technically feasible within such ranges, considerable regulatory and commercial hurdles will have to be overcome before it becomes a practical option.

eLoran

eLoran is a system of low frequency (100kHz) broadcasts from terrestrial stations that provides a PNT service that is independent of, and complementary to, GNSS. eLoran receivers calculate the distances the signals have propagated from the transmitters (Figure 2) to a user’s receiver, travelling as groundwaves over the surface of the earth. This calculation employs an initial assumption that the world is made entirely of sea water. Then, additional propagation delays due to the signal’s travelling more slowly over land are measured and published as a grid covering each service area. These additional delays, called Additional Secondary Factors (ASF), are measured once and for all, published, and stored within the user’s receiver. However, ASFs do change slightly in response to short-term weather, and longer-term seasonal, effects. A Differential-Loran (DLoran) reference station, installed within or close to the service area, measures these small changes in real time. It sends correction data to the eLoran transmitting station for broadcasting to the mariner via a Loran Data Channel on the eLoran signal itself. These corrections are then applied automatically by the receiver, so giving the highest possible accuracy.

Figure 2: European Loran transmitters used by the ACCSEAS North Sea Region test-bed.

PROTOTYPE PNT DATA PROCESSOR

The ACCSEAS project is also developing an integrated PNT module that will combine multiple PNT sources in an effective manner. The functionality will follow the architecture shown in Figure 3.

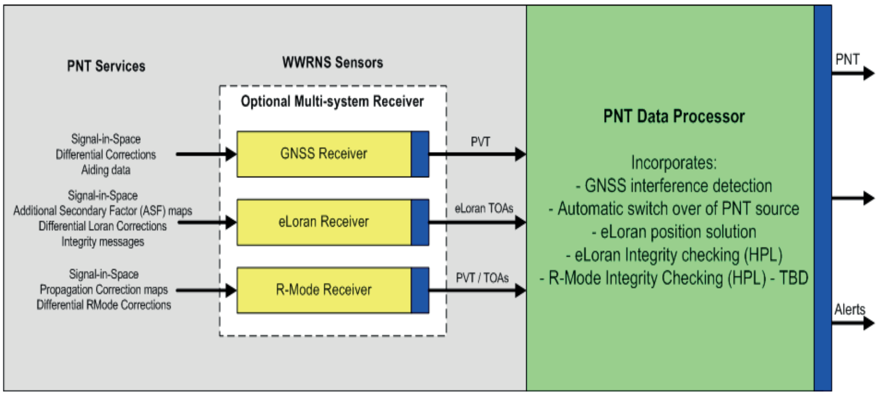

Figure 3: ACCSEAS Resilient PNT architecture.

An early prototype PNT data processor has been produced that uses software written in Matlab™ to process data from two systems: GPS as the primary source, and eLoran as the backup. The processor monitors the performance of these individual sources of PNT separately and independently. When problems are detected with the primary source, it switches seamlessly to the backup. The approach chosen - monitoring and analysing the two systems independently - avoids the requirement for cross-system calibration and cascaded filtering, so 'quarantining' the Integrity Risk [9].

The decision as to whether GPS is being affected by interference is made using information derived from the GPS receiver's NMEA output message. The algorithm uses satellite information data to build a model of the signal performance it expects to see for the satellites in view. Any significant change in the performance of the received satellite signals is then flagged. When the GPS performance falls below a threshold, the PNT data processor substitutes eLoran for GPS as the source of its PNT output. Since no eLoran NMEA sentences have yet been defined, simulated GPS NMEA messages are delivered.

THE BENEFIT OF RESILIENT PNT

As part of the ACCSEAS project, the GLA conducted a series of resilient PNT demonstrations in February 2013, both to test the prototype data processor and to demonstrate the importance of resilient PNT.
The prototype resilient PNT data processor was installed on the bridge of a GLA buoy tender, *THV Galatea*. On *Galatea* data from two GPS receivers is distributed to multiple bridge systems via NMEA data splitters. For these demonstrations the PNT data processor was inserted into the GPS feed that serves the AIS, ECDIS, Gyro-compass and radar displays (Figure 4).

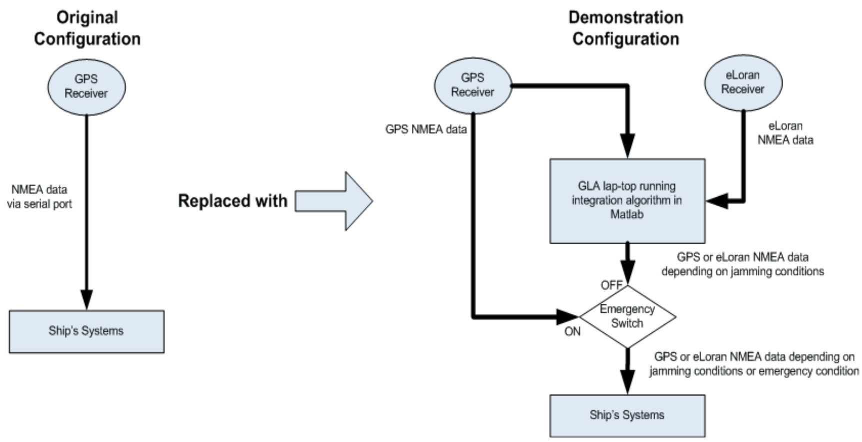

Figure 4 : Schematic of the prototype data processor integration with the bridge systems.

The UK Ministry of Defence was contracted to operate an L1-frequency GPS jammer aboard the *THV Galatea* at a power level low enough to affect the *Galatea* only. The vessel was constrained to operate in a GLA experimental area called the *Cork Hole,* just off Harwich on the east coast of England (Figure 5).

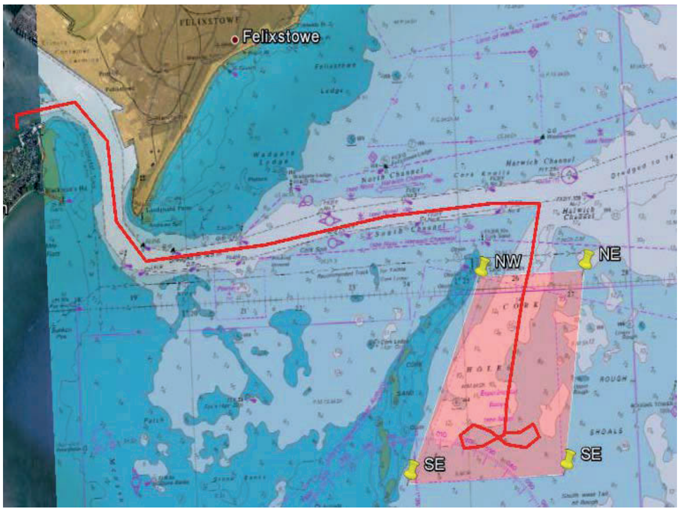

Figure 5: The Resilient PNT demonstration took place in the area shaded red.

The demonstration followed the scenario of a vessel unwittingly steaming towards a source of GPS interference, perhaps radiating from another vessel or from a GPS jamming device on land. To simulate this, the power of the jammer on the bridge of *Galatea* was slowly increased until the on-board GPS receivers failed. During a first run with the data processor disabled, multiple bridge systems started to indicate alarms, reporting the loss of either position or timing information. This repeated the experience of previous GLA jamming trials [10]. Had the crew not been briefed on the experiment, the number of separate alarms would have caused considerable confusion as they sought to understand their causes.

For the second run, the prototype PNT data processor unit was enabled and the scenario repeated. Now the data processor monitored the performance of GPS and first detected the jamming at a level below that which would cause the ship's bridge systems to alarm. The data processor then switched the source of the PNT data it output to eLoran and indicated to the crew that it had done so. The transfer was quiet, seamless and automatic. This time, no alarms were raised; the many bridge systems that used this source of data continued to operate using eLoran PNT data in place of GPS.

Of course, those bridge systems fed from the other GPS receiver all failed and gave alarm signals. In a full implementation of a resilient PNT system of this kind all GPS data feeds would be made resilient in this way.

POST-MISSION ANALYSIS

Figure 6 shows the GPS track of the first run. The ship entered the jamming zone from the north-west. The gaps in the track correspond to periods when GPS was lost. Less obvious, but a greater hazard, are sections of the track recorded when the jamming signal was too weak to cause loss of lock, but strong enough to cause errors in the measured positions. Under those conditions the GPS simply wanders off! These periods are visible at the beginnings and end of the various gaps; they are clear examples of Hazardously Misleading Information (HMI).

Figure 6: The reported track of the vessel as provided by the GPS receiver during the first run of the demonstrations.

Figure 7 shows the second run. The output of the data processor output in purple is overlaid on the GPS receiver output in green, to show this HMI. Where GPS was available, the two traces overlap exactly. The red ovals in the figure identify the sections of the track where the data processor substituted eLoran data for GPS.

Figure 7: The Resilient PNT output is overlaid with the GPS position alone.

GLA ELORAN PROGRAMME

The GLA's eLoran strategy is: to extend their current trials; to continue building a European consensus in favour of eLoran; and to move towards an eLoran Initial Operational Capability (IOC) in certain areas of UK waters by mid-2014. Given a combination of ASF mapping and differential operation, eLoran can deliver the full IMO *Port Approach* standard of performance. The accuracy then is 10m (95%). This level of performance will be provided at the major ports on the east coast of the United Kingdom shown in Figure 8.

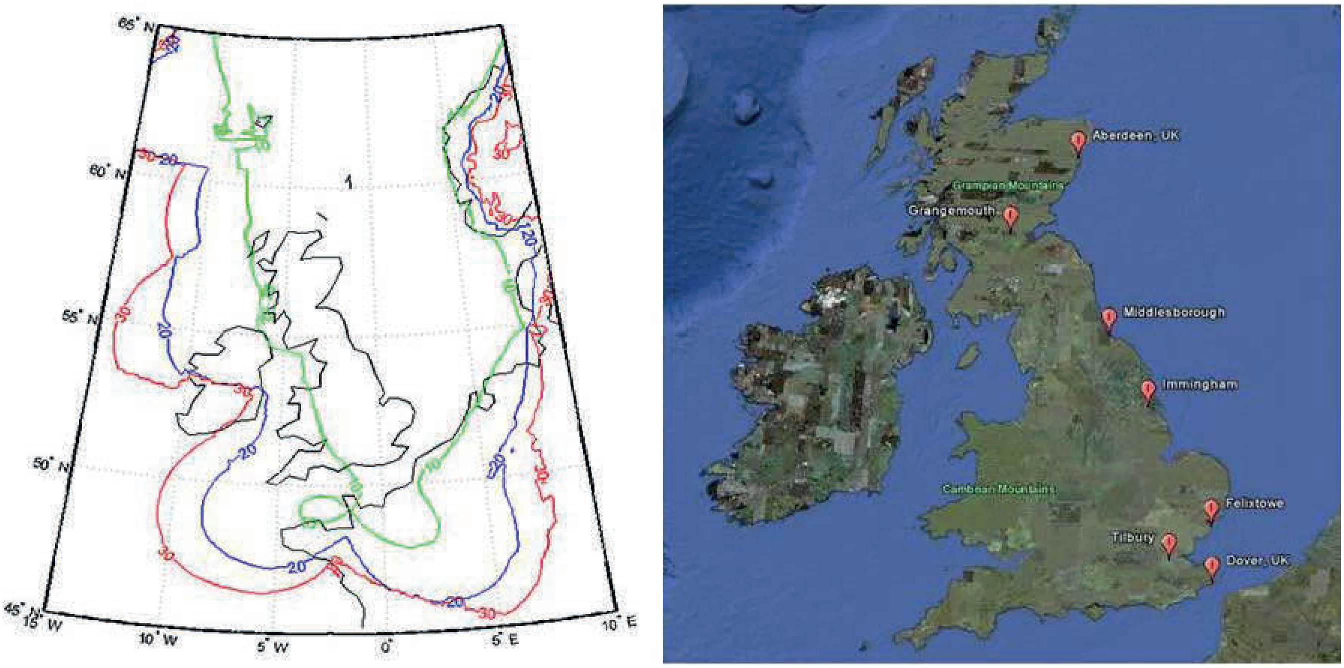

Figure 8: Potential coverage of GLA IOC level eLoran. Better than 10m(95%) accuracy is expected within the green contour, given ASF mapping and differential eLoran. The major ports which will be covered by eLoran from IOC are shown in the right-hand figure.

Within the IOC programme, an existing prototype differential eLoran service that has been operating at the ports of Harwich and Felixstowe for more than 2 years will be upgraded. In addition, new installations are being provided to cover: the port of Dover and the northern part of the English Channel; the Thames Estuary up to Tilbury; the Humber Estuary, including the ports of Immingham, Grimsby and Hull; Middlesbrough; the Firth of Forth up to Grangemouth; and the port of Aberdeen. In each of these areas, ASFs are being mapped throughout the proposed coverage and a Differential-Loran Reference Station is being installed [11]. Correction data from these reference stations will be sent across a Virtual Private Network (VPN) to the eLoran transmitter at Anthorn in north-west England and potentially to the Sylt station in Germany. These stations will broadcast the corrections, together with additional data, using Eurofix modulation on the Loran Data Channel (LDC).

Figure 9 illustrates the structure of the GLA's IOC DLoran system. It includes Reference Station Monitoring and Control Centres in Harwich and Edinburgh. The data backbone of the service is a Virtual Private Network running over the Internet. Differential correction data is sent via the VPN to the eLoran transmitters. The data they broadcast is then received, decoded and applied by mariners' eLoran receivers.

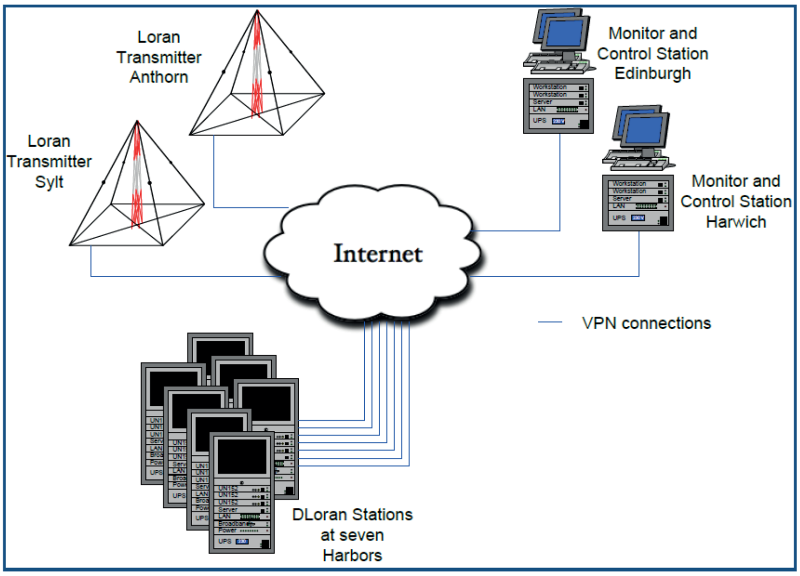

Figure 9: GLA IOC level differential-Loran system.

At the time of writing the DLoran Reference Station hardware and the Monitor/Control Stations are being developed and constructed. Initial hardware, comprising rack cabinets, has been delivered. Factory Acceptance Testing will take place in March 2014, with final delivery of all equipment by April 2014, ready for installation at the sites during May 2014.

This UK IOC eLoran will provide areas for demonstrations and trials so mariners can gain experience in using the service, allowing them to see for themselves the benefits that eLoran brings to the resilience and integrity of their operations, particularly in the context of e-Navigation. It is the aim of the GLA to declare IOC before the end of 2014, following validation testing.

The GLA also aim to declare Full Operational Capability (FOC), with DLoran reference stations installed at up to 40 sites around the UK coast, by 2019 in time for e-Navigation services to start coming into operation.

CONCLUSIONS

The ACCSEAS project has not only developed a prototype resilient PNT solution, but this has been successfully tested and demonstrated under live conditions on a ship's bridge. The benefits of such a system were clearly shown; when GPS was lost to jamming with the PNT data processor unit enabled, the ship's crew were informed but then were able to continue to navigate seamlessly, safely and efficiently and were not distracted by the many alarms that would otherwise have sounded.

ACCSEAS will consider several alternative means of obtaining PNT information. For the demonstrations described here, eLoran was used to provide this vital data - demonstrating that it is available for use today.

The GLA and the ACCSEAS project continue to support the use of multiple PNT sources to keep the mariner safe and avoid the use of HMI.

The GLA continue to progress their implementation of eLoran. IOC will be declared before the end of 2014, with FOC in place by 2019 in time for e-Navigation services to become operational.

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