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AIDS TO NAVIGATION KNOWLEDGE AND INNOVATION

From the Torre de Hercules to e-Navigation and beyond

PROCEEDINGS

e-Navigation & beyond

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E-NAVIGATION & BEYOND

e-Navigation & beyond

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SUMMARIES AND PROCEEDINGS

8798 E-NAVIGATION AND THE ACCSEAS PROJECT

Alwyn I. Williams. General Lighthouse Authorities, United Kingdom and Ireland

The International Maritime Organisation's concept of e-Navigation is defined as "the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment". The aims of e-Navigation are numerous, but are based around improving maritime safety and efficiency.

The North Sea Region of Europe is a crossroads of regional and global shipping and is well positioned to benefit from e-Navigation, to provide safe and efficient access to the region's busy ports. The North Sea Region presents major challenges to future maritime safety and the efficient movement of goods and people, because of the growth of shipping, both in terms of vessel numbers and size, and the increase in off-shore structures, whether platforms or wind farms. The ACCSEAS project uses the North Sea Region as a prime example for demonstrating the potential benefits of innovative solutions based on e-Navigation.

La Organización Marítima Internacional define el concepto de e-Navegación como «la recopilación, integración, intercambio, presentación y análisis armonizados de información marítima a bordo y en tierra a través de medios electrónicos para mejorar la navegación de amarradero a amarradero y los servicios relacionados, para la seguridad en el mar y la protección del medio ambiente marino». Los objetivos de la e-Navegación son numerosos, pero todos tienen por objeto mejorar la seguridad y eficiencia marítima.

La Región del Mar del Norte de Europa es un cruce de caminos del tráfico marítimo regional y global y está muy bien posicionada para beneficiarse de la e-Navegación y así proporcionar acceso eficiente y seguro a los concurridos puertos de la Región. La Región del Mar del Norte presenta importantes desafíos para la futura seguridad marítima y el eficiente movimiento de bienes y personas, dado el crecimiento del tráfico marítimo, tanto en número de buques como en tamaño, y el incremento de estructuras mar adentro, ya sean plataformas o parques eólicos. El proyecto ACCSEAS utiliza la Región del Mar del Norte como un excelente ejemplo para demostrar los beneficios potenciales de innovadoras soluciones basadas en e-Navegación.

Le concept e-Navigation de l'Organisation Maritime Internationale se définit comme « l'harmonisation par des moyens électroniques, de la collecte, l'intégration, l'échange, la présentation et l'analyse des informations maritimes à bord et à terre, pour améliorer la navigation de quai à quai et les services associés, pour la sécurité et la sûreté en mer et la protection de l'environnement. » Les buts de l'e-Navigation sont nombreux mais tournent tous autour de la sécurité et l'efficacité maritime.

En Europe, la Mer du Nord est une zone de croisements de navigation régionale et mondiale, une bonne situation pour profiter de l'e-Navigation et offrir un accès sûr et efficace à cette zone de grands ports. La Mer du Nord pose d'importants défis à la sécurité maritime du futur et au transport efficace de fret et de passagers, en raison de l'accroissement de la navigation, en termes de nombre et de dimensions des navires et d'augmentation des structures off-shore, plates-formes ou champs d'éoliennes. Le projet ACCSEAS utilise la Mer du Nord comme premier exemple démontrant les profits potentiels de solutions innovantes basées sur l'e-Navigation.

e–Navigation and the ACCSEAS project

Alwyn I Williams

General Lighthouse Authorities for UK and Ireland

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1. INTRODUCTION

The ACCessibility for Shipping, Efficiency Advantages and Sustainability (ACCSEAS) project aims to identify issues which obstruct maritime access to the North Sea Region (NSR), identify potential solutions, prototype and demonstrate these successful solutions using the International Maritime Organisation's (IMO) e-Navigation concept in a test-bed in the NSR. The project will develop 'proof-of-concept' tests which will eventually lead to a proposed sustainability plan for future e-Navigation provision in the NSR and will look to inform the e-Navigation initiative globally. The entire process of the implementation of prototype solutions in the e-Navigation test-bed will be supported by training and simulation, so that the test-bed will have aspects of both real-world and simulated implementation. The project is part funded by the European Regional Development Fund through the INTERREG IVB programme.

The ACCSEAS Project runs from April 2012 to February 2015, with budget over €5M its partners are: General Lighthouse Authorities, United Kingdom; Chalmers University of Technology, Sweden; Danish Maritime Authority, Denmark; Federal Waterways & Shipping Administration, Germany; Rijkwaterstaat, Ministery for Infrastructuur and the Environment, Netherlands; Swedish Maritime Administration, Sweden; Norwegian Coastal Administration, Norway; SSPA Sweden AB, Sweden; Flensburg University of Applied Science, Germany; Maritiem Instituut Willem Barentsz, Netherlands; World Maritime University, Sweden.

This paper will provide an overview of the project's progress so far, starting with the detail of the requirements gathered, through the logic used to identify potential e-Navigation services that can be considered for demonstration, to the implementation of the services. It is intended to cooperate with and build on the achievements of the 'EfficienSea' and 'Monalisa' projects to develop an innovative test-bed of e-Navigation solutions, including resilient positioning, navigation and timing, robust e-Navigation services, safe and efficient berth-to-berth operations, dynamic route planning, information exchange, display and decision aids.

The criteria for these decisions are based on the difficulties experienced by today's vessels navigating through the many different challenges within the NSR; but also considers those difficulties expected in the future, given the expected restriction of the seaways. The potential solutions will consider the many different services that can be provided by the many different providers as part of their e-Navigation maritime service portfolio's (MSP), which will include a review of services offered today as well as potential services that can be introduced. These new services include the potential for route guidance information, improved information exchange as well as enhanced position, navigation and timing information from multiple sources.

The implications of the proposed new services will be explained in terms of how they will benefit the mariner through the improvement in safety and efficiency. This paper will also consider Resilient PNT, and focuses on one trial carried out in ACCSEAS on Absolute Radar Positioning.

2. ANALYSIS OF THE NORTH SEA REGION

The NSR faces a number of problems in the near future, with increased density of shipping, reduced space and manoeuvrability as a result of the growth in offshore installations. This could lead to traffic pinch-points at approaches to ports and potentially increased risks of collision and grounding.

There are many sources of data that provide a picture of competing demands on sea space in the region in the 2020+ timeframe. A view such as the planned wind farms of the UK, Denmark and Germany shown in ***Figure 1*** provides a simple introduction to the nature of growth in offshore renewable energy installations. It is immediately apparent that large areas of the North Sea could be dedicated to the use of renewable energy, thereby reducing the sea space for ships to navigate and manoeuvre. When taken together with the trend in the growth in shipping – both in numbers and size of vessels – it is clear that higher density of ships may be forced to navigate in more restricted sea areas. A typical container ship size enables it to transport around 4,000 to 10.000 TEU (Twenty Foot Equivalent unit based on a single 20ft container). The Marco Polo vessel started operation in November 2012 with a capacity of 16,020 TEU; it is 396 m long, 54 m wide, with a draft of 16 m. Even larger vessels up to 18,000 TEU or more are currently being built [1]. Higher density of shipping and larger vessels in the increasingly confined sea space of the North Sea could correlate with greater risk of grounding and collision, hence impacting the safety and efficiency of access to the region's ports.

The e-Navigation services being prototyped in ACCSEAS are, among other instruments, intended to mitigate this increase in risk.

Based on expectations about the impact of areas of open sea being allocated for energy extraction (such as wind farms), ACCSEAS' research suggests that the North Sea Region's navigable space will be reduced [2]. The research indicates that navigable space allocated to wind farms could increase by up to 5240% within just a few years, from the current c.440km² up to c.23,500km². This would constitute c.5.5% of all navigable space in the region, with a further 860km² taken up by exclusion zones around oil and gas platforms. Crucially, the precise location of many planned and proposed wind farm sites means that they could have a significant impact on manoeuvrability within key shipping lanes in the North Sea Region. The size and location of such sites, coupled with projected increases in shipping traffic and vessel size, may pose serious safety and efficiency concerns.

The project's Geographic Information System (GIS) enables officially recognised transnational data to be collected to determine a picture of the region as it may appear in the timescales of 2020+. Based on this data, the project can assess maritime traffic trends and the issues that obstruct available safe access. It is important that the picture of the 'North Sea Region tomorrow' generated by ACCSEAS is based on officially recognised sources of data. So great care has been taken to seek out these sources and maintain their traceability within the ACCSEAS GIS to the original data. The combination of these data sources overlaid on each other produces the very complicated picture of the North Sea Region in 2020+ that is shown in ***Figure 2***.

Using the latest AIS data, ACCSEAS has been able to apply the IALA Waterways Risk Assessment Program (IWRAP) to the identified routes to determine the risk of collision and grounding in the

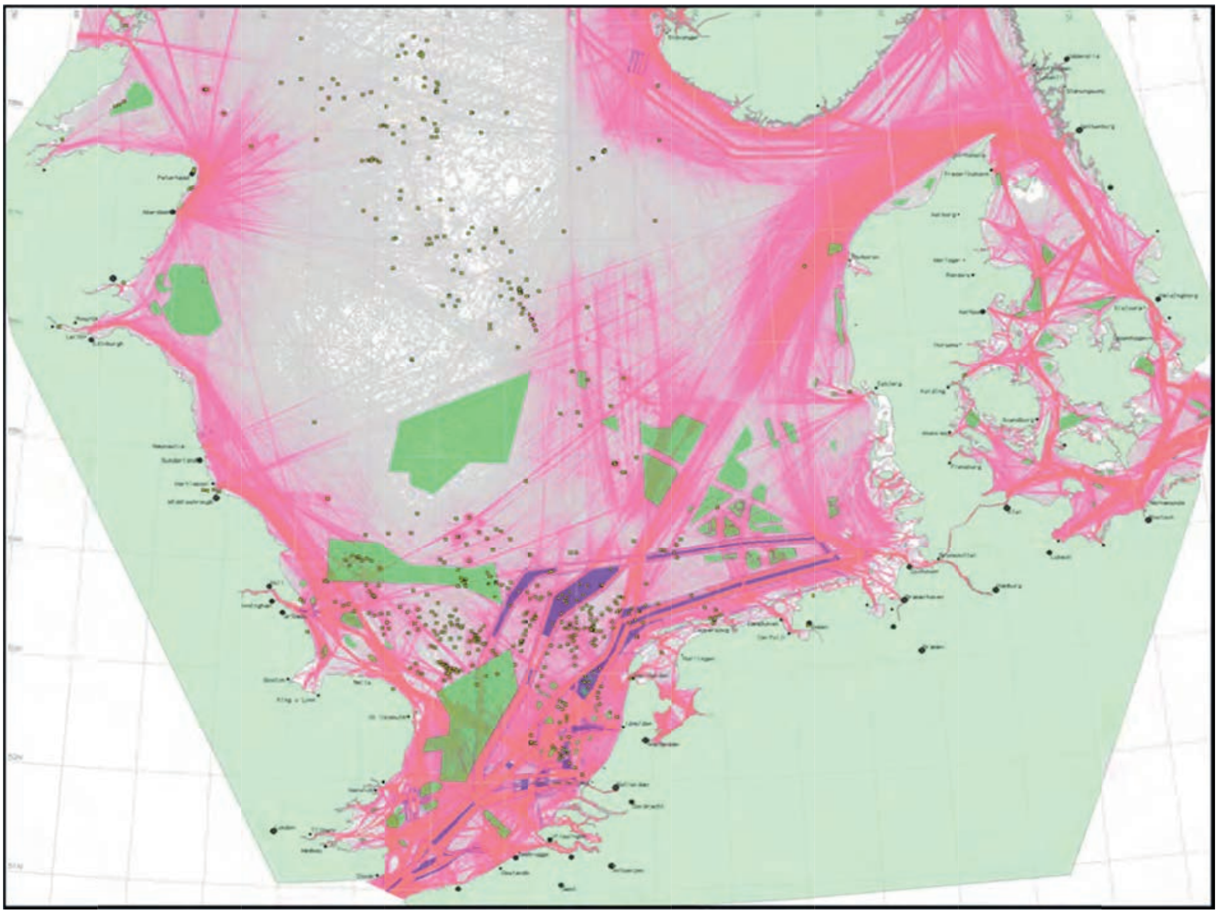


Figure 1: Traffic density of traffic during 2012. Green areas shows proposed windfarm areas; purple highlights the traffic separation schemes; yellow dots represent oil/gas platforms. Note that the grey area in the northern North Sea represents limited traffic data, and does not necessarily represent a lower density of traffic in that area

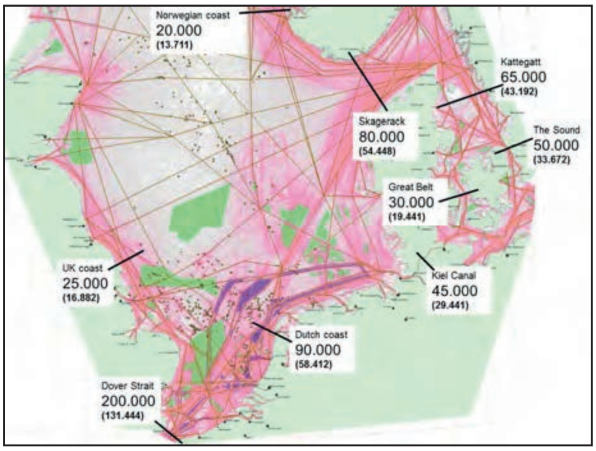


Figure 2: 2012 (in parenthesis) and 2020+ forecasted traffic levels in the North Sea Region. Lines in brown show identified routes

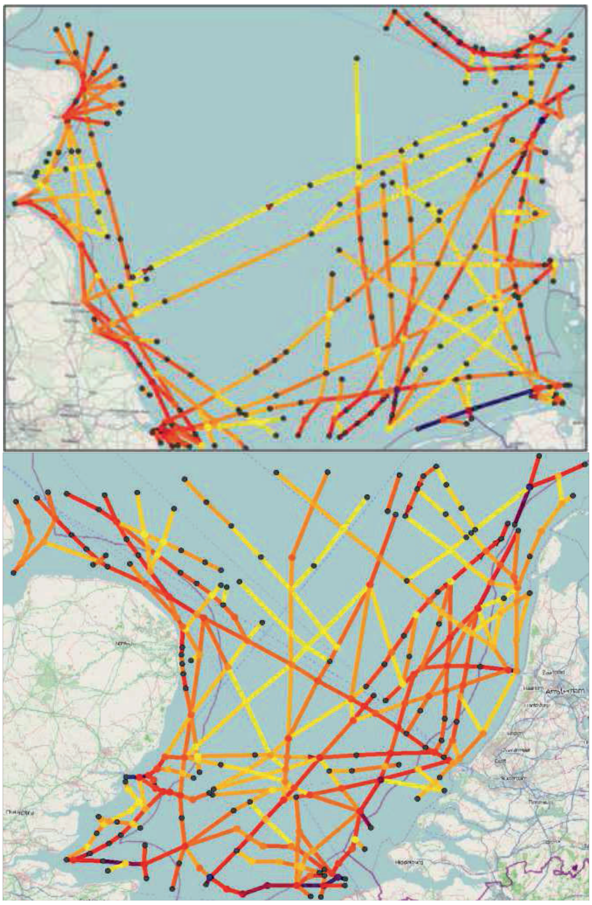


Figure 3: Risk analysis results of the routes identified in the (a) northern North Sea and (b) the southern North Sea. Darker the colour, the higher the risk of collision and/or grounding

region. The results, in ***Figure 3*** show that there are certain areas that are of higher risk than others, in particular in the southern North Sea where it is predicted that there will be 4.2 accidents per year in the region shown, 25% of which are in the darker area at the southern-most point of the figure.

Such multi-use developments are already having an effect on shipping. An example is illustrated in ***Figure 4Figure*** in which the Zeebrugge ferries from Belgium to Hull in the UK are forced to deviate from their natural course to avoid the Thornton Park wind farm. This creates manoeuvres that may not be expected by vessels steaming north in the Traffic Separation Scheme. In the 2020+ time frame, the ferries' route may be further displaced avoiding areas such as the East Anglia ONE wind farm of 300 turbines, a part of the East Angle Zone, on which construction is planned to start in 2016. Further to the west, the ferries may need to change course again to avoid areas such as the Sheringham Shoal wind farm which has just become operational off the Norfolk coast.

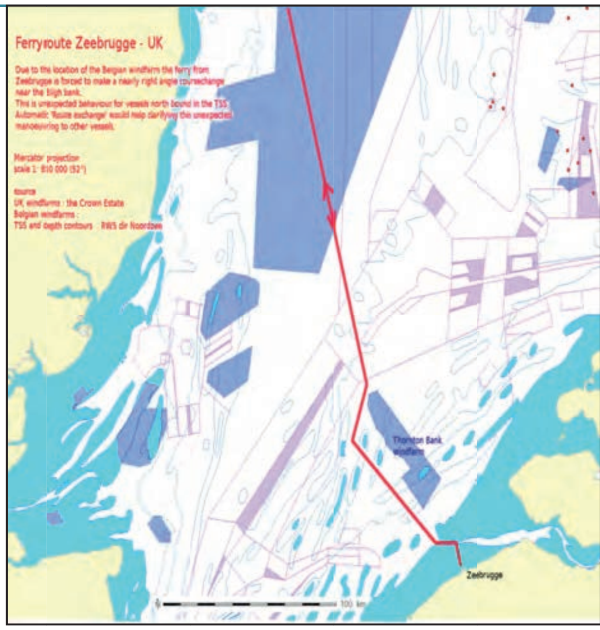
Not all the designated areas under consideration for offshore renewable energy installations will necessarily be developed in the 2020+ timescale. It is also unlikely that in practice wind turbines will be built within Traffic Separation Schemes, but the picture demonstrates the need for the NSR maritime community to be adequately represented in future transnational marine spatial planning.

It is clear that the 2020+ picture is particularly congested with conflicting and competing uses for sea space, especially in the southern part of the North Sea. The need for transnational coordination of sea space management and marine spatial planning is evident. It is reassuring to know that the European Union has recognised the importance of this, and that one of the North Sea Commission's objectives is maritime spatial planning [3].

3. MARITIME SERVICES PORTFOLIO AND ROUTE TOPOLOGY MODEL

The analysis of the NSR showed that there is scope for using technology to assist maritime navigation so that the risk of collision and grounding are minimised. The IMO have recognised that there is scope to improve navigation through the harmonisation and standardisation of navigation-, communication equipment and services. The ACCSEAS project, following on from the analysis, sets out to demonstrate how the e-Navigation

Figure 4: Potential impact of new North Sea Region developments on the Zeebrugge - Hull route →



The project will propose the Maritime Service Portfolio (MSP) for the region, which describes the range of operational and technical services that are available to the mariner (or shore-based operators) to enhance maritime navigation. These services would be made available to the mariner through harmonised data structures in the form of the International Hydrographic Office (IHO) S-100 data specification. Using standardised data structures will allow similar services to use standard portrayal methods and standard communications means to provide the services to the mariners, regardless of the location of the service. A number of services have been proposed that may assist the mariner in the NSR, and some of these are described in more detail below.

The project is also aiming to assemble the Route Topology Model (RTM) for the NSR. The RTM is a methodology to visualise the routes that vessels take in a given area. It is *not* intended to restrict vessel movement, but simply to allow mariners/shore-based operators/planners to see how vessels move.

Developing the RTM is a two-stage process. As the RTM is innovative, a generic description is required that defines the elements that make up an RTM. For example, a "leg" is defined as a path that vessels take in a given area. Using these common elements and definitions, an instance of an RTM can be defined for a specific area and for a specific reasons based on a defined methodology. An example of this would be to define a leg as a continuous stretch of traffic with a traffic density of greater than 400 vessels per unit area per year. Referring back to ***Figure 2***, the brown lines could be construed to be a rudimentary RTM based on AIS data, for example.

Once an instance of the RTM has been developed, this would allow the tool to be used by a diverse range of users to enable the vessel movements to be visualised in a clear way. It could also be used by the mariner to plan routes through the region and maximise efficiency and accessibility to the region's ports. The ACCSEAS project will develop example instances of the RTM for the region to show the benefits of the tool for the users of the NSR, particularly when combined with the MSP to allow the mariner to determine the services along the route chosen for their vessel.

4. E-NAVIGATION SERVICES AND RESILIENT PNT

The services that could be included in the MSP are a major outcome of the ACCSEAS project. In this paper, we shall focus on a selection of those services, and how they could improve the efficiency and accessibility of shipping in spite of the challenges raised above.

No-go Area

The "No-go" area service is a means for the mariner to determine, in a simplified way, the areas that they should avoid due to insufficient clearance under the keel of their vessel. The service takes into account detailed bathymetry data, and using the current tidal conditions together with the vessel's dynamics, it is able to determine, on the fly, the location the vessel should avoid. At the time of writing, the service is in the early stages of development, but the project aims to demonstrate the service in the Humber Estuary where shifting sands pose a constant grounding risk to vessels approaching the ports along the estuary. Whilst there are technological challenges to overcome, a key element to the success of the service will be the portrayal of the information. ***Figure 5*** shows an example of how the service may show the "no-go" area. The purple area tells the mariner that this is an area that has a high grounding risk if the vessel was to enter that area. With this information, the spatial awareness of the mariner is increased considerably, particularly in tighter channels.

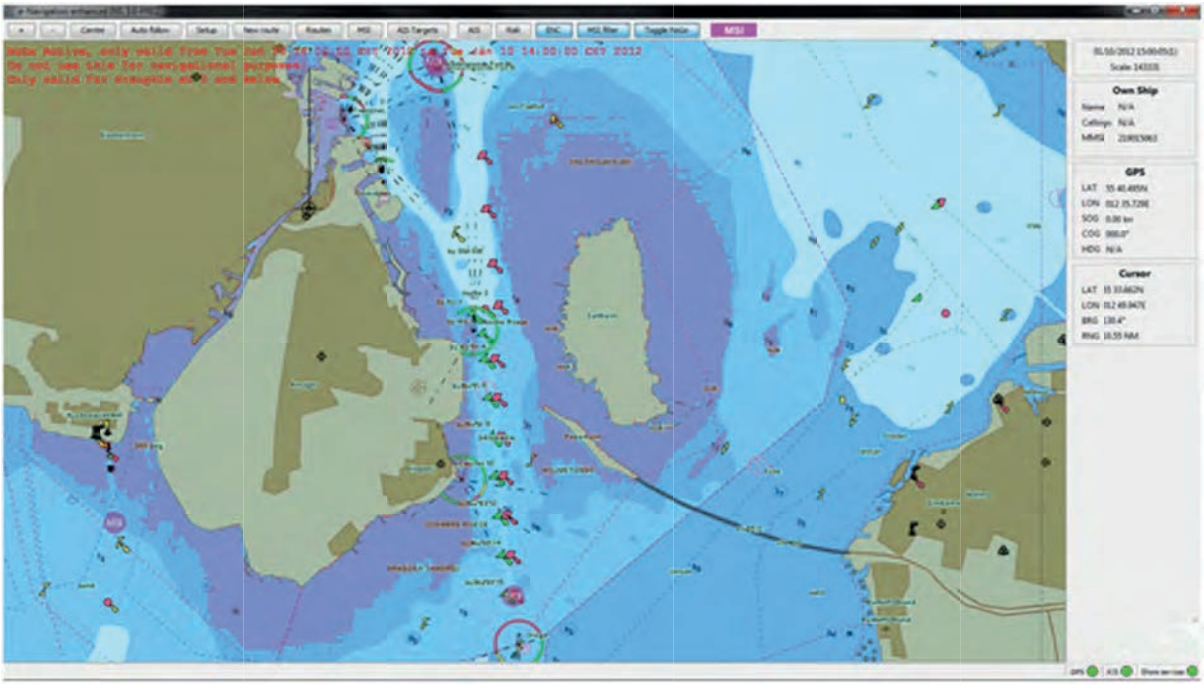


Figure 5: Example of the no-go area e-Navigation service. The purple shading shows the area that the vessel should not enter due to insufficient under-keel clearance

Maritime Safety Information/Notices to Mariners (Temporary and Permanent) Service

The most important information to vessels is that related to safety, including Maritime Safety Information (MSI), Notices to Mariners (NM) and chart corrections. These three information types, together with nautical charts and position updates form the basis for safe navigation of ships.

Chart corrections, and the way they are promulgated, have evolved tremendously over the past 10 years and are in many ways very different from MSI and NM today. Chart corrections are geo-referenced and displayable by nature. MSI and NM are often geo-referenced but not necessarily displayable with internationally standardised text and symbols.

The main differences between MSI and NM today are the method of promulgation and the speed of handling and thereby quality assurance. The contents of the two message types are on the other hand more or less the same. MSI is today promulgated in text or voice via SafetyNET, NAVTEX, coast radio stations and is in some countries accessible on the Internet. NM's are promulgated on paper weekly, fortnightly or monthly and are often accessible on the internet in PDF format. The handling of data and information provided through the above methods are time consuming for the Mariner, increases their workload, and there is a risk of human error causing important information to be lost or misinterpreted.

Maritime Information messages, MSI and NM, may in the future be broadcast or transmitted via any available communication method, e.g. satellite, GSM (mobile), VHF-data, AIS, etc. in addition to traditional systems such as NAVTEX and radio broadcasts. Maritime Information Messages should be received and displayed on navigation displays automatically for correct and immediate assessment by the navigator.

It is important that ALL vessels still receive ALL Maritime Information messages. To avoid the often discussed overload of information, it should be possible for the Mariner to filter the Maritime Information messages so only messages relevant to the specific vessel's navigation is displayed, e.g. by distance from own vessel and route. Important information should be shown on a navigation display without further action by the navigator (***Figure 6***) – additional information should be accessible in textboxes or in separate menus if needed or wanted.

Vessel Operations Co–ordination Tool

The Vessel Operations Co-ordination Tool (VOCT) builds on promising results from tests conducted during a previous EU project, EfficienSea. It was recognised that communication, timely and correct, between parties during a Search and Rescue (SAR) operation is of utmost importance. Today information is primarily exchanged via different ways of voice communication which is both time consuming and contains a risk of misunderstandings. The VOCT is a service to optimise communication and improve situation awareness during SAR, counter pollution and similar operations. Search areas, search patterns, datum, drift calculations, areas searched and other important information is exchanged electronically between parties and is presented graphically on vessels' and coordinators' displays. Inclusion of a calculation module for search areas and patterns into the Ship e-Navigation Prototype Display (EPD) and Shore-EPD was investigated, and good response has been received by users in trials carried out in ACCSEAS.

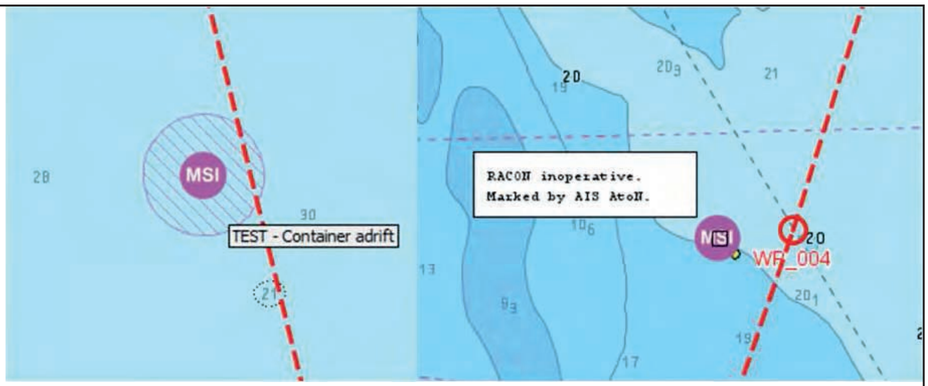


Figure 6: Example of the MSI/NM service on the electronic chart system

Resilient PNT

Underpinning all the e-Navigation services and the e-Navigation concept in general, is Resilient Position, Navigation and Timing (PNT). Although Global Navigation Satellite Systems (GNSS) will be the primary method, all GNSS are vulnerable to interference, deliberate and accidental, because of their extremely low signal strengths. Reliance on a single electronic position source, with known vulnerability, is not an acceptable risk, particularly when almost all e-Navigation services require a position input to work. Therefore the provision of Resilient PNT is an essential prerequisite for e-Navigation to succeed.

In ACCSEAS, a GNSS jamming trial was carried out off the East Coast of the UK, and the resulting video demonstrated that it is possible for GNSS to be successfully substituted by an alternative PNT source using an integrated navigation system [4]. Using such a system, and displaying the current status of the electronic positioning systems, will give the Mariner a clear understanding of where they are, and how much confidence can be afforded to that information. Given that a number of bridge systems rely on PNT, it is necessary to ensure that the PNT system is resilient and not reliant on a single source.

5. ABSOLUTE RADAR POSITIONING TRIAL

ACCSEAS also investigated the use of absolute Radar positioning using modified radar and Racon equipment. A trial carried out off the East Coast of the UK demonstrated the feasibility of such a system as an alternative non-GNSS means for determining the ship's position

The trials took place over four days, which were used for 'static' and 'dynamic' tests. In the static tests, the vessel held station at a number of points, at different distances from the Racon locations, and the dynamic tests involved sailing parallel with the coast through the trials area. In addition several tests were carried out with the vessel rotating through 360° at a fixed location. The data processing associated with the radar used both range and bearing from the racons, to calculate position, combined with the latitude and longitude encoded using FSK modulation on the dash of the Morse character of the Racons. The summary of results given here is derived from observations on board the vessel and from post-trial analysis.

The calm conditions resulted in distinct nulls in the responses due to cancellation between the direct and reflected signals. This response accords with conventional radar theory. The appearance of the Racon paints on the experimental radar was similar to that on the vessel's conventional radar. The first dash of the Racon response showed striations from the modulation, but was clearly distinguishable. There was considerable spoking when the vessel was close to a Racon, because of triggering by side-lobes.

The maximum ranges at which the Racons could be seen was about 20 M, however, responses at these ranges were sporadic and inconsistent. The maximum ranges at which consistent responses were received varied between 8 and 12 M depending on location and time. Therefore a usable range of 10 M is probably to be expected. The accuracies also varied considerably, depending on the number of Racons being received, their geometry relative to the vessel and the consistency of response. During static tests 'ideal' locations were found at which both Racons were almost continuously available, with ranges of less than 10 M and the geometry was good – the two Lines of Position (LOP) crossing at right angles. Combined position accuracies at these points were 5-10 m. When geometry was poor or only one Racon could be received, accuracy was in the region of 50-100 m. The plots shown in ***Figure 7*** indicate typical performance, with single Racon accuracy of 40 m within 5 M, 100 m at 12 M, but with two Racons accuracy of 2 m was achieved. Whilst the availability of the single Racon fix at under 5 M was 98%, the availability of the two-Racon fix was dictated by that of the more distant Racon at 87%.

The results of the trial were encouraging, although more work is needed to fully understand the capabilities of the system.

6. OTHER SERVICES TO BE TESTED

One of the main objectives of e-Navigation is the collection of harmonized data and information, their seamless transfer and distribution between ship and shore, as well as between all relevant stakeholders involved in the safety of navigation, the efficient management of shipping and the protection of the marine environment.

The development of a worldwide concept, combining present and possible future maritime communication means is necessary. The ACCSEAS project will investigate the potentials of such a concept, known as the Maritime Cloud. This concept incorporates proven systems such as VHF, MF, HF and satellite communication services - not necessarily restricted to INMARSAT – but may also include the use of VDES, Satellite AIS, Internet services and for instance GSM. The potentials of the Maritime Cloud, presented at the 59th Session of the Sub-Committee on the Safety of Navigation, attracted the attention of both the IMO and IALA.

Already mentioned solutions such as the Maritime Safety Information/Notices to Mariners Service and the Vessel Operations Co-ordination Tool will

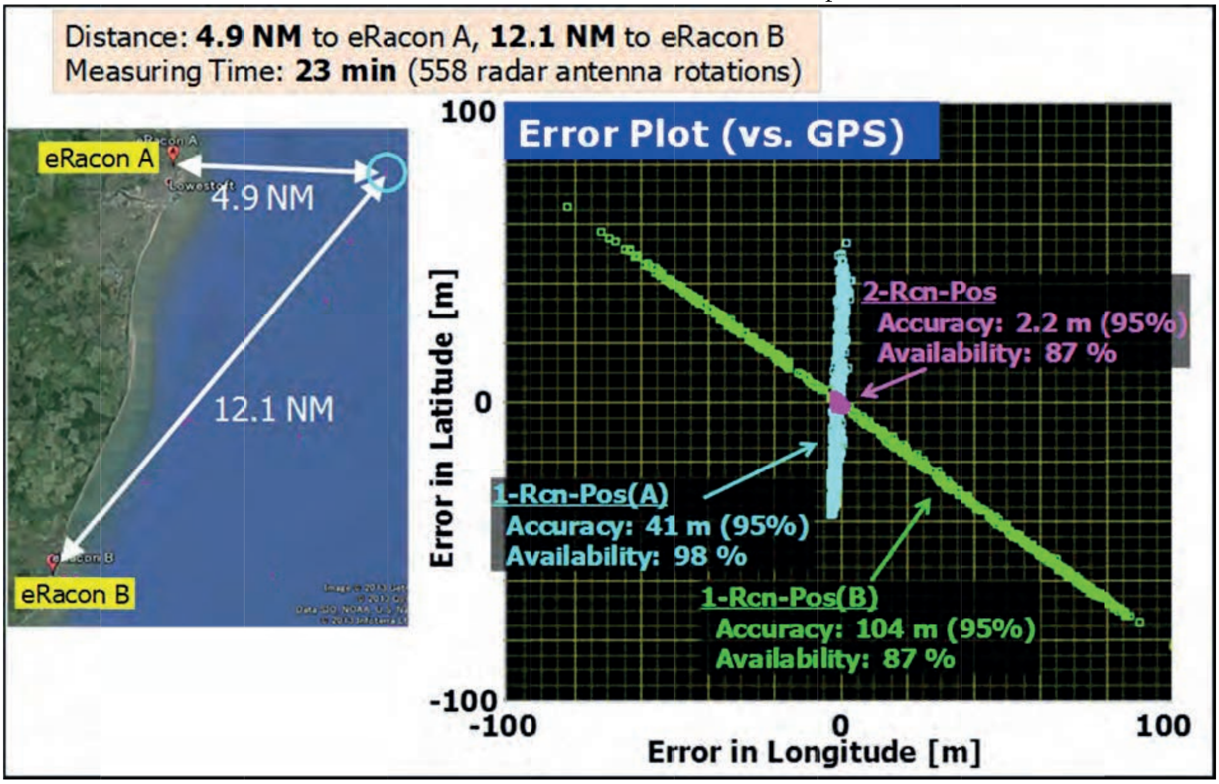


Figure 7: Results of the Absolute Radar Positioning trials in the UK.

be tested using the principles and means of the Maritime Cloud.

An important aspect to be tested will be the interfacing between the variety of communication means and the ship born and shore based data and information sources. In this respect potentials of the IVEF protocol will be further explored during the ACCSEAS project for the transnational data exchange between VTS and Maritime Rescue Coordination Centres, as well as for instance the transfer of real time radar data from ship to shore.

7. CONCLUSIONS

This paper has presented some results from the ACCSEAS Project, illustrating the significant challenges facing shipping in the North Sea Region. The ACCSEAS project has also been able to propose and test solutions based on the IMO's e-Navigation concept to increase the level of spatial awareness to the mariner in a more challenging future environment. The solutions presented in this paper are an example of those being developed within ACCSEAS, with others being considered such as route exchange, augmented reality and dynamic prediction of ship movements.

ACCSEAS will shortly demonstrate the services that have been matured sufficiently to show how e-Navigation and the services within it can reduce risk and improve accessibility in the North Sea Region. ■

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66 PERFORMANCE SIMULATION OF THE FUTURE KOREAN ELORAN SYSTEM

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During the 16 days' GPS jamming attack from North Korea in 2012, it was reported that 1,016 airplanes and 254 ships in South Korea could not receive GPS signals. As a complementary positioning, navigation and timing system to GPS, the South Korean government recently decided to deploy an eLoran system which is a high-power terrestrial radionavigation system. As an effort toward eLoran in Korea, initial performance simulation results of the future Korean eLoran system are presented in this paper. The eLoran performance simulation tool of this paper is able to accommodate environment variables of Korea and visualize expected navigation accuracy of the eLoran system given arbitrary transmitter locations and transmission powers. In addition to the simulation results, the current status and future plans for deploying eLoran in Korea are also presented.

Durante los 16 días del ataque de interferencias GPS de Corea del Norte en 2012, se informó de que 1016 aviones y 254 barcos en Corea del Sur no podían recibir señales GPS. Como sistema complementario de posicionamiento, navegación y temporización del GPS, el gobierno de Corea del Sur decidió recientemente implementar un sistema eLoran, que es un sistema de radionavegación terrestre de alta potencia. Como muestra del esfuerzo dedicado al eLoran en Corea, en esta ponencia se presentan los resultados de simulación de rendimiento inicial del futuro sistema coreano eLoran. La herramienta de simulación de rendimiento eLoran de esta ponencia es capaz de albergar variables de entorno de Corea y visualizar la precisión de navegación esperada del sistema eLoran una vez proporcionadas ubicaciones de transmisor y potencias de transmisión arbitrarias. Además de los resultados de la simulación, también se presenta el estado actual y los planes futuros para implementar el sistema eLoran en Corea.

Pendant les 16 jours de brouillage du GPS par la Corée du Nord en 2012, on a constaté que 1016 avions et 254 navires situés en Corée du Sud n'avaient pas pu recevoir les signaux GPS. Le gouvernement de Corée du Sud a donc récemment décidé d'installer un système eLoran, système puissant de radionavigation à base terrestre, comme système complémentaire de positionnement et de temps. Les premiers résultats de simulation des performances du futur e Loran de Corée sont donnés dans ce rapport. L'outil utilisé pour cette simulation est capable d'intégrer des données sur l'environnement et d'estimer la précision que l'on peut attendre du eLoran suivant la position arbitraire des émetteurs et la puissance des émissions. De plus, on présente le statut actuel le plan d'installation future du eLoran en Corée.

Performance simulation of the future Korean eLoran system

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

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1. INTRODUCTION

eLoran is a ground based high power navigation system that uses low frequency (100 Hz) radio waves. In contrast to the satellite based navigation systems such as Global Positioning System (GPS) of the United States, eLoran is robust to signal jamming because of its very high transmission power. GPS is used in diverse fields and now it is deeply entrenched in our daily lives. However, the more the society relies on GPS, the higher the risk of the service interruption due to unintentional interference or intentional jamming. Carroll [1] mentioned the vulnerability of GPS and Narins *et al.* [2] insisted the necessity of a robust alternative position, navigation, and timing system.

In South Korea, there was a series of actual jamming attacks from North Korea. During August 23 26 in 2010, jamming signals were broadcast from Gaesong area, which is about 8 km north from the Military Demarcation Line (MDL) between South Korea and North Korea. According to the Central Radio Management Office of South Korea, this jamming attack affected 181 cell towers, 15 planes, and 1 battle ship in South Korea. One year later, another jamming attack occurred for 11 days. At that time, 145 cell towers, 106 airplanes and 10 ships in South Korea had difficulty in receiving GPS signals. In 2012, jamming attacks continued for 16 days and 1,016 airplanes and 254 ships were affected. After experiencing these jamming attacks, South Korea has decided to deploy an eLoran system as a complementary Position, Navigation, and Timing (PNT) system to GPS [3].

In this paper, the Korean eLoran program is briefly introduced in Section II. After presenting the performance simulation tool for Korea in Section III, example eLoran accuracy plots over Korea are generated by the simulation tool in Section IV. Conclusions are given in Section V.

2. CURRENT LORAN-C INFRASTRUCTURE AND FUTURE ELORAN SYSTEM IN KOREA

Korea is in the coverage of the Korea Loran C chain with GRI 9930, which contains five stations in the northeast Asia as shown in ***Figure 1***. Two stations are in Pohang and Gwangju, Korea, other two stations are in Nijima and Gesashi, Japan, and the last one is in Ussuriysk, Russia. The master station is the Pohang station in Korea and the control station is in Daejeon, Korea. This Loran C chain is still operating, but it is not widely utilized due to its relatively low navigation performance comparing to Global Navigation Satellite Systems (GNSS) such as GPS. Since Japan plans to discontinue its Loran C operation by the end of 2014, this Korea Loran C chain may not stably provide the legacy Loran C service from 2015.

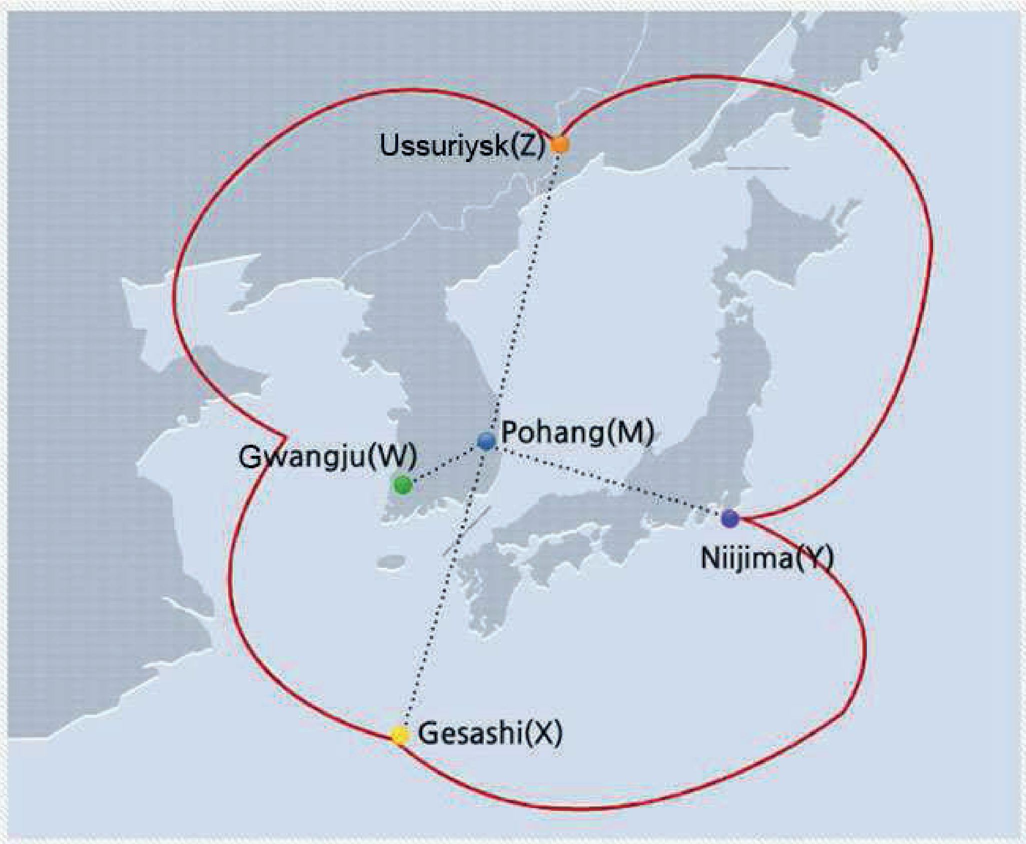


FIGURE 1: Locations of transmitters of the Korea Loran-C chain (from DGNSS Central Office, Korea)

As Seo and Kim [3] announced based on the eLoran design development and construction documents [4] prepared by ANSE Technologies, the South Korean government recently decided to deploy an eLoran system which can provide much better navigation performance than the legacy Loran C system. The initial plan locates the five transmitters as in ***Figure 2***. Two existing Loran C stations in Pohang and Gwangju planned to be upgraded to eLoran stations, and additional three stations planed to be built in Jeju, Ganghwa, and Ulleung. In addition, 43 differential eLoran stations planned to be deployed over the country to provide a nationwide 20 m accuracy coverage. Currently, as of February 2014, there are on going discussions to change this initial architecture of the Korean eLoran system, but the final decision is not yet made.

FIGURE 2: Initial plan of the transmitters locations of the future Korean eLoran system ([4], Figure 3 of [3])

3. ELORAN PERFORMANCE SIMULATION TOOL FOR KOREA

This paper presents an eLoran performance simulation tool for Korea, which can estimate the navigation performance such as accuracy of the future Korean eLoran system. This simulation tool development is based on the previous study of Lo *et al.* [5], which simulated the eLoran performance over the conterminous United States (CONUS).

In this section, the process of simulating eLoran accuracy is explained. In order to estimate eLoran accuracy, it is necessary to estimate the Signal to Noise Ratio (SNR) of received signals. In Section III A, the received signal strength is calculated with the consideration of signal attenuation due to the effective ground conductivity. Then, the atmospheric noise estimation over Korea is discussed in Section III B. Using the estimated received signal strength and atmospheric noise, the SNR is calculated in Section III C. Lastly, the accuracy of the future Korean eLoran system is predicted in Section III D based on the obtained SNR.

A. Received Signal Strength Simulation

Generally, the amount of signal attenuation is related to the distance that the radio wave travels. Signal strength decreases logarithmically when the propagation distance of the signal increases, but the distance is not the only factor that affects the signal attenuation. The character of ground along the traveling path of a signal induces additional signal attenuation to the signal strength. This effect due to the character of ground is evaluated numerically and represented as an effective ground conductivity. As discussed in [6], the equation showing the relationship between a received signal strength and an attenuation factor is,

$$\mathrm{PL}(r)[\mathrm{dB}] = \mathrm{PL}(r_0) - 10n\log\left(\frac{r}{r_0}\right) + ea$$

PL(r) is the signal power loss at a distance r, r_0 is a reference distance, n is a propagation path loss coefficient, and ea is an extra attenuation due to the effective ground conductivity. Thus, the signal attenuation is a function of the effective ground conductivity. ***Figure 3*** shows the signal attenuation patterns for different effective ground conductivities. The signal strength decreases more rapidly along the terrain with a lower effective conductivity. Since the effective ground conductivity of sea water is 4 S/m, which is much higher than the one of land, the attenuation over the sea surface is significantly smaller than the one over the land surface. The effective ground conductivity data from the ITU [7] are used to simulate the received signal strengths over Korea in this paper.

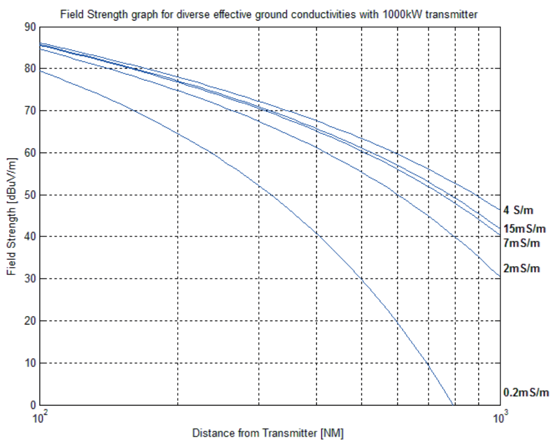


FIGURE 3: Signal strength attenuation for various effective ground conductivities

B. Atmospheric Noise Estimation

The research about the atmospheric noise and its influence on radio wave communications has been performed by the International Telecommunication Union (ITU). (Refer to Boyce [8] for details.) The ITU has collected the atmospheric noise data named as F_a since 1956 when it was CCIR, the predecessor of ITU, and it organized the data as a form of a document [9]. Because the atmospheric noise is a stochastically distributed variable, not a specific value, the data contains only the medium value of a certain percentage condition (90%). Therefore the value on the document has to be converted into the value with the desired condition. Next formula is used to change the 90% F_a value on the document to the F_a with required P% [8].

$$F_{a,P} = F_{am} + D_u \cdot \frac{\text{norminv}(P/100\,,0{,}1)}{\text{norminv}(90/100\,,0{,}1)}$$

F_{am} is the medium F_a value of the distribution represented by the data from the ITU document, and D_u is the upper decile of the distribution. With this $F_{a,P}$, the atmospheric noise E_n for a certain percentage P%, is calculated by the following formula.

$$E_n[\text{dB}(\mu V/m)] = F_{a,P} + 20\log f_{MHz} + 10\log b - 95.5$$

f_{MHz} is the frequency of radio wave and b is the bandwidth of radio wave. The detailed process of induction of this equation is included in [8]. The obtained atmospheric data varies with the season and the time slot of a day. For instance, ***Figure 4*** shows an example output from our software with the condition of a winter season and 21:00 ~ 22:00 time slot.

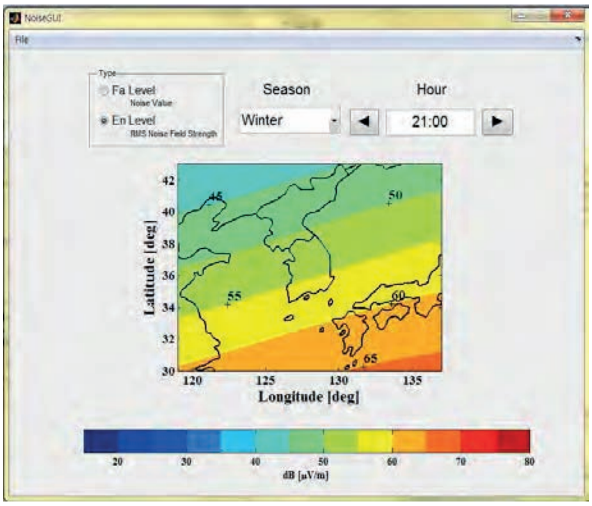


FIGURE 4: Example output of the atmospheric noise over Korea

C. SNR Calculation

Most of the atmospheric noise is due to the lightning and it has a peak at 10 kHz and bandwidth between 1 kHz and 20 MHz [8]. Since the eLoran signal is a 100 kHz radio wave and it is within the bandwidth of the lightning, the atmospheric noise becomes the main source of the noise for the eLoran receiver. Therefore, the SNR of received eLoran signals can be estimated as a ratio between the received signal strength and atmospheric noise. The received signal strength of eLoran signal is simulated in Section III A, and the atmospheric noise over Korea is obtained in Section III B. Thus, the ratio between those two results becomes SNR.

D. Accuracy Simulation

In order to simulate accuracy of the eLoran system, the error standard deviation of position measurements is required. The standard deviation can be obtained by the following formula.

$$\sigma_i^2 = J^2 + (\sigma_{256}^2 \cdot \frac{256}{T_{avg} \cdot pps_i}) \times 10^{-\frac{SNR_i}{10}}$$

J is the jitter of a transmitter, σ_{256} is a reference standard deviation of 256 pulses, T_{avg} is the integration time in seconds, pps_i is the number of pulses per second transmitted from the i^{th} transmitter, and SNR_i is the SNR of the signal transmitted from the i^{th} transmitter that we obtained in Section III C. Weight matrix W is a diagonal matrix which is composed of the error standard deviation for each station.

$$W = \begin{bmatrix} \sigma_1^2 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_N^2 \end{bmatrix}^{-1}$$

Then the position error matrix can be calculated by the following equation.

$$\begin{bmatrix} \sigma_x^2 & 0 & 0 \\ 0 & \sigma_y^2 & 0 \\ 0 & 0 & \sigma_t^2 \end{bmatrix} = (G^T W G)^{-1}$$

G is a geometry matrix which contains cosine and sine values of azimuth of each station. Then horizontal 95% accuracy is calculated by the following formula.

$$\text{Accuracy} = 2\sqrt{\sum_i K_i \sigma_i^2} = 2\sqrt{\sigma_x^2 + \sigma_y^2}$$

The horizontal accuracy of the planned Korean eLoran system is simulated through this series of calculations. The accuracy simulation is performed with various conditions and example results are shown in ***Figure 5***. Note that Figure 5 represents repeatable accuracies which do not consider temporal and spatial variations of Additional Secondary Factor (ASF). The accuracy from this simulation assumes ASF errors are mostly mitigated by differential eLoran stations and ASF maps.

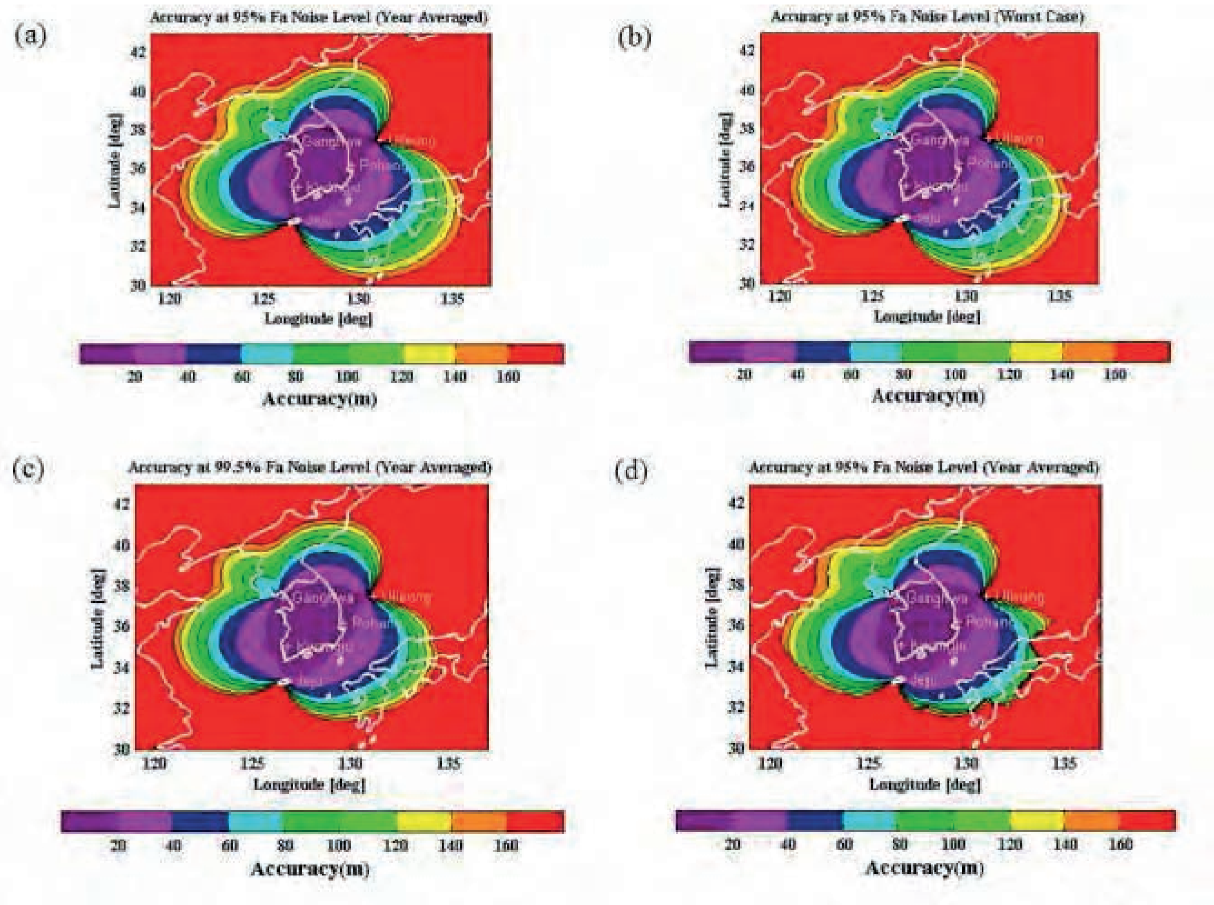


FIGURE 5: Example accuracy simulation results for various conditions (a) Repeatable accuracy plot for 95% noise level, year averaged, -15dB of SNR threshold (b) Repeatable accuracy plot for 95% noise level, worst case of a year, -15dB of SNR threshold (c) Repeatable accuracy plot for 99.5% noise level, year averaged, -15dB of SNR threshold (d) Repeatable accuracy plot for 95% noise level, year averaged, -12dB of SNR threshold

4. SIMULATED ELORAN ACCURACY OVER KOREA

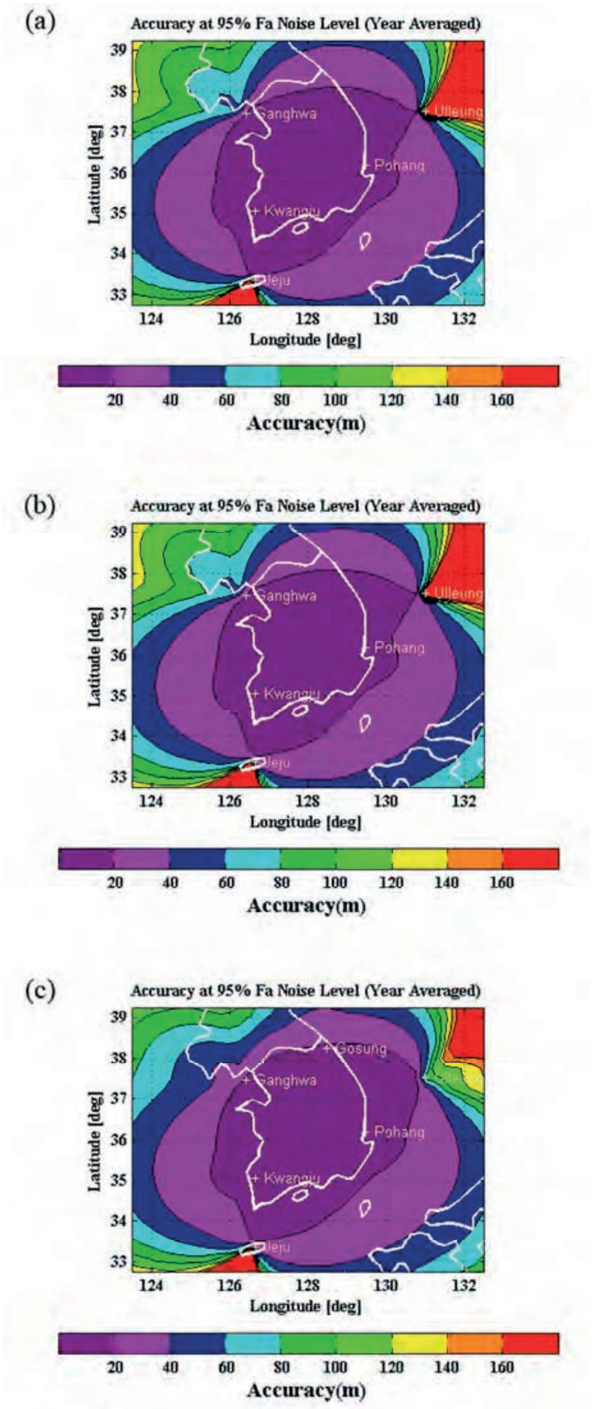
As of February 2014, the locations and powers of the transmitters for the Korean eLoran system are not yet confirmed. There are several proposals for the transmitting powers. Three example cases are presented in Table 1 and the accuracy plot for each case is shown in ***Figure 6***. The first case assumes 1000 kW transmitting powers of the five stations. The second case is a set of reasonable powers without noticeable impact on the coverage. The coverage area in Figure 6(b) is not much smaller than the case 1 in Figure 6(a). In order to expand the coverage, the case 3 uses additional transmitter in Goseong. The expanded area with a 20 m accuracy is shown in Figure 6(c). Again, these accuracy plots in Figure 6 represent ideal accuracy when temporal and spatial ASF errors are mitigated by differential eLoran stations and ASF maps respectively.

5. CONCLUSIONS

In this paper, an eLoran performance simulation tool for Korea is presented. The simulation tool can calculate the eLoran accuracy based on the SNR estimation, which is the ratio between the received signal strength and the atmospheric noise. This tool can simulate the accuracy performance for various conditions such as transmitting powers, locations of transmitters, an SNR threshold of a receiver, seasons, noise levels, and so forth. Example accuracy results obtained by this tool were presented in this paper. This simulation tool

	Pohang	Gwangju	Jeju	Ganghwa	Ulleung	Gosung
Case 1	1000	1000	1000	1000	1000	-
Case 2	150	50	250	250	100	-
Case 3	150	50	250	250	1000	250

↑Table 1: Three sample cases of transmitting powers for the future Korean eLoran system



will be further expanded to simulate other navigation performances such as integrity, availability, and continuity. ■

ACKNOWLEDGMENTS

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← Figure 6: Simulation results for the cases of Table 1 (a) Accuracy plot for the case 1 of Table 1 (b) Accuracy plot for the case 2 of Table 1 (c) Accuracy plot for the case 3 of Table 1

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46 RECAPITALIZATION OF THE MF RADIO BEACON SYSTEM BASED ON VRS

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Germany and Sweden have been providing a DGPS radio beacon service for maritime usage for almost twenty years. The current DGPS service, according to the so called "IALA-Standard" provides GPS corrections within the maritime radio beacon band (283.5 – 325.0 kHz). The GPS L1 C/A-Code corrections are normally generated from local on-site reference receivers. Furthermore the GPS corrections are monitored and integrity checked to inform users in case of satellite failures or when the service is outside the defined performance specifications. Due to the fact that most of the hard- and software of the DGPS system was installed around 1995, the whole service is getting more and more difficult to operate and maintain. In addition it could also be necessary to provide augmentation information for future GNSS signals from GPS, Galileo, GLONASS or COMPASS. Therefore a re-engineering and further development of the existing maritime DGPS service towards a modernized DGNSS service is necessary to fulfill future maritime requirements.

Germany has decided to recapitalize the existing DGPS system based on the concept of virtual reference stations (VRS). Sweden is also investigating this approach and is developing a proof of concept in this regard.

The VRS concept is based on a network of GNSS sensor stations and is able to transmit the calculated DGNSS corrections using different radio links. Germany is planning to transmit the corrections using the MF radio beacon and AIS shore stations based on AIS message #17. Another important functionality of the new VRS concept is the development of a Pre-Broadcast-Monitoring algorithm. The new Pre-Broadcast-Monitor process performs all integrity checks within the VRS server and prevents the transmission of incorrect GNSS corrections to the user.

The paper generally explains the plan to recapitalize the existing DGPS service based on the VRS concept and the use of Pre-Broadcast-Monitoring and the transmission of GNSS corrections via IALA MF radio beacons and AIS-Message #17. The paper further reports about the various tests and developments regarding the VRS implementation in Germany and Sweden.

Alemania y Suecia llevan ofreciendo un servicio de radiobaliza DGPS para uso marítimo durante casi veinte años. El servicio DGPS actual, de acuerdo con la llamada «Norma IALA» proporciona correcciones GPS dentro de la banda de radiobaliza marítima (283,5 – 325,0 kHz). Las correcciones GPS L1 con código C/A normalmente son generadas desde receptores de referencia locales in situ. Además, las correcciones GPS se supervisan y se comprueba su integridad para informar a los usuarios en caso de fallos de satélite o cuando el servicio está fuera de las especificaciones de rendimiento definidas. Debido al hecho de que la mayoría del hardware y software del sistema DGPS se instaló alrededor de 1995, el servicio en su conjunto es cada vez más difícil de operar y mantener. Además, también podría ser necesario proporcionar información de aumentación para futuras señales GNSS desde GPS, Galileo, GLONASS o COMPASS. Por lo tanto, para cumplir los futuros requerimientos marítimos es necesaria una reingeniería y una evolución del servicio marítimo DGPS existente hacia un servicio DGNSS modernizado.

Alemania ha decidido renovar el sistema DGPS existente basándose en el concepto de estaciones de referencia virtuales (VRS). Suecia también está investigando este enfoque y está desarrollando una prueba de concepto a este respecto.

El concepto VRS se basa en una red de estaciones sensor GNSS y es capaz de transmitir las correcciones DGNSS calculadas utilizando diferentes enlaces de radio. Alemania está planeando transmitir las correcciones utilizando la radiobaliza MF y estaciones costeras AIS basándose en el mensaje AIS #17. Otra funcionalidad importante del nuevo concepto VRS es el desarrollo de un algoritmo Predifusión-Supervisión. El nuevo proceso Predifusión-Supervisión realiza todas las comprobaciones de integridad dentro del servidor VRS y evita la transmisión de correcciones GNSS incorrectas al usuario.

La ponencia explica de modo general el plan para renovar el servicio DGPS existente basándose en el concepto VRS y el uso de Predifusión-Supervisión y la transmisión de correcciones GNSS a través de radiobalizas MF de la IALA y el mensaje AIS #17. La ponencia también informa sobre las diversas pruebas y desarrollos relacionados con la implementación de VRS en Alemania y Suecia.

L'Allemagne et la Suède ont fourni un service de DGPS pendant presque 20 ans. Le service DGPS actuel, conforme à la « norme AISM », fournit des corrections GPS dans la bande des radiophares maritimes (283,5 - 325 kHz). Les corrections GPS code L1 G/A sont normalement générées par des récepteurs de référence locaux. De plus, les corrections GPS sont surveillées et l'intégrité est vérifiée pour informer l'utilisateur en cas de panne d'un satellite ou si les performances du service ne correspondent pas à leurs caractéristiques normales. Etant donné que les matériels et logiciels du système DGPS ont été installés vers 1995, le service est de plus en plus difficile à gérer et à entretenir. En outre, il pourrait aussi être nécessaire de fournir une information augmentée pour les futurs signaux GNSS du GPS, de Galileo, de GLONASS ou de COMPASS. Il convient donc de repenser et redévelopper le service DGPS maritime existant pour en faire un service DGNSS moderne satisfaisant les besoins maritimes futurs.

L'Allemagne a décidé de restructurer le système DGPS existant en se basant sur le concept de stations de référence virtuelles. La Suède aussi étudie cette approche et développe un projet de concept dans ce sens.

Le concept VRS est basé sur un réseau de stations de capteurs GNSS et est capable de transmettre des corrections DGNSS calculées en utilisant différentes liaisons radio. L'Allemagne prévoit de transmettre les corrections en utilisant le radiophare MF et les stations AIS à terre sur la base du message AIS # 17. Une autre fonctionnalité importante du concept VRS est le développement d'un algorithme de contrôle avant transmission (Pre-Broadcast Monitoring). Cette nouvelle fonctionnalité assure tous les tests d'intégrité à l'intérieur du serveur VRS et évite la transmission à l'utilisateur de corrections GNSS erronées.

Le rapport explique le plan de restructuration du service DGPS existant basée sur le concept VRS, l'utilisation du Pre-Broadcast Monitoring et la transmission de corrections GNSS par les radiophares MF de l'AISM. et le message AIS # 17. Le rapport rend compte aussi des tests et développements concernant l'installation du VRS en Allemagne et en Suède.

Recapitalization of the MF radio beacon system based on VRS

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Recapitalization of the MF radio beacon system based on VRS

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1. Background

Germany and Sweden have been providing a DGPS radio beacon service for maritime usage for almost twenty years. The DGPS service, according to the "IALA-Standard" (International Association of maritime aids to Navigation and Lighthouse Authorities) provides GPS corrections within the maritime radio beacon band (283.5 – 325.0 kHz). The GPS L1 C/A-Code corrections are normally generated from local on-site reference receivers. Furthermore the GPS corrections are monitored and integrity proved to inform users in case of satellite failures or if the service is outside the defined performance specifications. Due to the fact that most of the hard- and software of the DGPS system was installed around 1995, the whole service is getting more and more difficult to run and maintain. In addition it could also be necessary to provide augmentation information for future new GNSS signals from GPS, Galileo, GLONASS or COMPASS. Therefore a re-engineering and further development of the existing maritime DGPS service towards a modernized DGNSS service is necessary to fulfill future maritime requirements.

According to this, IALA has developed a recommendation[1], [1] of future DGNSS which identifies the following new concepts to re-engineer the existing radio beacon DGPS:

- Hard- and software replacement
- Use of a modular software solution based on COTS (Commercial off-the-shelf) receiver technology
- SBAS integration (existing SBAS, such as WAAS or EGNOS could offer a low-cost solution to service providers)
- Use of virtual reference stations.

Germany and Sweden have decided to make use of the virtual reference station (VRS) concept. The driving factors were:

- The concept utilizes standardized hard- and software. In addition raw data could be used from national surveying administrations. As a result the concept can be implemented with moderate investment costs.
- The integration of future GNSS signal is easily possible.
- Performance enhancements can be achieved, since accuracy could be improved and could be located to regions of relevance (harbours, regions with high accuracy requirements).
- This solution supports the e-Navigation architecture of separating functionalities into different services. This means that the observation and generation of GNSS corrections could be separated from the transmission technology (MF, VHF or local hotspots).
- The VRS concept enables the improvement of the integrity monitoring functionality by using a Pre-Broadcast-Monitoring process.

It is planned that Germany will transmit GPS code corrections within the MF transmission service and from AIS base stations using AIS message #17. Further it is intended to investigate the transmission of network RTK from local hotspots. Such short range transmissions could be used to support guiding systems which enable lock entrance maneuvers.

Another important functionality of the new VRS concept is the development of a Pre-Broadcast-Monitoring process. At present nearly all radio beacon DGPS stations transmit the GPS corrections over the MF radio link. An on-site integrity monitor receives the transmitted signals and calculates a position using the received PRC and RRC. An alarm is issued if the position is outside the preset threshold. The new Pre-Broadcast-Monitor process performs all integrity checks within the VRS server and prevents the transmission of incorrect GNSS corrections to the user.

2. The Virtual Reference Station (VRS) Concept

2.1 VRS Functionality

The virtual reference station technique is based on a network of GNSS sensor stations within a given area. The sensor stations transmit their measured GNSS raw data to a central server (VRS server). Based on the received raw data streams, the VRS server is able to calculate different GNSS correction data streams for any locations within the defined network (***figure 1***). Whereas the VRS methods in the surveying field normally use GNSS dual frequency phase corrections a VRS service for maritime navigation makes use of single frequency code corrections (GPS L1 C/A code).

A VRS based approach can be established by using a suitable number of GNSS receivers distributed over the intended coverage area. Best results could be achieved when the service area is enclosed by the GNSS receiver network. The data of a single GNSS receiver within the network should be used either for service generation or for service monitoring (PBM) to avoid correlation effects between service provision and monitoring, [2].

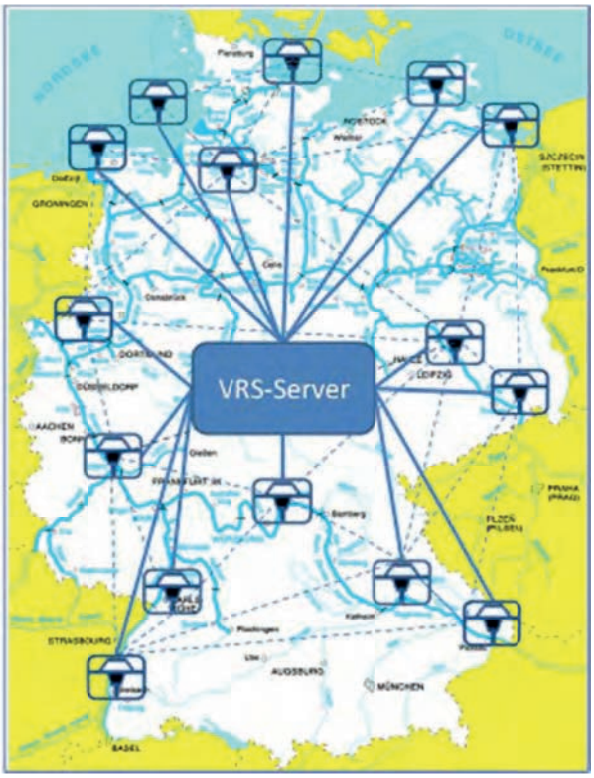

Figure 1: Example of a VRS-network in Germany

2.2 VRS Features

The main features of a VRS can be summarized as following:

- Within the VRS concept the DGNSS corrections and integrity messages are computed at a central server.
- The generated corrections could be transmitted from:
  - MF-Beacons (Conform to IALA R-121),
  - AIS-Base stations (Conform to IALA A.124) or from
  - Hotspots for enhanced position accuracy
- The VRS concept supports the idea to separate the DGNSS functionality into different shore-based services
  - DGN (DGNSS correction data service)
  - MF (medium wave service)
  - AIS service
- The concept can be realized with moderate investment costs
- VRS can fulfill high accuracy requirements
  - < 1 m for IALA MF radio beacons (or AIS)
  - < 10 cm for hotspots using short range RTK
- Advantages of the VRS solution are:
  - The GNSS-receivers could be off-the-shelf
  - (GLONASS and Galileo integration is easy)
  - The software is based on well-known principles and standards
- Performance enhancements (accuracy can be increased in specialized areas)
- Disadvantages of the VRS solution are:
  - Availability of the service dependent on communication links
  - Availability of the service dependent on VRS server owned and managed by partner

2.3 Pre Broadcast Monitoring (PBM)

As mentioned before one important feature of a new VRS service is the usage of an integrity functionality process to fulfill the requirements of a safety related system and being conform to existing maritime standards. Within the VRS concept the integrity functionality is based on a new “Pre Broadcast Monitoring (PBM)” algorithm which runs on the VRS server. The PBM enables all relevant checks before the transmission of the data (*figure 2*). The PBM can be divided into the following two fields:

2.3.1 Satellite related Monitoring

The PBM performs a detection of faulty satellites. A satellite is faulty, if

- the GPS system provider marks a satellite as „unhealthy“,
- the DGPS system provider marks a satellite as „unhealthy“ or
- the PRC or RRC of a satellite exceeds a user preset threshold.

As a result of the above checks the PBM algorithm will prevent the transmission of corrections or will mark faulty satellites with “do not use” within the RTCM messages (1 or 9-3).

2.3.2 Monitoring of the quality of the generated VRS corrections

The main task of the PBM is the detection of faulty or inaccurate VRS corrections. The calculations are based on calculated position deviations according to a given position and a preset threshold. For this kind of integrity monitoring it is important that the corrections will use independent GNSS raw data streams which are not included in the VRS generation process. A VRS correction stream is faulty, if

- the calculated position error is higher than the preset threshold
  → The VRS reference station will be marked as "unhealthy"
- the monitoring source is not available or monitoring functionality could not performed
  → The VRS reference station will be marked as "unmonitored"

It is important that both integrity functions will be performed within the 10 sec TTA limit.

2.4 In– and Output data streams

For the VRS test pilot three different input sources can be used:

- GPS raw data from existing GPS reference stations located at the DGPS radio beacon sites.
- GNSS raw data from new installed GNSS sensor stations located at the far field monitor sites
- GNSS raw data from existing networks hosted by the national surveying administration

The VRS output data streams are available for:

- transmissions of RTCM corrections within the radio beacon band, compatible with IALA R-121
- transmissions of AIVDM data within the AIS service (VHF), compatible with IALA A-124
- for future high precision applications it is planned to provide phase corrections which will be transmitted using local hotspots

The raw data inputs as well as the VRS correction outputs will be transported using Ntrip[2], [3].

3. VRS Realization

The German waterways and shipping administration has started two projects with respect to the realization of the described VRS concept. One is the realization of a VRS test pilot with transmissions of VRS corrections using the inland radio beacon network and the inland AIS installations. The second project will deal with the recapitalization of the maritime radio beacon network and the transformation of the existing DGNSS beacon system into a shore based e-

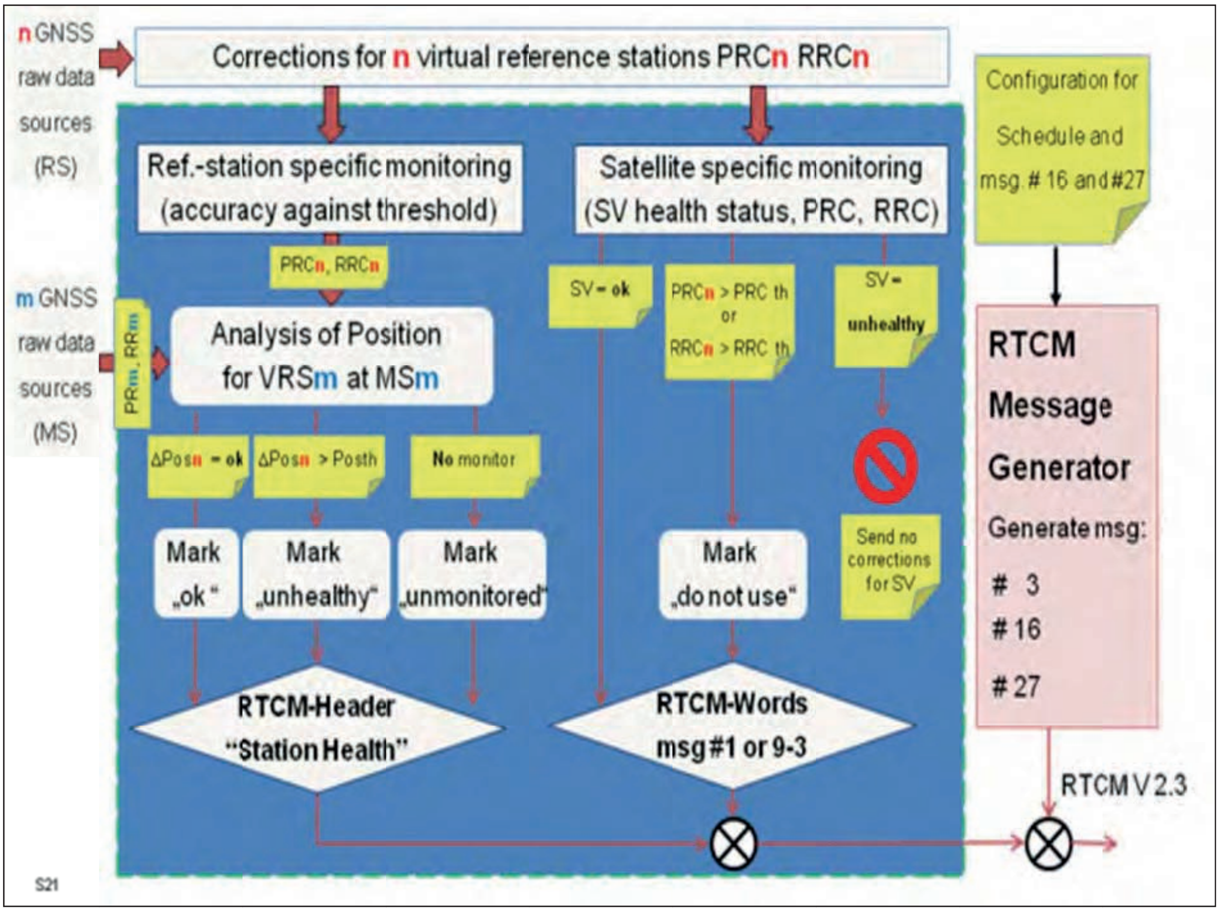

Figure 2: Pre Broadcast Monitoring (PBM) as part of the VRS-Server

Navigation architecture.

Swedish Maritime Administration has conducted a project during 2013 to test the concept of VRS before taking a decision about modernization of the Swedish DGNSS network. The project main goals were to use the corrections from the SWEPOS network (owned by Swedish Land Survey Agency) and to modulate them into the "air".

3.1 VRS test pilot for the transmission of VRS corrections using MF radio beacons and AIS along inland waterways

The main tasks of the VRS test pilot are:

- Specify the requirements of a VRS solution for safety related navigation applications containing PBM
- Develop, install and configure a VRS test system according to the specifications
- Modification of the existing DGPS radio beacon network and inland AIS base station network to enable VRS correction transmissions
- Evaluate the performance of the VRS test pilot
- Transform the test system into an operational system

3.2 Test configuration at the DGPS radio beacon site

Figure 3 shows the modified DGPS radio beacon system. During the test phase the VRS corrections will be transmitted from the spare transmitter. The onsite reference receiver can be used as a GPS sensor station to provide GPS raw data which are forwarded to the VRS server.

3.3 VRS Software

The main part of the development to realize the VRS functionality was carried out in different software modules. For the VRS test pilot the following software modules are currently used:

- Module used at the DGPS radio beacon station to provide GNSS raw data input streams to the VRS server :

  The software supports the continuous operation of permanent GNSS reference stations. EuroRef takes over the control and supervision of GNSS receivers, the acquisition and administration of GNSS raw data and the generation and transmission of GNSS corrections.

- Module to manage all in and output data streams at the VRS server:

  The NtripCaster is basically an HTTP server supporting a subset of HTTP request/response messages. The NtripCaster accepts request-messages on a single port from either the NtripServer or the NtripClient. Depending on these messages, the NtripCaster decides whether there is streaming data to receive or to send.

- Module to process the GNSS raw data input streams, generates the VRS corrections, performs the PBM and assembles the RTCM/AIVDM output data streams. For this purpose the Beacon.Net software, [4], is used.

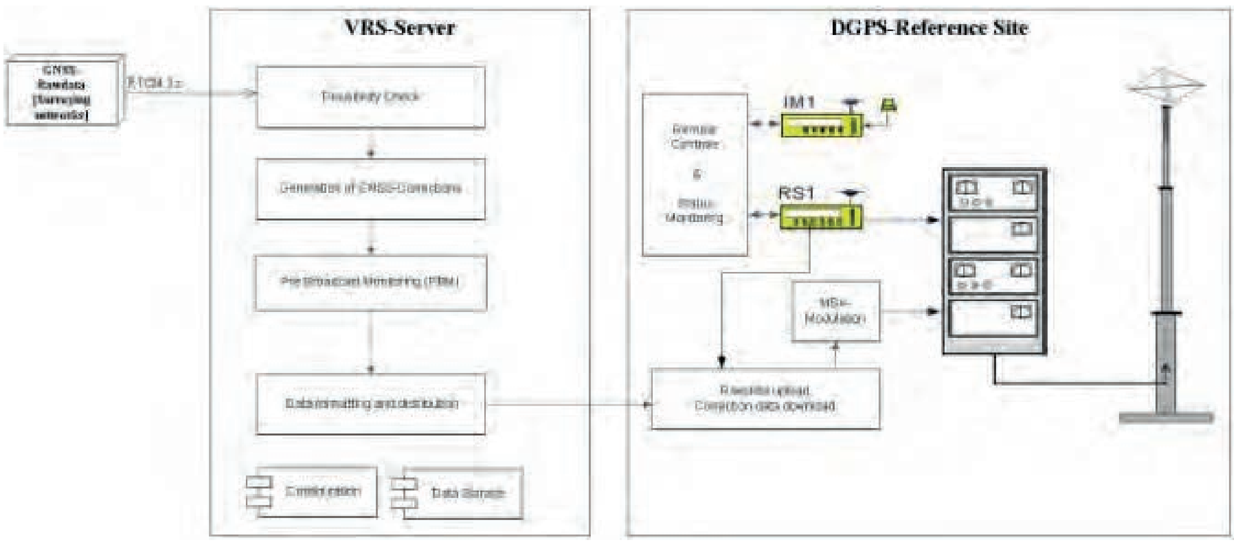

Figure 3: VRS prepared DGPS radio beacon site

- a web service which provides a graphical user interface for VRS configuration and status display (see *figure 4*).

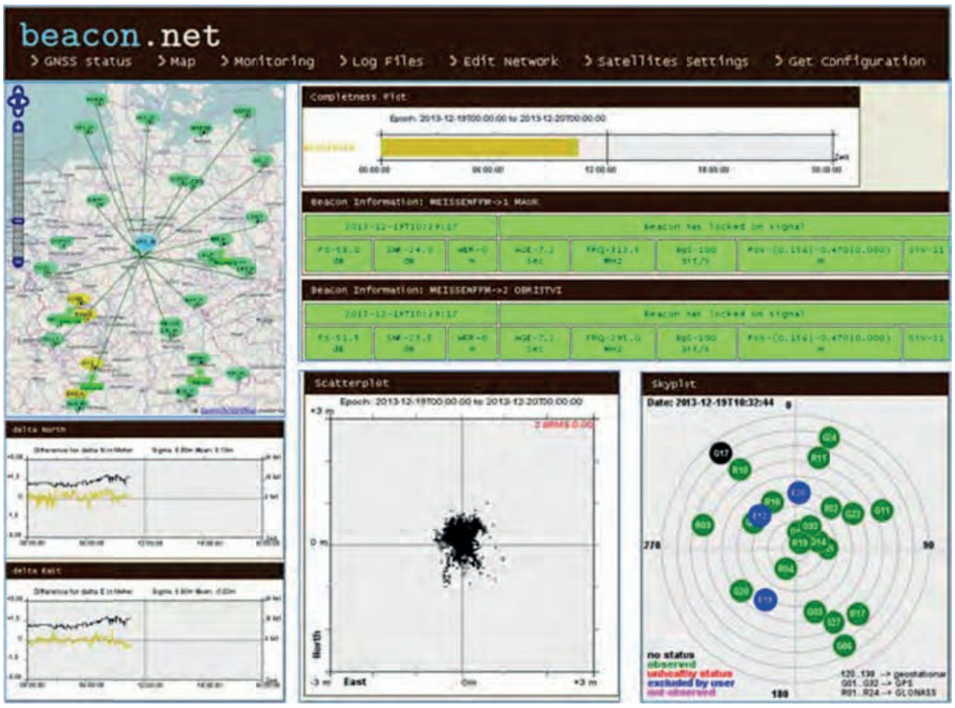

Figure 4: graphical user interface of the VRS software which runs at the VRS test pilot

3.4 VRS test results

A number of tests have been performed, [5], consisting of

- VRS accuracy measurements,
- data latency,
- PBM functionality,
- assessment of the VRS system with respect to the usage of different network constellations and various in- and output data streams,
- availability of network connections,
- transmission of combined GPS and GLONASS corrections and
- transmission of AIS message #17.

The results which could be measured at the VRS server, GPS-Simulators and far field monitor stations show

- slightly reduced average data age (latency) of about 4.3 to 4.6 seconds,
- higher average satellite visibility,
- accuracy level of below 1 m (95%),
- improved integrity monitor functionality due to PBM
- successful combined transmission of DGPS and DGLONASS and
- successful combined transmission of corrections using MF radio beacon and AIS message #17.

Concerning the availability of the network connections the measurements show

- high availability of input data streams due to the redundancy of existing GNSS networks and
- good availability for output data streams when using administration based network infrastructure.

3.5 Recapitalization of the maritime radio beacon network using the VRS concept

Within the next few years the maritime radio beacon network at the German coast will be re-engineered. The developed DGNSS concept will use different services which will be conform to the shore based eNavigation architecture, developed by the IALA. The new DGNSS system will be realized in the following shore based services:

- **DGN** (Differential correction service)

  The main function of the DGN service is to observe the GNSS signals, to provide GNSS raw data to the VRS server and to generate GNSS correction data which will be transmitted using the MF and AIS services.

- **MF** (Medium Frequency transmission service)

  The main function of the MF service is to transmit transparent input data (GNSS corrections, text data or navigational data) within the radio beacon band.

- **AIS** (Automatic Identification System service)

  The AIS service already exists. Within the DGNSS concept the main function of the AIS service is to provide GNSS corrections via VHF using the AIS message #17.

Figure 5 illustrates the general concept of generating GNSS corrections within the shore based system. Main part of the DGN is the described VRS concept. Further all essential components of the DGN as well as the relevant in- and outputs are shown.

3.6 Swedish VRS "proof of concept"

Sweden decided to perform a "proof of concept" project within the VRS field in order to prepare for the modernization of the Swedish DGPS network. The main goals for the Swedish "proof of concept" project were to:

- Start-up collaboration with SWEPOS to get access to VRS corrections
- Develop a module for generation of RTCM message 9-3 (SWEPOS only delivers RTCM message 1 for their current customers)
- Develop MSK modulator based on standard programmable hardware
- Receive and modulate correction from SWEPOS and close the loop with legacy Trimble IM receiver
- Compare results between corrections from the VRS solution with our legacy reference stations

Block schematic for the VRS project is depicted in ***Figure 6***.

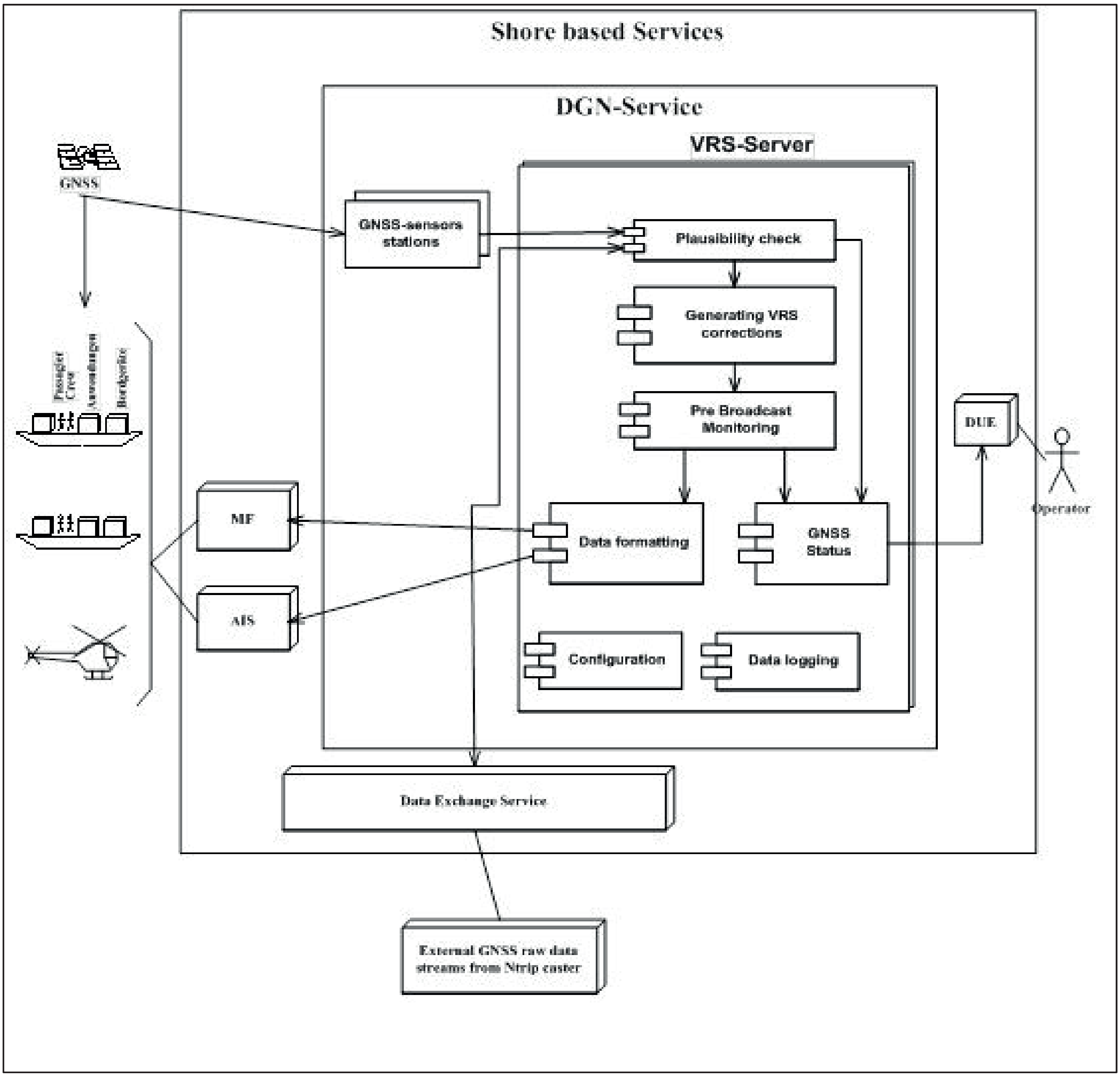

Figure 5: VRS concept based on new shore based services (DGN, MW and AIS)

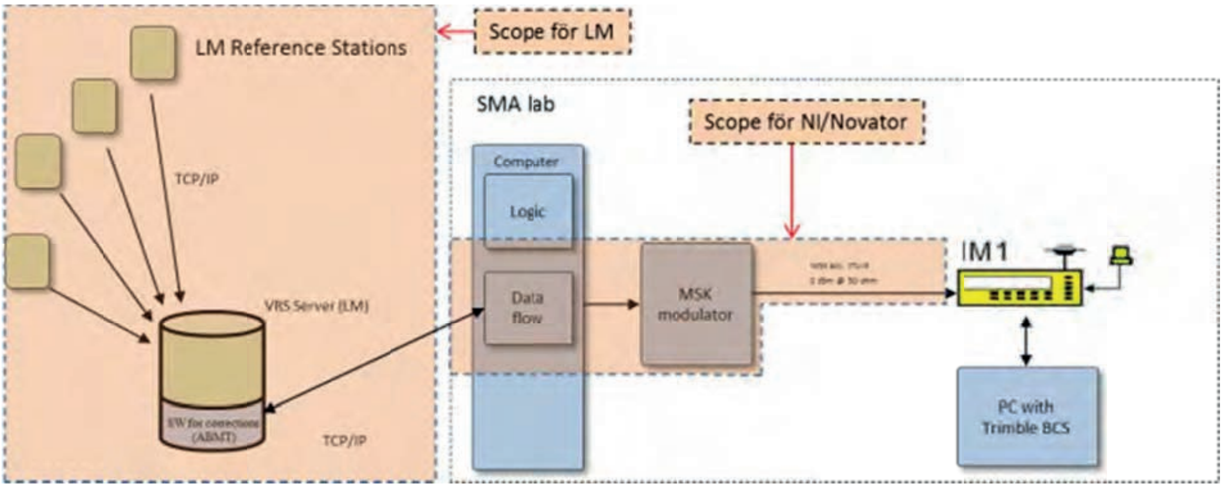

Figure 6: Block schematic of Swedish "proof of concept" project

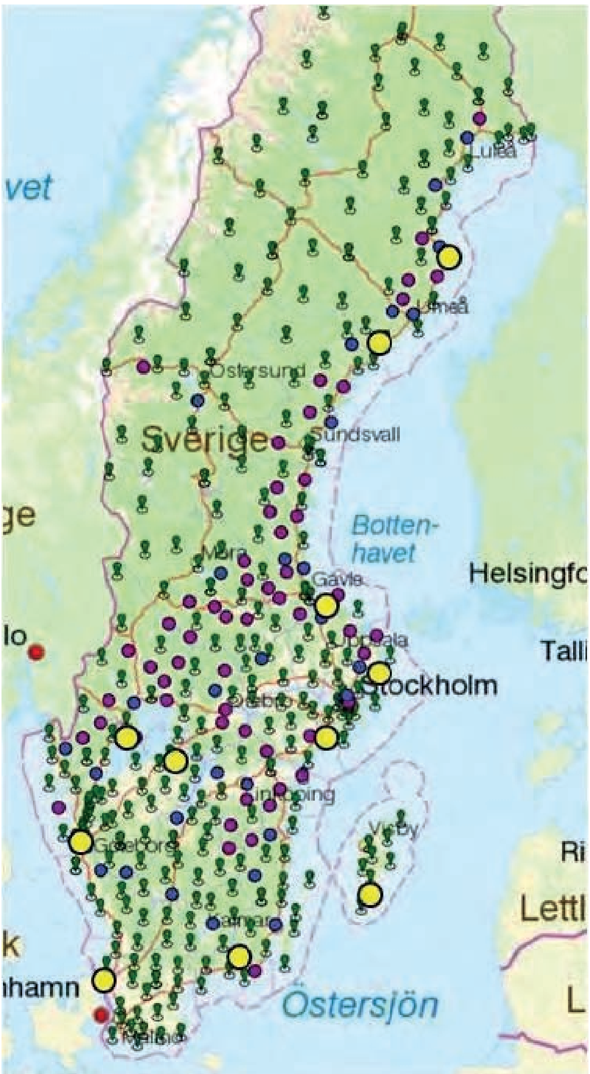

Figure 7: A map showing the distribution of SWEPOS reference stations (both existing and planned). Yellow circles are the reference stations for the DGPS net

3.6.1 Collaboration with SWEPOS

SWEPOS is owned by the Swedish Land Survey Agency and is funded by the government and user fees. SWEPOS's main tasks are to provide data from GNSS in order to enable users to determine centimeter accuracy positions in real-time. SWEPOS also delivers millimeter accuracy positions through post-processing.

Our first task in the project was to start-up the collaboration with SWEPOS. SWEPOS was very interested in participating and has played a major role in the project. Their participation is of course of outmost importance in order for the project to be successful.

SWEPOS manages about 300 reference stations and everything is processed at one central server system.

3.6.2 Development of message 9–3

SWEPOS offers only RTCM message 1 in their current system and an adoption to RTCM message 9-3 has to be done. SWEPOS personnel, who have very deep skills in programming software related to GNSS systems, offered their services in adopting the SWEPOS system. The resulting software adoption is called ABMT (AnpassningsBlock Marin Tillämpning).

Two different streams of corrections were offered for this project: one with the original RTCM message 1 and one with the RTCM message 9-3.

3.6.3 PC and MSK modulator

It was early identified that an MSK modulator should be very easy to realize with today's standard programmable electronics. The reason to believe that it should be feasible is that the data rate is very slow and the modulation scheme is well known and described in detail in various papers and standards.

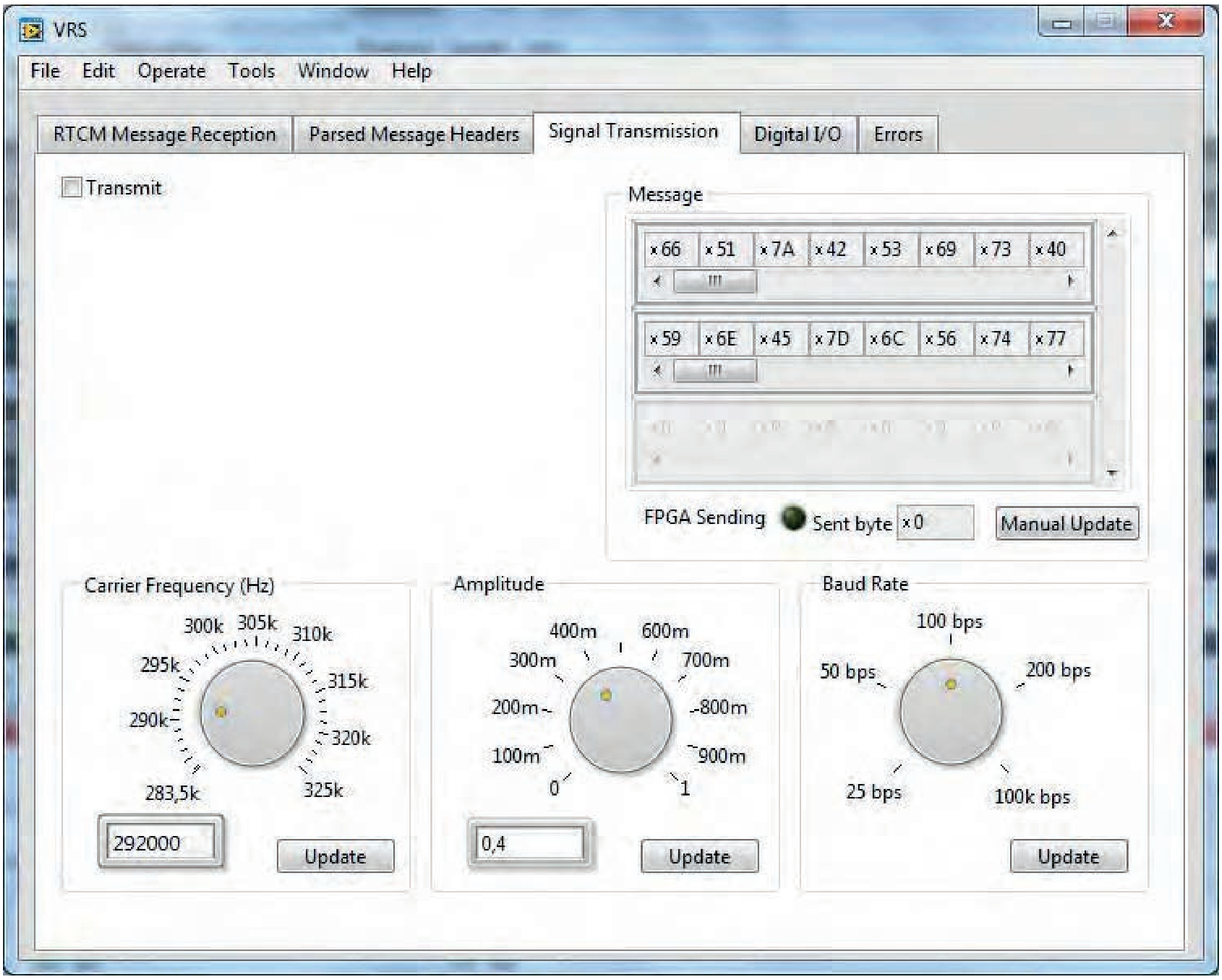

Figure 8: GUI for the MSK modulator

In essence, the modulation is performed by shifting the frequency between two different states depending if the output is '0' or '1', [6].

Nation Instruments (NI) was contacted for consultancy. In turn, NI appointed Novator Solutions AB for developing the software, while NI supports with hardware and software tools.

Sweden developed jointly with Novator and NI the MSK modulator. The hardware is based on NI's PXI chassie, and is equipped with a COTS PC and a COTS programmable analogue board. The PC handles the communication with SWEPOS and the data flow to the analogue board. The analogue board is fed with corrections from the PC which are then modulated into MSK on an 50 Ohm 0 dBm output.

A GUI was developed for controlling the MSK modulator. Adjustments can be made to the frequency, output level, bit rate, etc.

3.6.4 Receive and transmit corrections

The data flow between SWEPOS and the PC is handled by handshaking. The PC demands new corrections by sending a simple TCP/IP packet to the IP port on the SWEPOS server. The SWEPOS server replies with a RTCM message which is in turn handled by the PC. When the PC is finished with the processing and transmitting of the message, a new TCP/IP message is sent to SWEPOS server. This simple solution was deemed enough to prove the concept of using corrections from SWEPOS.

In order to verify the modulated corrections, a legacy Trimble 4000MSK IM receiver was used. The corrections from the MSK modulator were attenuated and fed into the MSK input port on the IM receiver. If an IM receiver recognizes the corrections it will use them to determine the position. This can be analyzed in a software (BCS) delivered by Trimble.

3.6.5 Results from tests

Tests were conducted in order to verify the performance of the VRS corrections and compare them with corrections from the legacy Trimble RS. No firm acceptance result was decided on

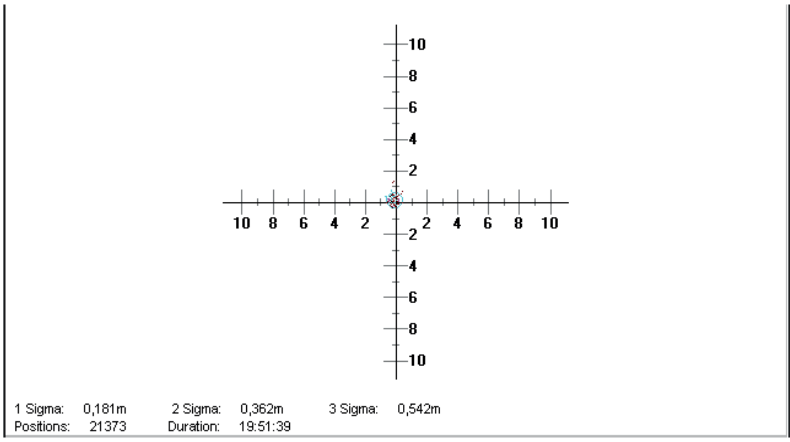

Figure 9: Scatter plot with VRS corrections

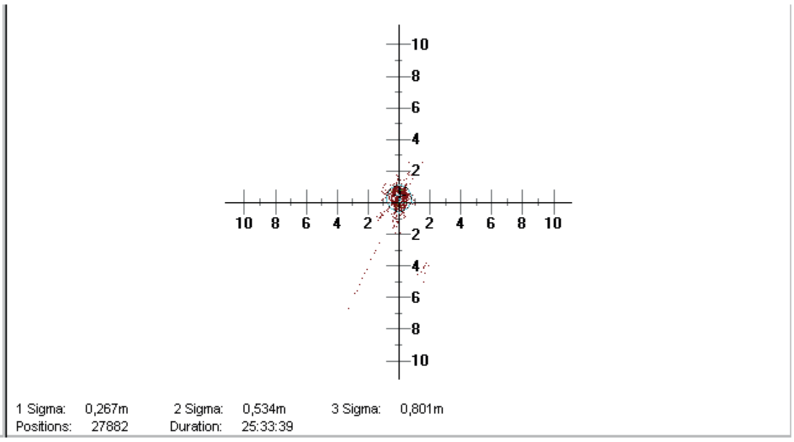

Figure 10: Scatter plot with legacy RS corrections

beforehand. The results from the tests were presented on the built-in scatterplot of Trimble BCS software. The BCS software receives the data from the com-port of the IM receiver.

The first test runs were made with RTCM message 1. Typical scatterplot is depicted in ***figure 9***. 3 sigma after 21373 positions was 0,542 meters.

In ***figure 10*** is a scatterplot for the legacy Trimble RS. 3-sigma after 27882 positions was 0,801 meters. This is somewhat less accurate but it should be noted that the two tests could not be performed in parallel.

Tests were also done with the modified software that produce RTCM message 9-3 (ABMT). Unfortunately, the performance of the positions using corrections from ABMT was poor. There are some logical problems when selecting three corrections that should be part of a message. This is not solved at the time of writing this paper.

4. Conclusion

The work concerning the implementation initiative of a VRS based DGNSS service can be concluded as follows:

- The realization of the VRS test pilot showed the possibility to build up a DGNSS system based on VRS corrections which is able to fulfill the requirements of IALA Recommendation R-121 (for transmissions in the MF band) and A-124 (for transmissions using AIS message #17).
- The new developed Pre Broadcast Monitoring (PBM) solves the question of providing the integrity monitoring functionality for the VRS solution. Further the PBM can improve the integrity monitoring function, because no unchecked correction data will be transmitted.
- The VRS concept fulfills the requirements of the developed shore based eNavigation architecture by separating functionalities in special services.
- The first results of the VRS test pilot installation on the DGPS radio beacon and AIS inland network are very encouraging.
- An MSK modulator can be implemented by utilizing standard programmable hardware.
- Future work is required in the following fields:
- For the German inland radio beacon network the VRS concept needs to be finalized regarding the question of a local backup in the case of network failure. Such local backup could also be used to provide GNSS raw data to the VRS server.
- The present German VRS concept should be extended to enable remote control of the onsite transmitter and antenna system.
- Further improvement of the existing German VRS software should be performed regarding
  - a full control of all relevant GNSS and DGNSS parameters,
  - included future RTCM message types (DGNSS, Integrity etc.).
- Recapitalization of the existing maritime radio beacon network at the German coast based on DGN, MF and AIS service.
- Further development of the Swedish “proof of concept” in order to prepare the DGPS modernization, with emphasis on
  - Develop the ABMT to transmit RTCM message 9-3
  - Secure the access to corrections from SWEPOS with high availability
  - Perform more tests, preferable on site.

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[6] ITU-R M. 823-3 Technical characteristics of DGNSS from maritime radio beacons in the frequency band 283.5- 315 kHz in region 1 and 285- 325 kHz in Regions 2 and 3.

[1] IALA Recommendation R-135
[2] (Network Transport of RTCM via IP)

69 SHIP DOMAIN OBSERVED IN AIS DATA

Tue Lehn Schiøler. *Rambøll, Denmark*

Radar data and visual observations has since the 1960'ies been used to study how close ship navigators are willing to pass each other. This is of great interest when making a model of ship traffic for example as basis for analysing the behaviour of ships in real time. With the introduction of AIS data it is now much easier to conduct studies involving a large number of observations. The paper presents observed distances between two ships passing each other and ships passing fixed objects based on a large number of AIS registrations. On this basis it establishes a minimum ship domain in which navigators feel comfortable when passing other ships or fixed objects. Hence, estimates of the free space surrounding a ship into which no other ships or object should enter are presented. The presentation will illustrate the results of innovative analyses based on large AIS data sets from the following parts of Danish waters: 1. Great Belt - Around the Great Belt bridge in the Great Belt VTS area. 2. Drogden - Sound VTS area. 3. Fehmarn Belt - Between Denmark and Germany, where a temporary VTS will be monitoring traffic during construction of a tunnel. The observed distances between ships are visualized by intensity plots illustrating the preferred distances by informative colour schemas. This will help clarify the suggested conclusions and provide a basis for discussion and creation of ideas for further work. The minimum ship domain is presented as a comfort ellipse inside which navigators feel comfortable when passing other ships or fixed objects. The dimensions of the comfort ellipse are presented and related to the ship length.

Los datos de radar y las observaciones visuales se han utilizado desde los años 60 para estudiar lo cerca que están dispuestos a cruzarse los navegadores de barcos. Esto es muy interesante cuando se hace un modelo del tráfico de barcos, por ejemplo, como base para el análisis del comportamiento de los barcos en tiempo real. Con la introducción de datos AIS, ahora es mucho más fácil dirigir estudios que implican un gran número de observaciones. La ponencia presenta las distancias observadas entre dos barcos al cruzarse y por barcos que pasan un objeto fijo basado en un gran número de registros AIS. En base a esto, se establece un dominio mínimo del barco en el cual los navegadores se sienten cómodos cuando se cruzan con otros barcos u objetos fijos. Por lo tanto, se presentan cálculos del espacio libre alrededor del barco en el cual ningún otro barco u objeto debe entrar. La presentación mostrará los resultados de análisis innovadores basados en grandes juegos de datos AIS de las siguientes zonas de aguas danesas: 1. Gran Belt—Alrededor del puente de Gran Belt en la zona de Gran Belt VTS. 2. Drogden – Zona de estrecho VTS. 3. Fehmarn Belt – Entre Dinamarca y Alemania donde un VTS temporal realizará un seguimiento del tráfico durante la construcción de un túnel. Las distancias guardadas entre barcos se ven mediante zonas de intensidad que ilustran las distancias preferidas mediante esquemas de color informativos. Esto ayudará a aclarar las conclusiones sugeridas y proporcionará una base para el debate y la creación de ideas para un trabajo posterior. El dominio mínimo de barco se muestra como una elipse de confort dentro de la cual los navegantes se sienten cómodos al cruzarse con otros barcos y objetos fijos. Las dimensiones de la elipse de confort se muestran y están relacionadas con la longitud del barco.

Les données du radar et les observations visuelles sont utilisées depuis les années 1960 pour savoir combien les navigateurs veulent passer près les uns des autres. Ceci revêt un grand intérêt lorsque l'on conçoit un modèle de trafic maritime, par exemple comme base d'analyse du comportement des navires en temps réel. Avec l'introduction des données AIS il est plus facile de mener des études impliquant un grand nombre d'observations. Ce rapport montre les distances observées, dans un grand nombre d'enregistrements AIS, entre deux navires passant l'un près de l'autre ou à proximité d'objets fixes. Sur cette base il définit un espace minimum dans lequel les navigateurs se sentent à l'aise lorsqu'ils passent à proximité d'autres navires ou d'objets fixes. Il présente donc des estimations de l'espace autour du navire dans lequel aucun autre navire ou objet ne doit pénétrer. La présentation illustrera les résultats d'analyses innovantes basées sur un grand nombre de collections de données AIS provenant de différentes zones des eaux danoises : 1. Le Grand Belt – Autour du pont du Grand Belt dans la zone du VTS Grand Belt. 2. La zone du VTS Drogden – Sound. 3. Fehmarn Belt – Entre le Danemark et

l'Allemagne où un VTS provisoire surveillera le trafic pendant la construction d'un tunnel. Les distances observées entre les navires sont visualisées à l'ide de points illustrant les distances préférées à l'aide de schémas de couleurs. Ceci aidera à clarifier les conclusions avancées et servira de base à la discussion et à la découverte d'idées pour des travaux futurs. L'espace du navire minimum est présenté comme une ellipse de confort à l'intérieur de laquelle les navigateurs se sentent à l'aise lorsqu'ils passent près d'autres navires ou d'objets fixes. On en présente aussi ses dimensions rapportées à la longueur du navire.

Paper not available

91 THE IMPLICATIONS OF USING NON-APPROVED PNT DEVICES AT SEA

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The use of smart phones and tablets for positioning and navigation is increasing, not only at sea, but also within other transport sectors. Leisure craft users can use these phones and tablets, but they are not approved for use on SOLAS [1] vessels, although there may be a temptation to use such systems on the bridge of SOLAS vessels.

This paper reports the results of trials carried out on board a GLA vessel with several of these devices and draws some conclusions about their performance and usability. The "apps" reviewed have been developed for the leisure user, to the publishers' specifications. They are often very easy to use, highly configurable and informative. The integration of the many different sensors (GPS, accelerometer, gyros) appears to aid the performance, but affects update rate.

It is interesting to note that e-Navigation will develop greater integration between the various sensors available on the bridge, so there may be lessons to learn from these devices.

El uso de smartphones y tabletas para el posicionamiento y la navegación se está incrementando, no solo en el mar, sino en otros sectores del transporte. Los usuarios de embarcaciones de recreo pueden utilizar estos teléfonos y tabletas, pero no están aprobados para el uso en buques SOLAS [1], aunque puede ser una tentación utilizar tales sistemas en el puente de los buques SOLAS.

Esta ponencia informa sobre los resultados de las pruebas realizadas a bordo de un buque GLA con varios de estos dispositivos y saca algunas conclusiones sobre su utilización y rendimiento. Las aplicaciones revisadas se han desarrollado para el entretenimiento del usuario, según las especificaciones de los editores. Normalmente son muy fáciles de utilizar, altamente configurables e informativas. La integración de muchos sensores diferentes (GPS, acelerómetro, giroscopio) parece ayudar al rendimiento, pero afecta a la tasa de actualización.

Es interesante destacar que la e-Navegación desarrollará una mayor integración entre los diversos sensores disponibles en el puente, de modo que es posible que podamos aprender alguna lección de estos dispositivos.

L'utilisation de smart-phones et de tablettes pour le positionnement et la navigation s'intensifie, non seulement en mer mais aussi dans d'autres secteurs du transport. Les plaisanciers les utilisent, mais ils ne sont pas approuvés sur les navires SOLAS; bien que l'on pourrait être tenté de les utiliser à la passerelle des navires SOLAS.

Ce rapport donne les résultats d'essais faits à bord d'un navire de l'Autorité générale des phares (GLA) avec plusieurs de ces équipements et en tire quelques conclusions sur leurs performances et utilité. Les applications passées en revue ont été développées pour les plaisanciers, selon les spécifications des éditeurs. Elles sont souvent très simples d'utilisation, bien configurées et instructives. L'intégration de nombreux et différents capteurs (GPS, accéléromètres, gyrocompas) semble aider les performances, mais affecte la mise à jour.

Il est intéressant de noter que l'e-Navigation va développer l'intégration entre les différents senseurs disponibles à la passerelle, et il pourrait y avoir des leçons à tirer de ces équipements.

The implications of using non-approved PNT devices at sea

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INTRODUCTION

The General Lighthouse Authorities of the United Kingdom and Ireland (GLAs) comprise Trinity House, The Commissioners of Irish Lights and The Northern Lighthouse Board. Between them, they have the statutory responsibility to provide marine Aids-to-Navigation (AtoNs) around the coast of England and Wales, all of Ireland and Scotland, respectively. AtoNs take many forms, from the more traditional lighthouse to radio navigation systems, including the use of new GNSS when they become available.

While the definition and review of marine user equipment is outside the GLA area of responsibility, the GLA are keen to understand how the mariner is navigating and which systems they are using, in order to assess the impact on both their situational awareness and the effectiveness of GLA AtoNs. As such, given the temptation for smart devices to be used on board SOLAS vessels, it was considered important to understand the implications for safe navigation.

Expected limitations

There are several key differences in the use and installation of type approved equipment when compared to smart devices. When considering type approved equipment, the antenna is normally installed at the top of the mast to ensure the receiver can observe a clear sky view. Conversely, the smart device GNSS antenna is housed within the case and it is difficult to know the orientation. Also the smart device antenna will be attempting to receive signals from satellites whilst within the bridge structure, resulting in greater signal attenuation and multipath.

Another key difference is the level of standardisation used within the design of the receiver and how it interacts with other systems. Type approved systems have to adhere to the IMO GNSS receiver performance standards [2, 3, 4] and the IEC test standards [5]. In addition, the output of approved systems must also adhere to data portrayal guidelines [6] so that the information is provided in a common, clear and consistent manner.

Smart devices are not restricted to these performance standards; however, the result is that it is unclear how these devices have been designed and how they will react in different circumstances. In addition, the manner in which they interact with other systems, along with how their output is presented is generally down to the designer and the market they wish to attract.

Overview of Smart Devices

Smart devices are relatively powerful computers with a multi-core processor, over half a gigabyte of RAM and a large data storage capacity [7, 8, 9]. Inbuilt multi-constellation GNSS receivers can now be found in many smart devices as location based services (LBS) have become an integral part of the user experience on today's mobile devices and consumers expect these services to work wherever their mobile phones do. These receivers are often augmented by other inbuilt sensors, such as accelerometers, gyroscopes and compasses etc. [10]. Signals of cellular and WLAN networks are also widely used for positioning in today's mobile devices [7, 8, 9]; however, these solutions are primarily intended for use in urban areas, where there is a high density of transmissions that can be exploited. Since this study focuses on the use of smart devices at sea, cellular\WiFi based positioning is not considered further.

Another key strength of smart devices is the intuitive and easy to use human-to-machine interface. Smart devices are commonly equipped with high-resolution, high-contrast, touch screens. The use of standard interface control elements across all applications on a given platform also contributes to a consistent and positive user experience. However, the complex design and their intended area of use also imply a number of limitations. Designers of GNSS solutions for smart devices face a range of challenges such as: reduced space; interference from other radio systems integrated in the device; low-cost oscillators; and, poor antennas that often have to be placed in less than optimal locations, such as at the back of the device. The use of combined WLAN\Bluetooth\GNSS antennas is also common [10].

A major limiting factor for the use of smart devices as navigation aids is the battery life. Gathering location data is a power-intensive operation and continuous use of the location engine considerably reduces the running time of the device. To this end, some devices may use the inbuilt sensors to enable intelligent power management of the device's GNSS engine, activating it only when the device senses motion [11] – this function is called sensor aiding within most devices and is the name applied within this paper. Some limitations may also stem from the operating system used in the device. This can be illustrated by considering the two major systems used in today's smart phones and tablets – the Google (Open Handset Alliance) Android and the Apple iOS.

Android is an open-source, Linux-based, operating system built to enable developers to create mobile applications that take full advantage of all resources that a smart device has to offer. Android does not differentiate between the device's core applications and third-party applications; all can be built to have equal access to a device's capabilities. The open-source code and permissive licensing allows the system to be freely modified and distributed by device manufacturers, wireless carriers and enthusiast developers. Additionally, Android has a large community of developers writing applications ("apps") that extend the functionality of devices. Most modern Android-powered devices can acquire a user location through multiple underlying technologies (see above) and software developers have full control over which particular technology is used to obtain the location information [12].

Android devices are capable of providing their location, in terms of latitude, longitude, and time (both UTC and time elapsed since device boot), and may provide other information such as bearing, altitude and velocity. The location also typically includes an estimated accuracy figure (this only concerns horizontal accuracy and is defined by Android as the radius of 68% confidence). Software developers also have access to the raw data from the GNSS engine, including information about the satellites being tracked (azimuth, elevation, PRN, SNR, etc.), as well as the raw NMEA data from the GNSS receiver [13].

The iOS operating system was developed by Apple for use on iPhone, iPod touch and iPad devices and Apple does not licence its installation on other (non-Apple) hardware. The system and related services have been meticulously designed to give a consistent user experience.

Apple's close control over the software means that application developers (and users) are somewhat restricted in terms of how they interact with the device's component parts and what information they can access. This is due to Apple's layered architecture which means that the software that application developers create rarely talks to the underlying hardware directly. Instead, it communicates with the hardware through a set of well-defined system interfaces [14]. This method of abstraction generally makes it easier to create applications as it reduces the amount of code that needs to be written; however, it also abstracts out lower-level technologies, and sometimes may completely mask those technologies from the developer. Location services on the iOS platform serve as an example of such masking.

iOS applications obtain location information by using what Apple call the Core Location framework, which estimates the location and heading of the device by using data from the built-in cellular, Wi-Fi, GNSS and magnetometer hardware [15]. However, in contrast to Android, application developers have no direct control over (and generally no knowledge of) which technology the framework uses to obtain the position and heading information.

The iOS provides the user with the geographical coordinates and altitude of the device's location along with values indicating the accuracy of the measurements and when those measurements were made. Information about the speed and course on which the device is moving is also reported. In addition, values for true and magnetic north are presented. Unfortunately, neither NMEA data, nor the status of the GNSS engine and satellites information, is available on iOS.

TESTING

Two smart phones and a tablet PC were selected for these investigations. Each device was tested under static conditions against a survey-grade GNSS receiver. Ship trials were then conducted: the units were taken onto the bridge of a vessel, as if to be used to navigate. Data from each unit were extracted and analysed against the ship's bridge systems in order to provide a performance comparison. The trials on the vessel included static and dynamic comparisons.

Devices under Test (DUT)

After reviewing the many different devices on the market, the following three were chosen for testing based on technical reviews and popularity with users: Samsung Galaxy S III; Apple iPhone 4S; and an Apple iPad 4G. The specification of each device used in this study is shown in ***Table 1***, from which it can be seen that the devices are all based on similar hardware.

Each tested device is equipped with a multi-constellation GNSS receiver on a chip. It is reported that the chip used in the Samsung Galaxy is capable of tracking SBAS satellites, as well as

Key Features	DUT		
	1	2	3
Model	Samsung Galaxy S III	Apple iPhone 4S	Apple iPad 4G
OS	Android 4.0.4	iOS 5.1	iOS 5.1.1
CPU	ARM Cortex-A9, quad-core 1.4 GHz	ARM Cortex-A9, dual-core, ~ 800 MHz	Apple Swift, dual-core, 1.4 GHz
RAM	1024 MB	512 MB	1024 MB
Storage	16 GB	16 GB	16 GB
Location sensors	assisted GPS & GLONASS (WiFi and celluar not mentioned)	assisted GPS & GLONASS, digital compass, Wi-Fi, cellular	assisted GPS & GLONASS, digital compass, Wi-Fi, mobile data
Other sensors	accelerometer, geo-magnetic, gyro, light, pressure	three-axis gyro, accelerometer, proximity, light	three-axis gyro, accelerometer, light
GNSS IC	Broadcomm BCM47511	Qualcomm MDM6610	Not known
Connectivity	quad-band HSDPA / HSUPA, quad-band EDGE/GPRS, WiFi (a/b/g/n), Bluetooth 4.0	quad-band UMTS / HSDPA / HSUPA, quad-band GSM / EDGE, WiFi (2.4 GHz) Bluetooth 4.0	dual-band LTE, quad-band UMTS / HSPA, quad-band GSM / EDGE, WiFi (a/b/g/n), Bluetooth 4.0
Battery capacity	7.98 Wh	5.3 Wh	42.5 Wh

Table 1: Characteristics of the devices under tests (DUT) [7, 8, 9, 16, 18]

using assisted GPS and GLONASS [16, 17].

For these investigations, no SBAS corrections were used. All of the devices tested support both standalone and assisted GNSS modes of operation. The exact make and model of the GNSS chip on the iPad 4G is unknown to the authors, but it seems reasonable to assume that the solution is analogous to that employed in the iPhone. All devices include a three-axes MEMS accelerometer, angular rate sensor (gyroscope), and a magnetometer. The Samsung Galaxy also includes an atmospheric pressure sensor to aid in height measurements [7, 8, 9].

As pointed out in the preceding section, one of the main deficiencies of smart phones and tablets that hinder their use as a navigation aid, is the limited battery time. With power consumption between 1 W and 2 W [18] and battery capacities typically between 5 Wh and 8 Wh, a smart phone that is actively being used for navigation is unlikely to remain in operation for more than a few hours. For this reason, external battery packs (Powertraveller™ Power Gorilla) were used during the trials, which allowed continuous data logging over the period of two to three days.

Applications Used

The smart phones use different operating systems and therefore require different applications. A wide range of location-based applications are available for both the Android and iOS platforms, freely or for purchase.

Developers include companies well established in the field of navigation (such as Navionics, Transas, or Garmin) as well as numerous enthusiast programmers. As part of this study, over 20

Key Features	Application	
	Ultra GPS Logger	SensorData
Operating system	Android	iOS
Data available for logging	raw NMEA data from the GNSS receiver	3D acceleration, 3D gyro data, location data (latitude, longitude, horizontal accuracy, altitude, course, speed, time), proximity sensor data
Output format	text file, GPX, KML	CSV
Sample interval	1 s – 24 hrs	10 ms – 100 sec
Other features	logging by time or distance travelled	data streaming using UDP
Cost	free	£5.99

Table 2: Applications used for data logging during static trials [19, 20]

applications for both platforms were tested, following which 4 were selected for use in the trials. The initial testing revealed a number of issues, some of which are briefly described in the Results section of this paper.

The applications used within this project can be divided in two categories: sensor data loggers, and marine charting application. The sensor loggers usually have no mapping or navigation functionality, however, they often allow more control over the use of the GNSS engine and the other sensors, and generally provide more detailed sensor information than the charting software. Two sensor loggers were used in the static tests (see below) and ***Table 2*** summarises their key characteristics.

The Ultra GPS Logger is a feature-rich location data logger for GPS\GLONASS enabled Android devices. One of the most attractive features of this application is the ability to log raw NMEA data from the devices' GNSS chip. From this data, information on the position, time, number of satellites in use (SVs), HDOP, Signal-to-Noise Ratio (SNR), and other parameters of interest can be extracted.

The Sensor Data application provides access to data from all the position and motion sensors in the iPhone and iPad. Location data reported by the application include latitude and longitude coordinates, altitude, course and speed. The horizontal accuracy parameter can also be recorded, although the algorithm used to determine this value is not defined.

The second group of applications used in this project are maritime charting applications. Charting applications are becoming increasingly popular among leisure craft users and, while none of these "apps" have IMO approval, there are indications that they are also being used on commercial vessels [21]. These applications are often very easy to use and informative. Common features include: routes and waypoints creation, recording of tracks, information on chart objects (AtoNs, wrecks, points of interest), and tide and current predictions. Unfortunately, charting applications generally allow very little or no control over the sensors used for positioning and they often have limited logging capabilities (only basic location data are logged with the inability to set the sampling rate, etc.) which hinders performance analyses.

Two charting applications were used in the dynamic trial to record the track followed by the vessel (see below). ***Table 3*** summarises the key characteristics of these applications.

Key Features	Application	
	Nautical Charts-UK/IRL	Transas iSailor
Operating system	Android	iOS
Charts	raster, derived from UKHO data, re-projected for WGS84	vector, Transas TX-97
Data available for logging	latitude; longitude; altitude; speed; time	latitude; longitude; time
Output format	GPX	GPX, KMZ, KML
Sample interval	unknown; probably based on time	unknown; probably based on distance travelled
Other features	voice-enabled route assistant; distance-bearing tool; POI; track analysis	routes; waypoints monitoring (course, distance, XTE, ETA); information on chart objects (e.g. AtoNs, wrecks); range-bearing line
Cost	£15.49	free application (w/o charts); chart folios available through in-app. purchase, around £12 per folio

Table 3: Applications used location data logging during dynamic trials [22, 23]

The Nautical Charts UK/IRL application for Android offers access to raster charts derived from the United Kingdom Hydrographic Office data. In addition, Point of Interest (POI) layers can be displayed containing information on AtoNs, harbour facilities, obstructions, etc. The iSailor application for iOS devices uses detailed vector charts, again complemented with information on chart objects both on the water and ashore. Both applications also offer basic navigation tools such as an electronic range and bearing line, and enable real-time waypoint and navigation data monitoring.

Static Trials

Two sets of static trials were conducted. Firstly, the performance of each device was evaluated under open-sky conditions against a known position (known to millimetre level) as calculated using a Septentrio PolaRx2 dual-frequency surveying GNSS receiver. During these tests the DUT was placed in a protective casing and installed on the roof of the Trinity House office building in Harwich, UK, from which there was generally a clear sky view, with only a minor obstruction to the east. Sensor data from each DUT was collected over a period of two days and subsequently processed using software developed in house to calculate the reported accuracy.

The second set of trials was conducted onboard a GLA vessel, THV Alert, while she was moored alongside Trinity Pier in Harwich. For these trials, the DUTs were installed on the bridge of the vessel, left lying on the console (***Figure 1***). The orientation of the DUTs was arbitrary; however all of the units were placed face up to simulate being used. Approximately two hours worth of data were collected for each device and the performance of the units was evaluated against the ship's DGPS position.

The position offset of each unit relative to the location of the DGPS antenna was determined from the ship's drawings, and the position biases in the DUT data were eliminated through post-processing using software developed in the MATLAB® environment. Heading information needed for the elimination of the offset was obtained from the ship's gyrocompass. The measurement uncertainty associated with the reference coordinates, taking into account uncertainties in the DGPS measurements, ship's heading and position offsets relative to the DGPS antenna is estimated to be at the meter level.

Dynamic Trial

The dynamic trial was conducted onboard THV Alert while she was manoeuvring in the River Stour Estuary, near Harwich, UK. The DUTs were installed on the bridge of the vessel in the same manner as in the static trials. The true position of the vessel was obtained through the use of the vessel's survey equipment (PosMV) which combines data from two DGPS receivers and an inertial measurement unit (IMU). The position offset of each unit relative to the zero reference of the vessel was determined from the ship's drawings, and the position biases in the DUT data were eliminated through post-processing. Heading data needed for the elimination was provided by the PosMV system. The measurement uncertainty associated with the truth system, taking into account uncertainties in the PosMV measurements and DUT position offsets is known to within 1 metre.

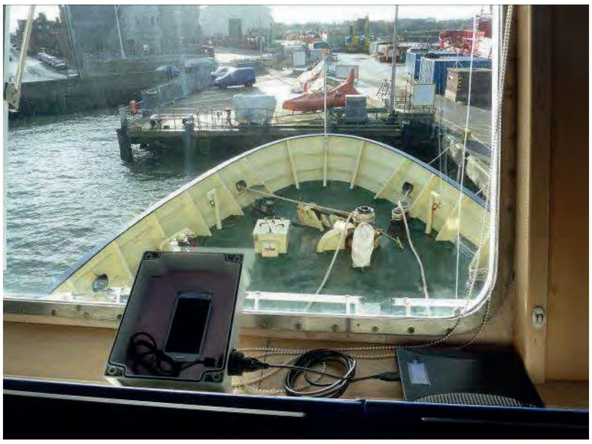

Figure 1: Static trials onboard THV Alert

RESULTS

When considering the accuracy results from the various tests it has to be noted that we expect a poorer accuracy when the devices are used within the bridge structure. One would reasonably expect the signals to be attenuated and for the effect of multipath to be greater. There were other aspects which were not expected, including periods of software instability, intermittent reporting periods and erroneous time reporting.

Issues

During the initial testing and selection of applications several issues with software instability were experienced which included unexpected termination of data logging and application lock-ups with a subsequent loss of data.

Erroneous course information was observed during the dynamic trials. ***Figure 2*** shows the same moment in time when the vessel was returning to port. The left image is a photograph of the vessel Electronic Chart Display and Information System (ECDIS) on which the vessel outline can be seen heading south, onto the berth (note the ECDIS image is North up). The right image is a screen capture from the iPad at the same time. The red dotted line indicates the true direction of travel; however the vessel heading is indicated as directly up and not towards the berth. (Note the iPad image is shown head up).

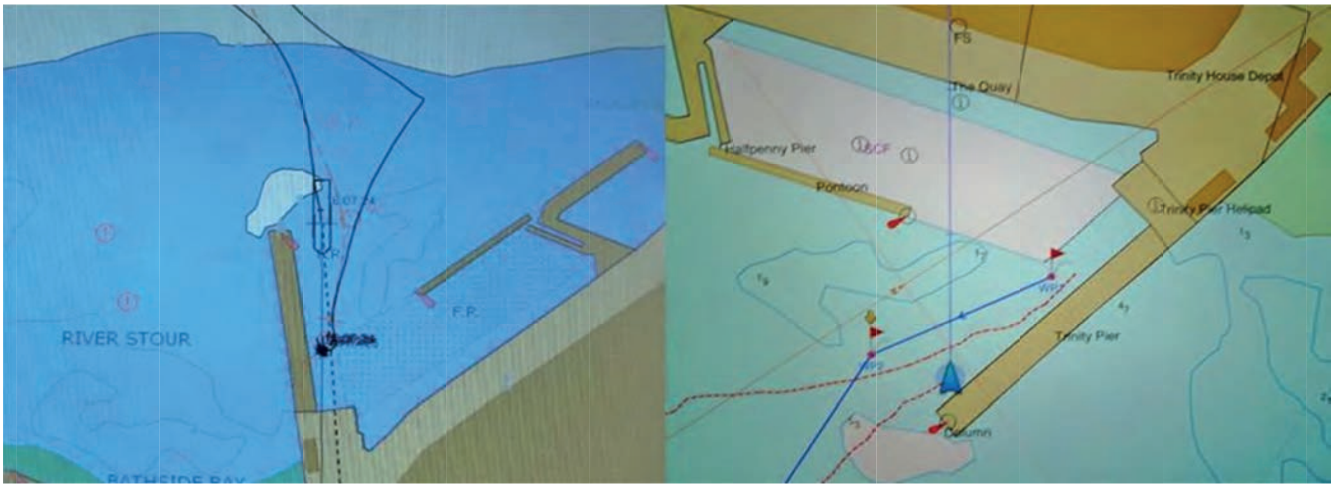

Figure 2: Comparison of the vessel's ECDIS display (left) compared to the iPad display (right) as the vessel approached the quay. The iPad display shows an incorrect vessel heading

Unfortunately, none of the charting applications allowed us to set the position update rate. The result is shown in ***Figure 3***, where the Samsung device (dark blue) appears to output data every second, along with the PosMV system (green), whereas the position outputs for the iPhone (magenta) and iPad (cyan) are intermittent.

The last issue of note relates to the presentation of time within the devices. The Android applications seem to derive UTC time from the integrated GNSS receiver, whereas the iOS applications appear to use the device time but may report it as UTC, depending on the application.

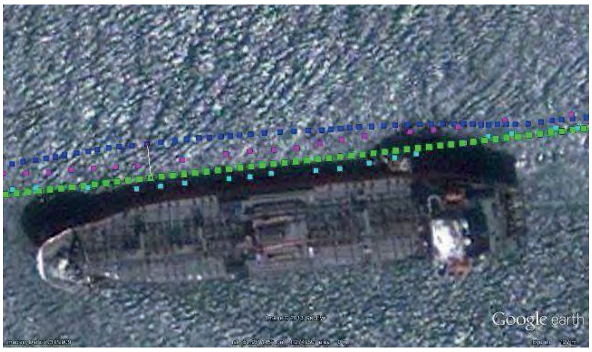

Figure 3: Google Earth plot with the position updates from each of the devices and the PosMV truth position; Samsung (dark blue), iPhone (magenta), iPad (cyan) and Pos MV truth (green)

Static Trials

The results of the open-sky trials are summarised in ***Table 4***. The position bias refers to the distance between the surveyed position and the average reported position. The iOS devices provide an estimate of the position error, although it is unclear how this is calculated. The third row in the Table relates to the percentage of position fixes that fell within this reported position error. Further, the table shows the median SNR, number of SVs used in the position solution and HDOP. As discussed above, this data is only available for the Android device (columns 1a, 1b). Finally, the table shows the service availability figures, calculated as a percentage of the number of position updates expected in a given time given a known update rate.

As discussed in the introductory section, Android devices allow some control over the sensor aiding function. In order to illustrate the effect of the aiding, two datasets were collected for the Samsung smart phone, one with the aiding disabled and one with this option enabled. The results of these tests are summarised in columns 1a and 1b, respectively. To the best of the authors' knowledge, iOS does not allow the possibility to switch the sensor aiding off, and therefore only one dataset for each iOS device was collected (columns 2 & 3).

It was noted that enabling sensor aiding on the Samsung device, the number of reported positions reduces. This trend is also observed on the iOS devices, with the iPad providing few unique positions, although it provided the best accuracy performance. With aiding enabled the Samsung device, using the Ultra GPS logger application, failed to provide an output while stationary.

Aiding is enabled by default on the iOS devices; however, they continue to report the last calculated position when stationary. Note the iPad reports significantly fewer unique positions than the

Parameter	DUT			
	1a	1b	2	3
Accuracy, 95% (m)	11.9	9.5	5.2	4.5
Position bias (m)	2.2	1.5	1.5	1.9
Perc. of fixes within uncertainty radius	n/a	n/a	95.00	97.15
SNR, median (dB)	39	38	n/a	n/a
No. of SV, median	12	16	n/a	n/a
HDOP, median	0.6	0.6	n/a	n/a
Availability (%)	100.00	?	100.00	99.99

Table 4: Abbreviated results of the open-sky static trials (1a: sensor aiding disabled, 1b: sensor aiding enabled)

Parameter	DUT		
	1	2	3
Accuracy, 95% (m)	13	20	4
Residual position bias (m)	3	14	2
Perc. of fixes within uncertainty radius	n/a	1.76	99.64
SNR, median (dB)	25	n/a	n/a
No. of SV, median	18	n/a	n/a
HDOP, median	0.8	n/a	n/a
Availability (%)	100.00	100.00	100.00

Table 5: Abbreviated results of the static trial onboard THV Alert (DUT position offsets eliminated through post-processing)

iPhone and therefore the results obtained in this case may not be statistically significant.

Static data was also recorded with the devices installed within the bridge of the vessel. For these tests each device was arbitrarily placed around the navigator's position on the bridge and data was recorded using the same logger apps. The abbreviated results are shown in ***Table 5***.

A comparison of ***Table 4*** and ***Table 5*** reveals a significant drop in SNR compared to the values measured under open-sky conditions. The median SNR (calculated over all signals received during the measurement period and all epochs when each particular signal was available) dropped by 14 dB relative to the value measured under open-sky conditions. This is likely to be a result of signal attenuation as it passes through the bridge structure and was expected.

Surprisingly, the impact of the decreased SNR on the performance of the units was not as clear-cut. A significant deterioration in accuracy was only observed with the iPhone which showed a 14 m bias in the reported position and a marked increase in the scatter of the position fixes when installed inside. The bias was a likely result of multipath conditions and signal masking specific to the location of this particular device. However, the Samsung and iPad devices demonstrated practically the same level of accuracy inside the ship as they had shown during the open-sky trials.

Another surprising result of the static trials concerns the number of SVs used in the position solution. Reviewing the median number of SV's employed in the position solution by the Samsung for the static trials on the roof of the building (***Table 4***), 12 satellites were used when aiding was disabled and 16 used when aiding was enabled. The device then used 18 satellites when fitted in the ship. This seems to imply that the device is able to control the number of channels used within the receiver depending on the conditions or whether it is attempting to save power. All devices demonstrated a high level of availability during the testing. This is not too surprising given that the ability to locate the user anytime anywhere is one of the key design objectives for smart devices.

Figure 4: Route followed during the dynamic trial (green) with data from all DUTs overlaid

Dynamic Trial

Because of time restrictions on the trial vessel, dynamic data was only recorded for around an hour; therefore, the results presented are indicative of the level of performance to be expected. The trial route included a rough "figure of 8" manoeuvre when the vessel turned around to head back to port but noticed a problem with a mooring buoy in the channel and slowed to take a closer look. This was an unplanned manoeuvre but introduced an interesting effect that might have been missed otherwise.

The applications used to record the position were quite limited in the information they provided: essentially latitude, longitude and time. They were also limited in terms of user configuration options, which meant that the position update rate was set by the application and resulted in irregular outputs as discussed previously. When calculating the accuracy results, the recorded position of each device was compared to the true position for that epoch.

It can be observed that the position errors are comparable with the static measurements made on board, and *Table 6* details the accuracy figures, along with the worst-case position error for each device. However it can be noted that the update rate, and therefore the density of positions changes with time, with fewer positions plotted between 15:45 and 15:55. This period corresponds to when the vessel slowed down to check the mooring buoy, and it can be seen how the update rate is related to the speed of the vessel, for all devices. Incidentally, the iPad appears to have stopped providing any position information during this period.

Parameter	DUT		
	1	2	3
Accuracy, 95% (m)	9	18	20
Max. pos. error (m)	~ 18	~ 45	~ 40

Table 6: Abbreviated results of the dynamic trial onboard THV Alert (DUT position offsets eliminated through post-processing)

When reviewing the performance results for the dynamic trials, the Samsung device accuracy was remarkably good, with practically no difference in performance when compared to the open sky static measurements. Without completing further trials, it is not clear whether this is repeatable or should be expected for different locations on the bridge.

DISCUSSION

The results of these trials were very interesting and while it appears that the use of these devices is on the increase and that their accuracy performance is quite mixed, in order to be approved for use on a SOLAS vessel they would need to meet the relevant IMO performance requirements, as well as other aspects of the test specifications.

IMO Resolution A.1046 on the Worldwide Radionavigation System [24] provides the requirements for vessel radionavigation systems when navigating in ocean waters and harbour entrances, harbour approaches and coastal waters. The (more stringent) requirements for harbour entrance and approach are summarised in *Table 7*.

Accuracy (95%)	Integrity: T. to Alarm	Availability	Continuity (15 min)	Update Interval
≤ 10 m	10 s	> 99.8%	≥ 99.97%	≤ 2 s

Table 7: IMO performance requirements for harbour and coastal operations [24]

If we consider the accuracy requirement of less than 10 m 95%, then the Samsung unit appears to meet that, under both static and dynamic conditions; albeit from a limited data set. The iOS devices do not meet this requirement, with reported accuracies in the order of 18 m and 20 m 95%.

When considering the integrity requirement of being able to provide a time to alarm within 10 s, no device tested provides any integrity alarms, and therefore they do not meet this requirement. This may change in the future, with the potential to use the reported accuracy as some type of protection error, or potentially through the use of augmentation, whether via SBAS or other means.

The IMO definition of availability stipulates that the service is only available when it meets both the required accuracy and integrity elements. As no device meets the integrity component, they cannot meet the availability requirement. The continuity requirement is similar as it is deemed that the service must be available at the start of the continuity period and as no device can meet the availability requirement, they cannot meet the continuity requirement as defined either. The reported position update rate either varies with the vessel's speed during the dynamic trials or can be affected by sensor aiding and therefore may not meet the IMO requirement of 2 s.

So in general, these devices do not meet the IMO performance requirements and this is not surprising as they were never designed to. However there are aspects that do work quite well and shouldn't be ignored.

The ability to use and integrate the different sensors, as well as different GNSS constellations, has clearly improved the position solution, even though it appears to have been developed to save power. Such integration could be beneficial to vessels in the future, particularly within the e-Navigation context where more information is brought together on the bridge.

Ship systems have to adhere to the performance standards for data portrayal. These standards could benefit from the way in which the apps are developed to be easy to use, intuitive and easily updated.

CONCLUSIONS

From this study it can be concluded that from the devices studied, smart phones and tablets do not meet the IMO performance requirements for navigation in port and harbours.

It was noted that the accuracy performance is generally better than expected, but degraded when used on the bridge of the vessel; and that the use of sensor aiding can improve the accuracy, but can affect the position update rate.

It is also noted that apps are easy to use and update, give a clear position on the chart, but may provide some incorrect data, although this is considered to be app specific.

In general, the GLA conclude that caution should be exercised in using this equipment on any vessel and it should be borne in mind that they are not approved for use on SOLAS vessels. ■

NOTICE

The GLA do not endorse or approve the use of any of these devices and acknowledge that other smart devices and applications are available.

ACKNOWLEDGMENTS

The authors would like to acknowledge the crew of THV Alert for their understanding and time in conducting the dynamic trials.

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30 AIS AIDS TO NAVIGATION: DEVELOPMENT OF IMO POLICY AND NEW SYMBOLS

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AIS Aids to Navigation (AtoN) is effective and useful tool for the safety of navigation. However, because of the latest technology, the use of AIS AtoN, especially virtual AIS AtoN, requires the policy that is understandable for users and the new symbols that clearly show the type of AIS AtoN in order to avoid the confusion of users.

Therefore, the Japan Coast Guard proposed the development of policy and new symbols for AIS AtoN to IMO and coordinated the Correspondence Group (CG) for two years. Although the draft policy developed by the CG was approved by the IMO NAV Sub-Committee, there were some differences between the draft IMO policy and the IALA Recommendation and Guideline on virtual AtoN. These differences will be applicable for other future virtual AtoN and thus a study on .the IMO policy will also be helpful for the development of the virtual AtoN.

The paper describes the discussion at the CG and the NAV Sub-Committee, explains the differences and identifies the subject which is needed to be considered for the development and deployment of the future virtual AtoN.

Los dispositivos AIS de Ayudas a la Navegación (AtoN) son una herramienta eficaz y útil para la seguridad de la navegación. Sin embargo, debido a la última tecnología, el uso de AIS AtoN, especialmente AIS AtoN virtuales, requiere una política que puedan comprender los usuarios y nuevos símbolos que muestren claramente el tipo de AIS AtoN para evitar la confusión de los usuarios.

Por este motivo, la Guardia Costera Japonesa propuso a la IMO el desarrollo de una política y nuevos símbolos para las AIS AtoN y coordinó el Grupo de Correspondencia (CG) durante dos años. Aunque el anteproyecto de política desarrollado por el CG fue aprobado por el Subcomité NAV de la IMO, hubo algunas diferencias entre el anteproyecto de política de la IMO y la Recomendación y Directriz sobre AtoN virtuales de la IALA. Estas diferencias serán aplicables para otras AtoN virtuales futuras. Un estudio sobre la política de la IMO también será de ayuda para el desarrollo de AtoN virtuales.

La ponencia describe el debate en el CG y el Subcomité NAV, explica las diferencias e identifica la materia que debe considerarse para el desarrollo y la implantación de las futuras AtoN virtuales.

L'aide à la navigation AIS est un outil efficace et utile pour la sécurité de la navigation. Cependant, en raison des progrès de la technologie, l'aide à la navigation AIS, et particulièrement l'aide à la navigation AIS virtuelle, demande une politique compréhensible par les utilisateurs et de nouveaux symboles qui identifient clairement le type d'aide à la navigation AIS afin d'éviter de semer la confusion chez les usagers.

La Garde côtière japonaise a proposé à l'OMI le développement d'une politique et de nouveaux symboles et coordonné le Groupe de travail par correspondance (CG) pendant deux ans. Bien que le projet de politique du CG ait été approuvé par le Sous comité NAV de l'OMI, il y avait quelques différences entre le projet de l'OMI et la Recommandation et le Guide de l'AISM sur les aides à la navigation virtuelles. Ces différences seront applicables aux futures aides à la navigation virtuelles ; il serait donc utile, pour le développement des futures aides à la navigation virtuelles, d'étudier la politique de l'OMI.

Le rapport présente les discussions au sein du CG et du Sous comité NAV, explique les différences et identifie les points qui devraient être reconsidérés pour le développement et le déploiement des futures aids à la navigation virtuelles.

AIS aids to navigation: development of IMO policy and new symbols

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Background

After ITU issued the standard of universal shipborne automatic identification system, ITU-R M.1371, in 1998, several AIS derivative systems were developed and ITU amended the standard in 2001. New Recommendation ITU-R M.1371-1 assigned Message 21 as “Aids to Navigation Report” and AIS Aids to Navigation (AIS AtoN) station was developed.

In parallel with the development of technical standard on AIS by ITU, IMO also developed some related standards and guidelines. One of them was SN/Circ. 243 “Guidelines for the presentation of navigation-related symbols, terms and abbreviations” in 2004. This guideline assigned a diamond with crosshair centered as the symbols for AIS AtoN. ***Table 1*** shows the symbols.

Distinction between real AIS AtoN and virtual AIS AtoN is to find if a chart symbol exists with the AIS AtoN symbol or not. However, when AIS AtoN symbols appear on a radar display, the distinction is usually impossible since ordinary radar display does not show chart symbols. In addition, the AIS AtoN symbol does not show the type of AtoN such as lateral, cardinal, safe water, isolated danger which is important for the safety of navigation.

Japan Coast Guard (JCG) and Japan Aids to Navigation Association (JANA) carried out a study on usage of virtual AIS AtoN from 2005 to 2008. In the study, new AIS AtoN symbols were developed in order to distinguish between real and virtual AIS AtoN and to also show the type of AIS AtoN. The result of study showed that virtual AIS AtoN could contribute to both safety and efficiency of navigation with appropriate presentation on navigational display. Based on the study, JCG decided to propose IMO to develop new symbols for AIS AtoN.

MSC 86

In 2009, Japan proposed a new work programme for Sub-Committee on Safety of Navigation (NAV) to 86th Session of Maritime Safety Committee (MSC 86) of IMO in order to develop new symbols for AIS AtoN[1]. In this proposal, Japan introduced the draft of new symbols as shown in ***Table 2 on the next page.***

Responding the proposal, Comité International Radio-Maritime (CIRM) submitted comments that pointed out the inappropriateness of the draft symbols[2] .

At MSC 86, Japan explained the reason and intention of the proposal that since the present IMO symbols were not sufficient to clearly distinguished virtual from real AIS AtoN and to show the type of the AtoN, therefore the development of new symbols should be necessary and Japan would welcome the improvement of the draft symbols in order to solve the inappropriateness pointed out by CIRM. Although described the problems of the draft symbols, CIRM expressed that CIRM understood the intention of Japanese proposal and would cooperate the development of new symbols. IHO commented that navigation-related symbols including AIS symbols should be clearly different from chart symbols and therefore the draft symbols were not appropriate. But IHO also expressed their support to the proposal. After the discussion, many member countries and observers supported the proposal and MSC 86 approved the new work programme for NAV to develop new symbols for AIS AtoN.

NAV 56

After the decision of MSC 86, NAV 56 added the new work programme “Development of new symbols for AIS AtoN” to its agenda and was held in 2010. At NAV 56, Japan again submitted a paper that introduced the improved draft new symbols and the results of radar simulation tests[3]. ***Figure 1*** shows the improved draft new symbols and ***Figure 2 and 3*** show the result of radar simulation tests.

Regarding the Japanese paper, IHO, the United Kingdom (UK) and Denmark submitted their

Topic	Symbol	Description
AIS Based AtoN Real Position of Charted Object		Diamond with crosshair centred at reported position. (Shown with chart symbol. Chart symbol not required for radar.)
AIS Based AtoN Virtual position		Diamond with crosshair centred at reported position.

Table 1: Symbols for AIS AtoN by SN/Circ. 243

Type of AtoN		Real AIS AtoN		Virtual AIS AtoN	
		Floating	Fixed	Floating	Fixed
Cardinal Marks	North Cardinal Marks	BY AIS	BY AIS	BY V-AIS	BY V-AIS
	East Cardinal Marks	BYB AIS	BYB AIS	BYB V-AIS	BYB V-AIS
	South Cardinal Marks	YB AIS	YB AIS	YB V-AIS	YB V-AIS
	North Cardinal Marks	BY AIS	YB AIS	BY V-AIS	BY V-AIS
Lateral Marks (Region B)	Port hand Marks	G AIS	G AIS	G V-AIS	G V-AIS
	Starboard hand Marks	R AIS	R AIS	R V-AIS	R V-AIS
	Preferred channel to Port	RGR AIS	RGR AIS	RGR V-AIS	RGR V-AIS
	Preferred channel to Starboard	GRG AIS	GRG AIS	GRG V-AIS	GRG V-AIS
Isolated danger Marks		BRB AIS	BRB AIS	BRB V-AIS	BRB V-AIS
Safe water Marks		R W AIS		R W V-AIS	
Special Marks		Y AIS	Y AIS	Y V-AIS	Y V-AIS
Lighthouse		AIS	AIS	V-AIS	V-AIS

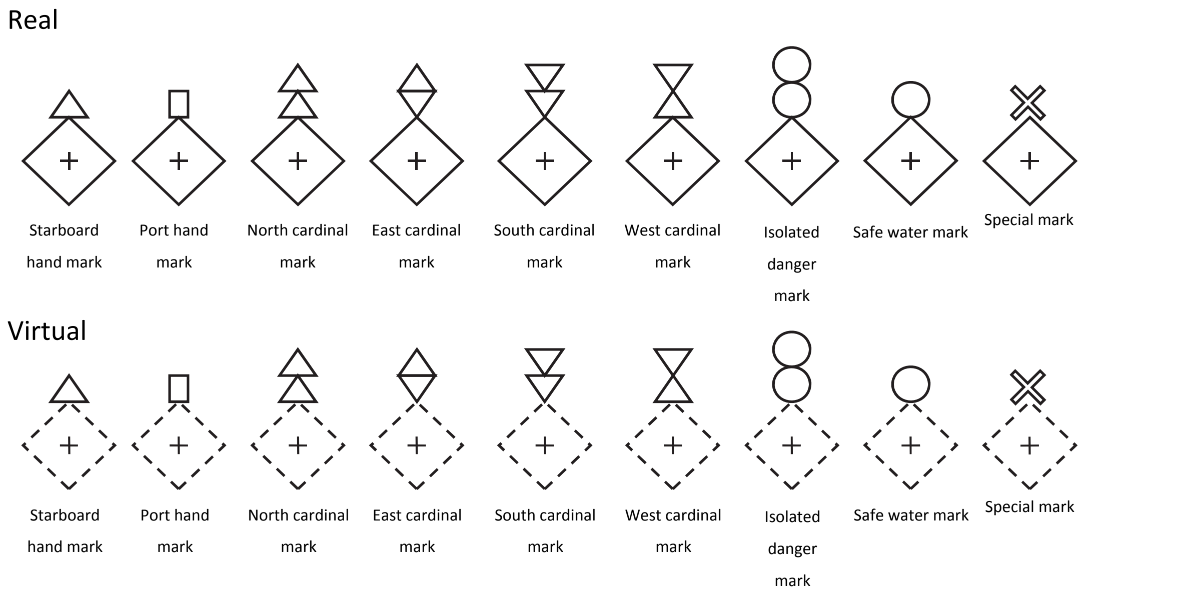


Figure 1: Improved draft new symbols for AIS AtoN at NAV 56

comments. IHO commented that while IHO was satisfied with the improved symbols, the IMO policy on the usage of AIS AtoN should be needed[4]. UK also commented that there had already been the symbol for virtual AIS AtoN developed by IEC that a letter "V" was superimposed in the symbol of AIS AtoN defined by SN/Circ. 243[5]. Denmark commented that while admitting the improvement of new draft symbols developed by Japan, the overall policy on the use of AIS AtoN was needed and an addition of symbols on Emergency Wreck Mark was also needed[6]. ***Figure 4*** shows the Danish proposal of draft symbols on Emergency Wreck Mark.

There were also information papers submitted by IALA and People's Republic of China. IALA informed that IALA already developed its Recommendation on Virtual Aids to Navigation[7]. China introduced their project regarding the use of Electronic Chart System and AIS[8].

During the discussion at NAV 56, responding to the Japanese paper, the Chair proposed the establishment of Correspondence Group for the

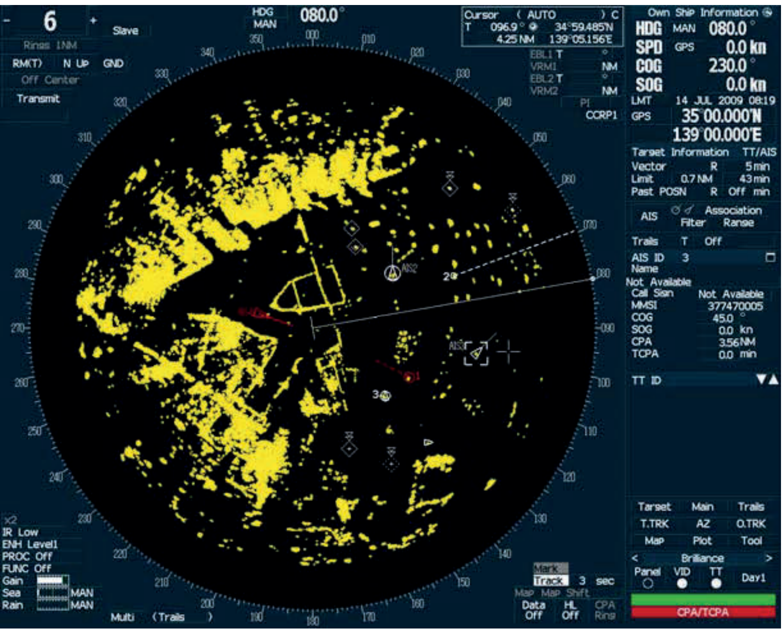


Figure 2: Radar simulator display (SXGA)

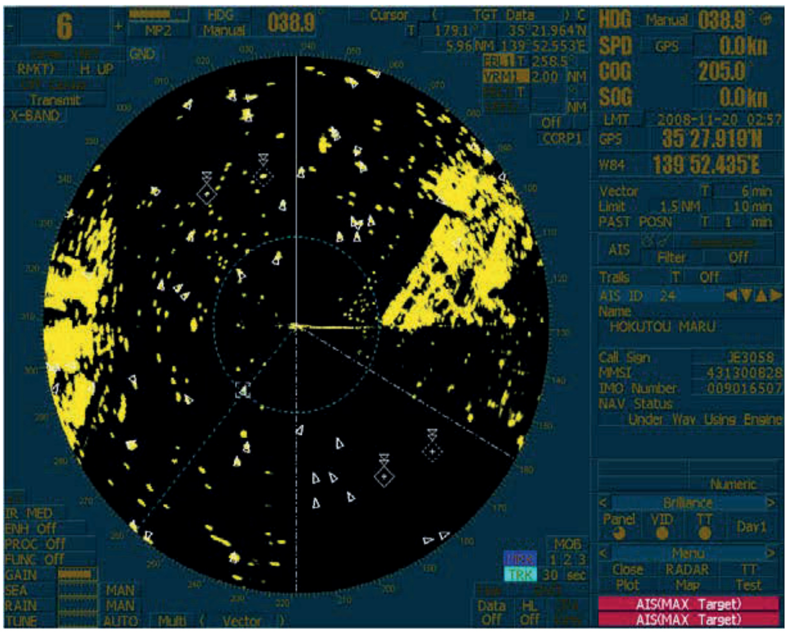


Figure 3: Radar simulator display (XGA)

development of new symbols. However, while expressing their appreciation to the Japanese effort, some countries and organizations expressed concerns that there were no IMO policy on the use of AIS AtoN and development of IMO policy was necessary before the development of new symbols. As a result, NAV 56 decided to not develop the new symbols unless IMO policy was developed. At the end of discussion, Japan commented that Japan understood the concerns expressed by the members and would consider including the development of the policy under the agenda.

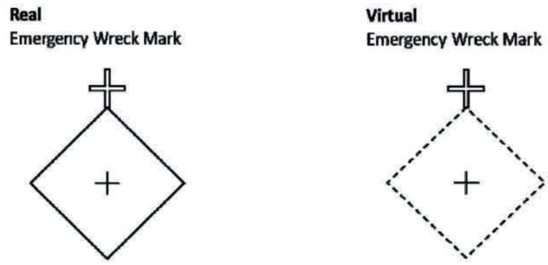


Figure 4: Draft new symbols for AIS AtoN of Emergency Wreck Mark

MSC 88

Responding the result of NAV 56, Japan and the United States (US) proposed the expansion of the agenda "Development of new symbols for AIS AtoN" in order to include the development of IMO policy to MSC 88[9]. Chile also submitted a comment paper that proposed inclusion of monitoring of remote AIS AtoN by satellite into the development of IMO policy[10].

At the discussion of MSC 88, many countries and organizations supported the both proposal and MSC 88 agreed the expansion of the scope of the work "Development of new symbols for AIS AtoN" to include the development of IMO policy. However there were also cautions expressed by some countries that the subject of satellite monitoring of AIS should be limited to AIS AtoN only since the position of IMO regarding the satellite monitoring of AIS ship station is no commitment.

NAV 57

Japan again submitted a paper that described 8 discussion points in the IMO policy, work plan and proposed the establishment of the Correspondence Group to NAV 57[11]. The 8 discussion points of the IMO policy on the use of AIS AtoN are as follows:

1. definition;
2. application or usage;
3. performance standards;
4. operation/management;
5. monitoring;
6. risks and limitations;
7. display of symbols; and
8. training.

The work plan is that the development of the policy is from NAV 57 to 58 and the development of the new symbols is from NAV 58 to 59. China also submitted a paper that proposed new symbols developed by China[12]. Table 3 shows the new symbols for AIS AtoN developed by China.

IALA submitted a paper that introduced IALA documentation, Recommendation and Guideline, related to AIS and AIS AtoN[13].

There were many supports to Japanese proposal and the establishment of the Correspondence Group was approved under the coordination by Japan. Regarding the draft new symbols proposed by China, some members expressed appreciation but commented that the development of new symbols should be discussed after the development of policy as the work plan proposed by Japan. The Terms of Reference for the Correspondence Group was as follows:

> *The Correspondence Group was instructed to consider documents NAV 56/11, NAV 57/8 and NAV 57/8/1, including comments made in Plenary and any other relevant information, develop a first draft of a policy for AIS AtoN and submit a report for consideration and review by NAV 58.*

First Correspondence Group

Sixteen states and seven organizations participated in the first Correspondence Group. The Group discussed the definition first. There were two opinions on the definition. One was to define AIS AtoN as Message 21 "Aids to Navigation Report" of ITU-R M.1371 (series) so the AIS AtoN would transmit single point information as conventional Aids to Navigation provides. Another was to expand the first definition and include the Application Specific Messages so the AIS AtoN would be able to transmit line of area information other than single point information. However the inclusion of Application Specific Message required careful consideration related to e-navigation and hence needed more time. Therefore the Group agreed to apply the first definition as the drat IMO policy.

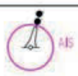
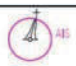
Name of mark	Physical AIS AtoN	Virtual AIS AtoN
Starboard hand mark		
Port hand mark		
North cardinal mark		
East cardinal mark		
South cardinal mark		
West cardinal mark		
Isolated danger mark		
Safe water mark		
Special mark		
Emergency wreck mark		
Lightship mark		

Table 3: Draft new symbols for AIS AtoN by China

There were also other discussions regarding the definition. IALA Recommendation A-126 categorizes AIS AtoN in three types, Real, Synthetic and Virtual, by its implementation way[14]. One opinion is that from mariner's view point, Real and Synthetic are same since the physical AtoN is existing therefore it is enough to mention only two types, Real and Virtual in the IMO Policy. Furthermore, regarding the name of "Real" AIS AtoN, other opinion is that because every AIS AtoN is real as information and the difference between Real and Virtual is whether the physical object exists or not therefore the name of "Real" should be changed to "Physical". The Group agreed the change of the name of "Real" to "Physical" but could not reach the consensus regarding the type of AIS AtoN and therefore the following three options were presented to NAV.

1. Use three types "Physical", "Synthetic" and "Virtual"
2. Use two types "Physical" and "Virtual"
3. Not mention types

Regarding the general principle of application, the Group agreed that although every AtoN authority takes careful consideration when establishing or deploying an AtoN in accordance with SOLAS regulation V/13, the establishment or deployment of AIS AtoN requires more careful consideration than the conventional AtoN. Because AIS AtoN is very new technology and it could make the confusion unless mariners correctly understand AIS AtoN. Therefore it was written in the draft policy that "it is highly important that mariners know how to interpret, understand and use AIS AtoNs before any decision of establishment or deployment is made."

Regarding the application of Virtual AIS AtoN, the Group agreed that unless the object is impossible to be maintained as charted due to changes with time such as navigable water in river, the permanent usage of Virtual AIS AtoN is not recommended since the permanent stable information should be marked in ENCs.

Finally the Group made the first draft of policy and submitted it with the report to NAV 58[15].

NAV 58

Responding to the report of the Correspondence Group, Australia submitted a comment paper that insisted the harmonization of the policy with other relevant documents on AIS AtoN in ITU, IALA and IEC[16]. The paper also stated that since there were some instances on the effectiveness of the permanent Virtual AIS AtoN, the phrase "the permanent usage of Virtual AIS AtoN is not recommended" could be redrafted as "as a general, virtual AIS AtoN would not be generally used on an ongoing basis".

At the plenary session of NAV 58, it was decided to use option 2, use two types "Physical" and "Virtual" as the type of AIS AtoN and the establishment of Drafting Group under the chair of US was approved. Regarding Virtual AIS AtoN, there was a strong opinion that the Virtual AIS AtoN should be used for only the safety of navigation and should not be used to replace the physical AtoN to save the cost. The Drafting Groups was tasked to review the first draft policy by the Correspondence Group and to prepare the revised draft policy with the proposed terms of reference for the next Correspondence Group from NAV 58 to 59.

Nine states and three organizations attended the Drafting Group. The Drafting Group considered the phrase "the permanent usage of virtual AIS AtoN is not recommended" and reflecting the

Australia's comment, amended it to "the usage of virtual AIS AtoN on an ongoing basis is not recommended". After the preparation of the revised draft policy, the Drafting Group also prepared the terms of reference for the next Correspondence Group as follows:

1. *consider documents NAV 58/7 and NAV 58/WP.7, including comments made in plenary and any other relevant information to further review from an editorial point of view and finalize a revised draft policy for AIS Aids to navigation;*
2. *develop symbols for AIS AtoN, taking into account the symbols contained in SN/Circ.243 and other relevant guidelines, standards and publications; and*
3. *submit a report for consideration and review to NAV 59.*

NAV 58 approved the revised draft policy and the terms of reference and the Correspondence Group was re-established under the coordination of Japan.

Second Correspondence Group

There were 17 states and 9 organizations including IHO, IALA and IEC which were closely related to the development of symbols, participated in the second Correspondence Group. The Group first reviewed the revised draft policy and made some editorial changes. After that, the Group started the development of new symbols. At that time, IEC also reviewed their standard on symbols for navigational display including symbols for AIS AtoN[17] and submitted their draft of new symbols. The IEC developed draft symbols were similar to the draft symbols submitted by Japan at NAV 56 but IEC also added symbols that indicated a failure of AtoN such as off position, light failure, Racon failure. The Group agreed to use the IEC developed draft symbols as the basis of the development and made some changes like addition of a cross hair to a symbol indicating off position. Finally the Group submitted the finalized draft policy with a draft MSC Circular and the draft new symbols for AIS AtoN with the amendment of SN/Circ.243 as the annex of the report[18].

NAV 59

In the plenary session of NAV 59, Norway raised a concern regarding the overload of VHF data link of AIS by AIS AtoN, the duplication or superimposition of AIS symbol and chart symbol by permanent virtual AIS AtoN and linkage between Maritime Safety Information (MSI) and AIS AtoN. Regarding the chart symbol, IHO informed that IHO developed the chart symbols for permanent virtual AIS AtoN. After the discussion, NAV 59 agreed to establish the Drafting Group that was tasked to finalize the draft policy and new symbols for AIS AtoN with the associated documents taking account of the comments made in the plenary. The US chaired the Drafting Group.

At the Drafting Group, taking the Norway's concerns into account, the amendments of text regarding the permanent application of virtual AIS AtoN was proposed. The proposed amended texts are as follows:

> *"Virtual AIS AtoN should not be used for permanently marking an object for which Physical AtoN would be possible, but, may be considered for marking an object or feature where it is difficult to establish a Physical AtoN due to environmental or economical constraints e.g. deep water, harsh sea conditions. Another case of the permanent application of Virtual AIS AtoN is for example marking a shoal that changes with time due to current or weather effects; and, where the object or feature is impossible to maintain as charted because of changes that occur over time;"*

> *"the permanent usage of Virtual AIS AtoN should be included in ENCs, paper nautical charts and nautical publications, and should, in general, not be duplicated as a multiple layer by AIS AtoN;"*

Regarding the texts, there was intensive discussion whether economical constraints became a justification for the establishment of Virtual AIS AtoN as permanent application. One opinion was that the word "economical constraints" would lead the easy deployment of Virtual AIS AtoN. The another opinion was that it was true that many AtoN Authorities were requested to reduce its budget and the establishment of physical AtoN in severe environmental condition became more difficult, therefore the word "economical constraints" was appropriate. After the discussion, the Drafting Group agreed to retain the sentence. The finalized draft policy and new symbols were submitted to the plenary with the report.

At the plenary, there was a discussion again regarding the word "economical constraints" and the sentence was amended as follows;

> *"Virtual AIS AtoN should not be used for permanently marking an object for which Physical AtoN would be possible, but, may be considered for marking an object or feature where it is difficult or economically unreasonable to establish a Physical AtoN due to environmental constraints e.g. deep water, harsh sea conditions. Another case of the permanent application of Virtual AIS AtoN is for example marking a shoal that changes with time due*

to current or weather effects; and, where the object or feature is impossible to maintain as charted because of changes that occur over time."

Finally, NAV Sub-Committee agreed the draft MSC Circular with draft policy of use of AIS Aids to Navigation and the draft SN Circular for the amendment of SN/Circ.243 and submitted to MSC for the approval.

Consideration

Comparing with other documents related to AIS AtoN, there are some differences, especially definition and kind or implementation way of AIS AtoN. The draft IMO policy defines AIS AtoN as follows;

An AIS AtoN is a digital aid to navigation (AtoN) promulgated by an authorized service provider using AIS Message 21 "Aids to navigation report" that is portrayed on devices or systems (e.g. Electronic Chart Display and Information System (ECDIS), radar or Integrated Navigation System (INS)). An AIS AtoN can be implemented in two ways.

1. Physical AIS AtoN:
   a Physical AIS AtoN is an AIS Message 21 *representing an AtoN that physically exists.*
2. *Virtual AIS AtoN:*
   a Virtual AIS AtoN is transmitted as a Message 21representing an AtoN that does not physically exists.

ITU document Recommendation ITU-R M.1371 (series) "Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band" does not define AIS AtoN but this document assigns Message 21 as "Aids to navigation report".

The definition of IEC document, IEC 62320-2 Ed.1 "Maritime navigation and radiocommunication equipment and systems - Automatic identification system (AIS) - Part 2: AIS AtoN Stations - Operational and performance requirements, methods of testing and required test results" is as follows[19]:

Aids to Navigation (AtoN)
Device or system external to vessels that is designed and operated to enhance the safe and efficient navigation of vessels and/or vessel traffic

Message 21
AtoN report transmitted on the VHF data link by an AIS station

Real AIS AtoN
AIS AtoN station which is physically located on the AtoN

Synthetic AIS AtoN
Message 21 transmitted from an AIS station located remotely from the AtoN

Virtual AIS AtoN
Message 21 transmitted from an AIS station for an AtoN which does not physically exist

IALA has two recommendations related to AIS AtoN, A-126 "the use of the Automatic Identification System (AIS) in Marine Aids to Navigation Services" and O-143 "Provision of Virtual Aids to Navigation". A-126 does not define AIS AtoN directly but there are some clues to guess what is AIS AtoN. At its introduction section, A-126 describes as flows:

The use of AIS within marine aids to navigation service is broadcasting of the aids to navigation report message (Message 21) and other AIS messages. This service is generally provided from an AIS AtoN Station or a base station.

It therefore can be understood that AIS AtoN provides AIS Message 21 and other Messages. However since A-126 explains other messages as supplementary AIS AtoN messages, it can be thought that the main function of AIS AtoN is Message 21 by A-126. A-126 also categorizes AIS AtoN into three group by its implementation way as same as IEC 62320-1. In addition, A-126 further categorizes Synthetic AIS AtoN into two sub-groups, Monitored Synthetic AIS AtoN and Predicted Synthetic AIS AtoN.

Message 21 contains information of AtoN such as name, position, position accuracy, off position indicator, type by IALA Maritime Buoyage System, dimension, virtual flag, time stamp, etc. Consequently, it can be said that these documents define the usage of AIS AtoN as conventional AtoN which provides single point information. The draft IMO policy applies the definition of AIS AtoN to the same definition of the above mention documents, though the categorization of AIS AtoN is different.

On the other hand, IALA Recommendation O-143 defines virtual AtoN as different from above mentioned documents. The definition is as follows:

A virtual AtoN does not physically exist but is a digital information object promulgated by an authorized service provider that may be presented on navigational systems.

O-143 further describes virtual AtoN as follows:

Virtual AtoN can be used to inform the mariner about dangers to navigation as well as safe waters, *areas in which extra caution may be necessary and areas to be avoided.*

They may be used to represent a line, area, position or other form that may be displayed graphically.

As a matter of fact, the function of representing a line, area, position or other form can be implemented by AIS, i.e. Application Specific Message, and AIS AtoN can transmit Application Specific Message as A-126 explains. In addition, Application Specific Message can convey more information such as weather data, tidal data, traffic signal, birth data, etc and some of the information are not provided from AtoN authorities. There is also another problem of usage on Application Specific Message. That is that international standard on effective and appropriate presentation method for Application Specific Message is still under development. Consequently, at the development of IMO policy, the definition by O-143 was discussed but not adopted. For world wide usage of Application Specific Message, further discussion at IMO should be required.

Conclusion

The draft IMO policy and new symbols for AIS AtoN may pave the way for more effective and appropriate usage of AIS AtoN. However, regarding virtual AIS AtoN, it can be said that Application Specific Message is more useful due to its flexibility. The discussion at IMO on the usage of Application Specific Message should be needed in the future.

[1] MSC 86/23/7 “New symbols for AIS AtoN”
[2] MSC 86/23/18 “New symbols for AIS AtoN – Comments on document MSC 86/23/7”
[3] MSC 86/23/18 “New symbols for AIS AtoN – Comments on document MSC 86/23/7”
[4] NAV 56/11/1 “Comment by IHO”
[5] NAV 56/11/2 “NEW SYMBOLS FOR AIS ATON”
[6] NAV 56/11/3 “Comments on document NAV 56/11 »
[7] NAV 56/INF.2 “IALA Recommendation on Virtual Aids to Navigation”
[8] .NAV 56/INF.11 “Project of promoting the use of Electronic Chart System (ECS) and AIS
[9] MSC 88/23/10 “Expansion of the scope of work”
[10] MSC 88/23/12 “Comment on document MSC 88/23/19 (Japan and the United States)”
[11] NAV 57/8 “Development of Policy and New Symbols for AIS Aids toNavigation”
[12] NAV 57/8/1 “Proposed new symbols for AIS AtoN”
[13] NAV 57/8/2 “IALA Documentation on AIS and AIS Aids to Navigation”
[14] IALA Recommendation A-126 “The Use of Automatic Identification System (AIS) in Marine Aids to Navigation Service”
[15] NAV 58/7 “Report of the Correspondence Group”
[16] NAV 58/7/1 “Comment on the report of the Correspondence Group”

[17] IEC 62288 “Presentation of navigation-related information on shipborne navigational displays”

[18] NAV 59/7 “Report of the Correspondence Group”

[19] When discussing “type” of AIS AtoN, IEC 62320-2 and IALA A-126 use type 1, 2 and 3 that is categorized by technical standard of the equipment itself.

94 AUTOMATIC IDENTIFICATION SYSTEM CAPABILITIES TO IMPROVE U.S. WATERWAY OPERATIONS

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The Automatic Identification System (AIS) was developed and mandated for carriage aboard vessels primarily to mitigate collisions by enhancing vessel and shore-side situational awareness. Shore-side entities (public and private) quickly adopted its use in tracking vessels and monitoring waterways. Various lower cost "receive only" uses of AIS have proven beneficial, however this use if very limited given the broader capabilities that AIS can provide to improve navigation safety, efficiency, and reliability. Using AIS to transmit information to vessels can increase the information available to vessel operators, present it to them in a non-intrusive way integrated with onboard navigation systems and decrease the burden on shore side authorities in disseminating urgent information. The U.S. Army Corps of Engineers (USACE) and the U.S. Coast Guard (USCG) are working together to develop these capabilities and coordinate use of their AIS infrastructure to provide nation-wide AIS services. This paper will provide more information on the potential for expanded use of AIS capabilities and describe current implementation efforts within the U.S.

El Sistema de Identificación Automático (AIS) se desarrolló y autorizó para el transporte en barcos en principio para reducir las colisiones aumentando la conciencia situacional del buque y la costa. Las entidades de costa (públicas y privadas) adoptaron inmediatamente su uso para el seguimiento de buques y control de la navegación fluvial. Hay diferentes usos de "solo recepción" de bajo coste del AIS que han demostrado ser beneficiosos, aunque este uso está muy limitado debido a las mayores capacidades que el AIS puede suministrar para mejorar la seguridad, eficiencia y fiabilidad de navegación. Mediante el uso del AIS para transmitir la información a los buques se puede aumentar la información disponible de los operadores del buque, presentársela de forma no intrusiva integrada en los sistemas de navegación de a bordo y disminuir la carga de las autoridades costeras en la difusión de información urgente. El Cuerpo de Ingenieros del Ejército de los Estados Unidos (USACE) está trabajando con la Guardia Costera de Estados Unidos (USCG) para desarrollar estas capacidades y coordinar el uso de su infraestructura AIS para proporcionar servicios AIS a nivel nacional. Esta ponencia proporcionará más información acerca del potencial del uso expandido de las capacidades AIS y explicará los esfuerzos de implementación actuales dentro de Estados Unidos.

Le Système d'identification automatique (AIS) a initialement été développé et rendu obligatoire à bord des navires pour limiter les collisions en donnant au navire et à la terre une meilleure conscience de la situation. Les entités terrestres (publiques ou privées) l'ont très vite adopté pour suivre les navires et surveiller les voies maritimes. Diverses utilisations à bas prix de l'AIS, en mode réception seul, se sont révélées utiles ; cependant cette utilisation est très limitée compte-tenu des larges possibilités offertes par l'AIS pour améliorer la sécurité de la navigation, son efficacité et sa fiabilité. Utiliser l'AIS pour transmettre des informations aux navires augmente la somme d'informations à la disposition des opérateurs de navires, les présente sous une forme non intrusive, intégrée aux systèmes de navigation embarqués, et réduit la charge de travail des autorités à terre en transmettant des informations urgentes. Le Corps des ingénieurs de l'Armée américaine (USACE) et la Garde côtière des Etats-Unis (USCG) travaillent ensemble au développement de ces possibilités et coordonnent l'utilisation de leur infrastructure AIS pour fournir des services AIS à l'échelon national. Ce rapport donnera plus d'information sur le potentiel d'une utilisation élargie des possibilités de l'AIS et décrira l'effort actuel de mise en œuvre aux Etats-Unis.

Automatic Identification System capabilities to improve U.S. waterway operations

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1. INTRODUCTION

The early 1990s saw a proliferation of vessel tracking systems being deployed around the world in areas as diverse as the Dover Straits, Panama Canal, Prince William Sound, and Sweden. While each of these areas benefitted from their respective tracking systems, each of these systems were incompatible with each other. Recognizing the value of such systems and the inefficiency of disparate systems, the International Maritime Organization (IMO), in collaboration with the International Telecommunications Union (ITU), International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), and, International Electrotechnical Commission (IEC), embarked on the development of a universal automatic identification system, now known as AIS. In doing so, they not only developed a autonomous, continuous, near real-time and robust tracking system, they created a system that relies on and exploits the use of a digital communications network to share pertinent navigation safety amongst vessels, but, particularly allowing its use by navigation data providers.

1.1 AIS technology

The Automatic Identification System is a navigation-communication protocol initially developed by the ITU to provide near real-time exchange of navigation data amongst its users and provide additional situational awareness information for use by vessel navigators and shore-side authorities, [1] and later adopted by the International Maritime Organization as a means to improve the safety of navigation.[2] AIS takes user encoded information and vessel sensor data and formats it into binary messages that are transmitted continuously and autonomously in the VHF-FM marine band. Information transmitted by vessels includes: dynamic information from shipboard sensors, including positioning (usually from GPS), speed, and heading; static information, such as vessel identity, radio call sign, and maritime mobile service identity (MMSI); and voyage-related information such as destination, ETA, vessel draft, navigation status (underway, anchored, moored, etc.). This information is received by other vessels or shore stations in range (line-of-sight), which is displayed on the AIS device at minimum as lines of text, or graphically if integrated into AIS capable portrayal systems, such as vessel's radar, electronic charting system (ECS) or on personal computers (PC).

Currently, there are 27 pre-defined AIS messages to transmit information or that are used to manage the AIS VHF data link (VDL). AIS uses a time-division multi-access schema to send these 27 ms long messages in "slots" of time – 2250 slots are available per minute on two AIS frequencies. Each slot can conveys 161 bits, 128 bits for unique dedicated data per message, and an AIS message can be a maximum of 5 slots, though 3 is the maximum recommended. The most routinely used messages are those that transmit vessel dynamic, static and voyage-related data (AIS messages 1, 2, 3, 5, 18 and 24). The other 21 messages are used for managing the AIS VHF data link (VDL), transmissions of specific navigation safety information (search and rescue aircraft position, Aids to Navigation (AtoN) information, safety text messages, etc.). There are also 3 messages that can transmit information that is not already pre-formatted (AIS messages 6, 8, 25 and 26). These are known as application-specific messages (ASM), in that they require a separate application from the AIS equipment to be able to process the data in the message. This separate system is commonly an ECS or PC. ASM provide an opportunity to provide information to the user that is not available currently, or only available through means not easily integrated with other digital data. The use of AIS ASM in improving inland waterway operations will be the main focus of this paper.

1.2 AIS carriage requirements

AIS is an IMO mandated safety of life at sea (SOLAS) navigation equipment carried aboard most large commercial vessels on international voyages and large vessels on domestic voyages.[3] In the United States, these international carriage requirements have been implemented in U.S. law[4] and expanded upon to include smaller vessels and thus most commercial vessels operating on U.S. navigable waters. Additionally, U.S. legislation requires that this same population of vessels integrate their AIS with onboard ECSs. Regulations to mandate ECS in the U.S. and implement this integration are pending. As anticipated, given the benefits of AIS, there has also been a gradual, yet steady increase of voluntary users, particularly on leisure craft.

2. USE OF AIS RECEIVE CAPABILITY

2.1 Real-time vessel monitoring

The first and most obvious benefit of AIS, which only increases upon broader use, was to receive real-time data to indicate vessel intentions and movements. Indeed, in addition to facilitating passing arrangements (mitigate collision) and enhancing situational awareness, it provides two additional purposes for AIS laid out by IMO: as a vessel traffic services (VTS) tool, and, as a means for authorities to monitor the movement of vessels and cargo in their waters. Use of AIS for real-time vessel movement monitoring is now indispensible and it has greatly improved the accuracy of VTS monitoring and tracking, reduced voice communications and reduced miscommunications, and allowed VTS to expand coverage at a lower cost than what was achievable with traditional tracking means, such as radar and cameras. River Information Services (RIS) tracking and tracing was greatly enhanced, as were other services, including ancillary services such as lock operations. Industry and vessel owners, while initially wary of the ability for their vessels to be monitored, have come around to widely use AIS commercial services to track their fleets and monitor their own vessel operations, and coordinate ancillary services such as assist and fleet tugs, pilotage, port reporting and stevedoring. In addition to real-time monitoring, AIS archived data can be and is used for many other purposes as well.

2.2 Vessel movement playback

Stored AIS data can be "played back" for training purposes, and, is now almost always used to recreate events following an incident or casualty to aid in assessing exactly what happened before, during and after an event. AIS data used in conjunction with Voyage Data Recorders (VDRs, maritime 'black boxes') have been invaluable in maritime investigation and legal proceedings; this real data vice witness accounts has led to more settlements vice protracted litigation.

2.3 Vessel traffic analysis

Archived AIS data has also been used for analysis of vessel traffic patterns over time. In particular, this has proven valuable when changes to vessel routing measures are being considered or new uses of water areas are being proposed, such as for offshore energy facilities (e.g., wind farms, hydrokinetic power generation, etc.).[5]

Recently, taking advantage of larger data availability and more advanced analysis techniques, more sophisticated analysis of archived AIS data has been undertaken. This has allowed much higher resolution analysis of waterway usage, aiding in decision making for channel improvements, vessel operations, including detailed analysis of vessel movements correlated with tidal cycles and development of baseline waterway vessel transit times.[6] Preliminary investigations are examining the potential to use AIS data to detect subtle changes in waterway condition based on analysis of vessel behavior.

2.4 AIS data quality

A reality that has come to light with broader use of AIS data is that of data quality. Since AIS depends on manually entered data, external sensors, proper installation, is prone to radio propagation errors (garbled slots), and other factors, it may provide inaccurate or outdated data.[7] An examination of AIS data quality is beyond the scope of this paper, but it is worth consideration by those using AIS capabilities.[8] Users who desire or need to rely upon AIS capabilities for important matters should use it in conjunction with other data sources, preferably authoritative sources (e.g., correlate vessel identification with information from the from the appropriate competent authority) and institute quality assurance measures as appropriate for the intended use or advertised level of service.

3. USE OF AIS TRANSMIT CAPABILITY

3.1 AIS transmit capability overview

In addition to receiving data transmitted from vessels for real-time monitoring and after-the-fact analysis, AIS can be used to transmit additional information to and from vessels. While this capability has been part of the AIS technology since its inception, it has only recently begun to be used more extensively. There are 27 standard AIS messages for transmission of navigation information. Besides the vessel-generated position and static data reports, several other messages have been pre-formatted to transmit additional information. These include time, safety-related text messages, differential GPS (dGPS) corrections, and Aids to Navigation (AtoN) reports. Also among the standard messages are several messages that are not pre-formatted and can transmit information not contained in the standard messages. These are called application-specific messages (ASM).

3.2 Application–specific messages

ASM use several standard AIS messages that have an undefined payload. This allows for custom use of the space in the message that can be sent via the AIS transport mechanism and does not rely on the

AIS equipment itself for decoding and presentation. The messages are passed through the receiving AIS units onto other applications that decode and interpret them. Usually this is other navigation software, such as ECS, but it may be a standalone application on a PC or another piece of equipment.

Several ASM were defined in early versions of the AIS standard (ITU-R. M1731) and the IMO published seven ASM for testing purposes to be used during the period 2004-2008. [9] These test messages could transmit the following information:

1. Meteorological and Hydrological data
2. Dangerous cargo indication
3. Fairway closed
4. Tidal window
5. Extended ship static and voyage related data
6. Number of persons on board
7. Pseudo-AIS targets

Testing and review of these messages by various national authorities and by IALA revealed problems and limitations with the test messages. Information was identified that was not available in the test messages. [10] Technical problems were identified, such as structure of the messages that was inflexible and made inefficient use of the AIS protocol. [11] Following the test period, IMO gathered input from the testing and issued 14 new ASM.[12] However, these messages were also found to have limitations, so competent authorities began developing additional messages and working through international standards bodies to harmonize their implementation. [13] This included creation of an ASM catalog where all ASM are listed with detailed information about their use, structure and operational information.[14] The intent of the creation of this catalog is that an entity desiring to use AIS for transmission of information can refer to the catalog, review existing messages and determine if they meet their requirements. If so, an existing ASM should be used. If not, a new ASM may be developed, but once it is created it should be included it in the catalog.

Testing of AIS transmit capability in the U.S. determined there should be standards for the creation of ASM. During testing it was found that the same data elements (e.g., latitude or longitude) were encoded in ASM in different ways. Different units for data elements were used, leading to confusion in interpretation and presentation of the data. The Radio Technical Commission for Maritime Services (RTCM) has drafted a standard for creation of ASM. [15] The standard includes requirements for the development of ASM, and methods to qualify them against those requirements. It is intended for use by competent authorities in determining which ASM are allowed to be transmitted in their designated area(s). It references existing requirements from IMO, IALA, ITU and IEC as they apply to creation of ASM, and specifies requirements that did not exist but are considered essential for the efficient use of ASM. Some of the newly-created requirements include addition of a message version parameter, use of standard units for data (including references to ISO standards), data precision indication, reference datum specification, and other requirements intended to harmonize the use of ASM.

3.3 Use of AIS ASM transmission capabilities

Early use of AIS transmission capability using the initial IMO-specified messages as well as new messages developed by authorities focused primarily on information that was of immediate usefulness to vessel navigators, primarily meteorological and hydrological data, as well as some waterway management information. The St. Lawrence Seaway and the USCG VTS St. Marys River began transmitting weather, lock order, and lockage times via AIS using their own message formats, prior to the issuance of IMO's test messages.[16] These were very successful, probably due to a combination of the usefulness of the information and that vessels transiting the St. Lawrence Seaway are a "captive audience" subject to Seaway regulation. This allowed for the rapid installation of equipment on vessels that could decode and display the transmitted information. While vessel operators in many other areas have expressed a desire for more information transmitted via AIS, actually implementing this has been more difficult, due to the larger population of vessels with varying equipment carriage (mandatory and voluntary), and implementing the capability in various shore side systems. Technical issues will be addressed in the next section of this paper.

Additional information that may be transmitted via AIS includes water levels, lock and dam status (dam gate settings, dam discharge, lock queue, lockage delay, maintenance activities, etc.), weather, emergency alerts, waterway restrictions and other information. The USACE Lock Operations Management Application (LOMA) project is developing the capability to transmit this information from AIS transceivers located along the inland waterways, primarily from lock locations, but eventually from transceivers covering lock pools and along the open river.[17]

In addition to using ASM to transmit information from shore to vessels, information can also be transmitted from vessels to shore side entities. This information can aid in data collection and waterway monitoring, including such information as vessel-collected weather information, additional information about the vessel (such as persons on board and air draft) that are not included in standard AIS messages, and more detailed cargo information. However, particularly with cargo data, concerns have been expressed about the security of transmitting this information, due to potential interception and misuse by commercial competitors or those with intent to harm waterway transportation.

Efforts are continuing to develop AIS transmit capabilities. These efforts include identifying data sources, developing processes to turn the data into AIS messages, and working with existing and planned AIS infrastructure to transmit the messages. These efforts also include outreach to vessel operators and navigation equipment manufacturers to gather requirements and involve them in testing of these new capabilities. Two examples of this effort are briefly described below.

3.3.1 Lock Approach current modeling

The USACE Coastal and Hydraulics Laboratory has begun a project to complete hydrodynamic models of the approaches to most of the 193 locks on the U.S. inland waterways system.[18] These models will provide predicted water currents in the vicinity of lock structures. These are areas where vessels approaching the lock are particularly vulnerable to adverse currents, as they are slowing to make their approach just as the currents are most affected by the lock structure and the increased flow as water is released through the dam, which is usually adjacent to the lock entrance. The output from these models could be very valuable to vessel pilots as they make their approach or even decide whether to do so or not. However, the model output is not in a format useful to vessel pilots and is in such large quantities that getting it to a vessel underway is impractical. Work is underway to develop and establish processes where the model output is converted into AIS messages and transmitted to vessel in the

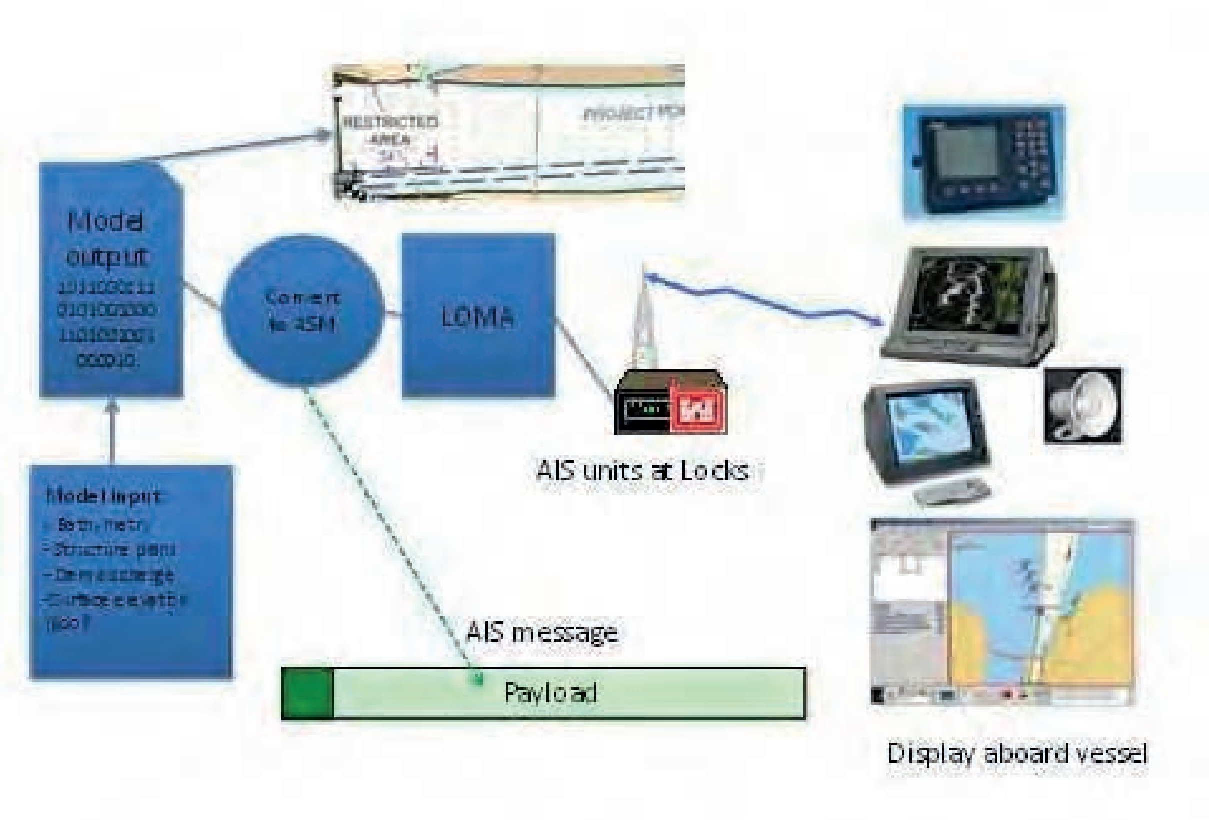

Figure 1. Lock approach current model information via AIS

vicinity of the locks (***Figure 1***). Initial efforts are focused on using existing AIS ASM (environmental message) to transmit current velocity at designated locations near locks. However, through interaction with waterway users, other means of communicating this information are being explored, which may lead to development of new ASM.

3.3.2 Marine Safety Information (MSI)

Several U.S. agencies issue marine safety information (MSI) to alert vessel operators of changes to the waterways that are not yet captured in existing publications or charts (e.g., new channel configuration), or to indicate a quickly-arising condition that may pose a hazard to navigation (such as a wreck or missing aid to navigation). The USCG provides Notices to Mariners, the Corps of Engineers provides Notices to Navigation Interests, and NOAA provides chart updates, among other MSI. This information is currently provided in different formats, usually only electronic versions of the original paper product (e.g., .pdf files). An effort sponsored by the U.S. Committee on the Marine Transportation System (CMTS) is underway to harmonize these information sources, and produce a common, electronic "bulletin" that can be more easily disseminated for use by mariners. With MSI available in a common electronic format, it can easily be converted into AIS ASM and transmitted to vessels in the areas affected by the notices. It is anticipated that existing ASM will be used, but as the project progresses, need for new ASM may be identified.

3.3.3 Electronic Aids to Navigation

This year the USCG embarked on a nation-wide test on the use of electronic aids to navigation, primarily using synthetic and virtual AIS broadcasts (message 21)[19]. The first phase of testing was conducted at the America's Cup races, where 16 virtual AIS ATONs were used to dynamically mark the race venue; as legs of the course were modified to the environmental conditions prior to each race. Since the America's Cup, the USCG has continued to use AIS ATON broadcasts in novel ways. AIS ATONs now allow Administrations to provide waterway users with navigational aids in locations that were not possible with traditional aids. For example, the USCG is now using AIS to mark bridge embankments and approaches, working closely with selected Pilot Associations and their use of personal piloting units (PPU) in determining the best location for such electronic aids.

4. TECHNICAL CONSIDERATIONS OF AIS TRANSMISSION

In addition to the identification of appropriate information to be transmitted and development of ASM to do so (if one doesn't already exist) there are technical considerations to be addressed in the implementation of AIS transmission capability. AIS technology has a variety of standards and guidelines, but many aspects of AIS transmission are not adequately addressed in these documents. These considerations also vary depending on the networks and systems used, the physical and radio environment in which they will be used as well as the operational environment. The following are some of the technical considerations that should be addressed.

4.1 AIS networks and systems

While it is possible to transmit information via AIS with a simple arrangement (e.g., AIS transceiver and data processor to create messages to be transmitted), it is more likely that a more sophisticated system will be used consisting of multiple AIS transceivers, network connections, databases and sources of information to be transmitted. The U.S. Army Corps of Engineers' LOMA system will be used as an example of a complex, multi-transceiver system. It has some unique characteristics, but the general capabilities and configuration are applicable to other systems.

LOMA consists of AIS transceivers (AIS AtoN units) located at lock locations on the U.S. inland waterway system. There are currently over 100 AIS transceiver sites all connected to the USACE internal network. The units communicate with an AIS Service Manager (AIS-SM) on a central server in Vicksburg, Mississippi. The AIS-SM consists of several AIS data routers, a database and coordinating software that manages the different components, provides a user interface, and creates ASM to be transmitted from the AIS AtoN units (***Figure 2***).

Considerations to take into account in the design of an AIS network that will be used to transmit information to vessels include:

- The amount of information anticipated to be transmitted. This will drive network capacity and ASM-SM capabilities (e.g., a large number of connections or information to be transmitted will require more data routing capability).

- Interoperability with other systems that will interface with the AIS service. These systems may provide data to be transmitted or may use information from the AIS system.
- Routing of AIS messages. An AIS message will likely have a geographical applicability, and therefore will only be transmitted from one or a few transceivers. A means to tag messages created centrally (or by external services and process them to ensure they are routed to the proper transceiver is required. Also, it is desirable that messages successfully transmitted provide a confirmation back to the message creator. This will also require a routing capability.
- AIS VHF data link (VDL) considerations. As described in section 1.1, the AIS protocol uses designated "slots" for messages to be transmitted in. In order to ensure transmitted messages have a high probability of being received by the intended audience, measures need to be taken to ensure the transmitted messages are sent in unused slots. Some AIS transceivers have this capability to determine slot availability themselves, but many do not so such processes must be done by a separate application.

As more testing has been done on transmitting information via AIS, functions and requirements that are not included in standards and recommendations are being revealed.[20] Some of the main functions that need to be accounted for include:

- The fetching of data to be transmitted. This may be meteorological observations from a sensor or weather service, lock queue information from a lock operations system, or other data source. In any event, there needs to be a process to identify and access the data in a scheduled, as-available, or as-needed basis in order to create an AIS message from it.
- Formatting the fetched data into an AIS message. Which message is to be used, how it is to be "packaged" (e.g., with other data in the same message), and other message structure factors must be considered.
- Queuing the messages for transmission. There needs to be a process that takes the message and, given the VDL situation the transceiver is experiencing, schedules the message for transmission. This may require VDL monitoring to determine load, available slots and use of assigned slots.
- Confirming transmission. Processes should exist that ensure messages are being transmitted and have a high probability of receipt in the advertised service area. There should also be a system acknowledgement that messages are being successfully transmitted, and for addressed messages that they have been successfully received by the intended recipient.

5. POLICY AND PROCEDURAL CONSIDERATIONS & QUESTIONS

As with most developing technologies, one must accept their technical realities, problems or limitations. The realities and limitations of AIS are well defined in its existing standards and associated guidelines. Novel technologies, such as AIS, bring about unique challenges because they are usually deployed and in wide spread use way before rules, regulations or policy is in place. While IMO and IALA have done an effective job in promulgating guidelines in the operational use of AIS, there are no rules or guidelines on the use of AIS data or use of AIS to disseminate marine safety information (MSI). While IMO has promulgated guidance on the use of ASM, and has adopted 14 ASMs, it provided no guidance on their content and their use within or in conjunction with existing marine safety information systems, e.g., NAVTEX. Should shore authorities use AIS to augment or even replace existing systems to disseminate of MSI? Should other entries, e.g. commercial services, be allowed to use AIS to disseminate navigation information?

Another consideration to take into account is the wide spread use of AIS data by multiple non-vessel stakeholders, such as investigators, spatial planners, logisticians, environmental monitors, local governmental authorities and entities etc. who had little or no say it its development, primarily because no one foresaw its broad use by such entities. What if anything should be done, to seek input from these entities in the future developments of AIS?

Finally, the one consideration which is not likely lost to all is that not all vessels are outfitted with AIS. While the U.S. and many other countries have or are in the process of mandating the use of AIS to a broader number of vessels, there is no movement afoot to lower the IMO AIS carriage thresholds. Should there be? Given the benefits of AIS and the continual decrease in cost of AIS equipment it is certain that the voluntary use of AIS will rise. Should voluntary use be kept in check? AIS is robust, but, physically constrained to a limited bandwidth (4,500 slots per minute). Therefore, users could technically exceed its capacity. Fortunately, AIS was designed to self-organize itself such that vessels will always receive messages from those vessels that are in their closest proximity, those that pose the greatest collision risk. Unfortunately, shore-side AIS networks will be the first to experience these limitations, because most were devised to provide the broadest coverage (high antenna heights) and a reasonable cost. It is likely as the amount of AIS message traffic increases, shore-side networks will receive more garbled unusable messages. Should message traffic be regulated to mitigate shore-side poor reception?

6. CONCLUSION

AIS is one to the most revolutionary advances in navigation equipment since the advent of radar. While this in itself is commendable and would suffice to make it a great technology, its ancillary benefits may define it as being the most noteworthy advancement in navigation in the 21st century. AIS is and will continue to provide valuable amounts of data that is and will continue to be used to better serve navigation at all levels in in the future. As initially envisioned and designed it will continue to enhance vessel situational awareness and mitigate the risk of collision. Similarly, shore authorities will rely upon it to enhance their situational awareness of how their waters are being used and by whom. Industry will also avail themselves of AIS data to better manage their fleets and operations, and thus improve transportation efficiency. Investigators will further expand its use in casualty analysis; and, thus provide better recommendations to improve navigation safety. Coastal and spatial planners will available themselves of AIS data to better plan and manage competing uses and users of the water. AIS provides for a very effective digital communications link, purposely open and non-proprietary, to facilitate the distribution and use of its data. It allows the sharing of pertinent navigation data from multiple sources. This sharing of data not only enhances navigation safety, but, enables efficiencies throughout the navigation and transportation domain. The latter is just in its

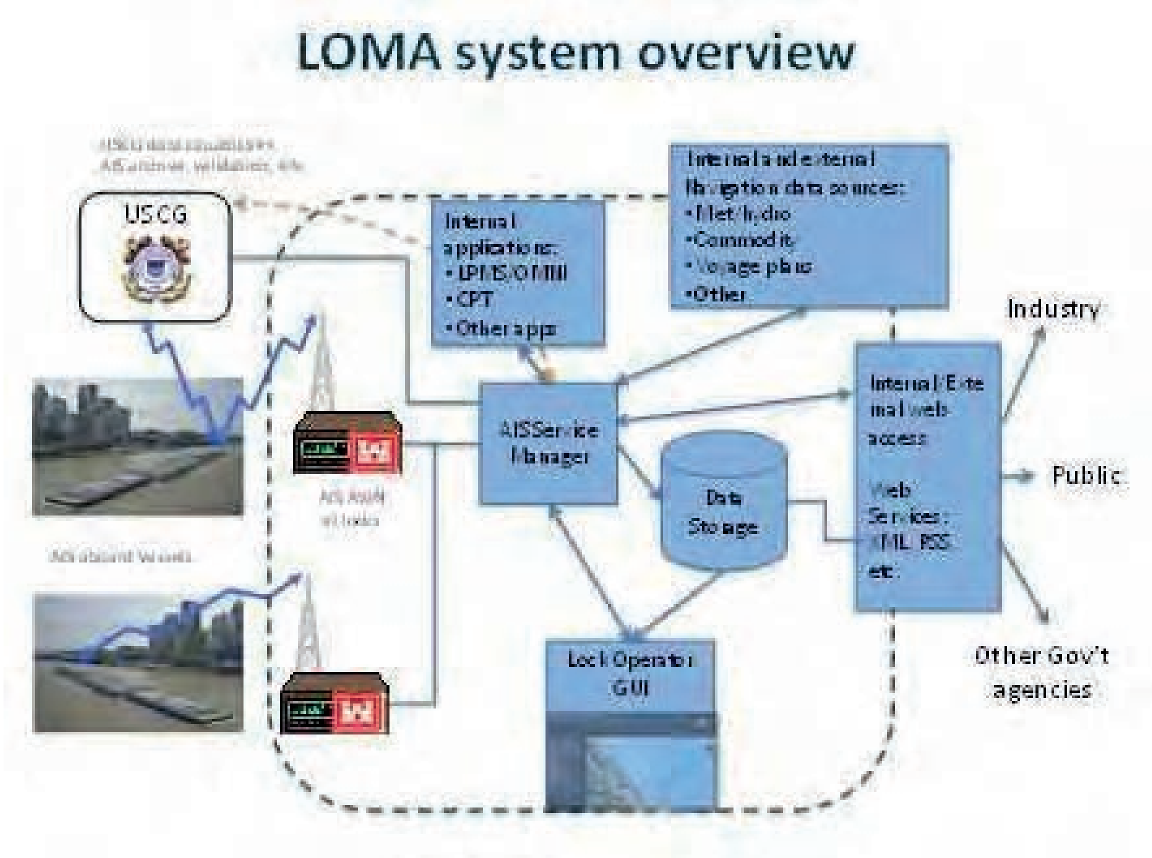

Figure 2: LOMA system overview

infancy, but, its promise and potential may just be the greatest achievement of AIS. The U.S. Army Corps of Engineers, USCG and multiple stakeholders are working diligently to make is so.■

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107 THE EUROPEAN SATELLITE-AIS DATA PROCESSING CENTER (EU SAT-AIS DPC) DEVELOPED BY CLS FOR THE EUROPEAN SPACE AGENCY (ESA) AND EUROPEAN MARITIME SAFETY AGENCY (EMSA). HOW WILL SUCH INFRASTRUCTURE SUPPORT E-NAVIGATION?

Gaëtan Fabritius. Collecte Localisation Satellites CLS, France

Recent allocation of new frequencies by the ITU for long-range AIS (message 27) and VDE (VHF Data Exchange) opens new opportunities for a space-contribution to maritime surveillance and e-navigation. Space however brings specific constraints which advanced algorithms and processing have to overcome. The European Space Agency and CLS (Collecte Localisation Satellites), subsidiary of the French Space Agency (CNES) has been involved since the very early stages at IMO, ITU and IALA levels to anticipate and explore the potential of space capabilities. This presentation will aim at presenting existing (2013) systems and current status (2014) of the R&D acitivity (signal processing, status of satellite constellation and related capabilities).

La reciente asignación por la ITU de nuevas frecuencias para el AIS de largo alcance (mensaje 27) y VDE (Intercambio de Datos VHF) abre nuevas oportunidades para una contribución espacial a la vigilancia marítima y la e-Navegación. Sin embargo, el espacio conlleva restricciones específicas cuyos algoritmos y procesamientos avanzados hay que superar. La Agencia Espacial Europea y CLS (Collecte Localisation Satellites), filial de la Agencia Espacial Francesa (CNES), han estado involucradas desde las primeras etapas a niveles IMO, ITU e IALA para anticipar y explorar el potencial de las capacidades espaciales. Esta presentación tendrá por objeto presentar los sistemas existentes (2013) y el estado actual (2014) de la actividad de I+D (procesamiento de señales, estado de la constelación de satélites y capacidades relacionadas).

La récente allocation par l'UIT de nouvelles fréquences pour l'AIS longue portée (message 27) et l'échange de données VHF (VDE) offre de nouvelles opportunités de contributions de l'espace à la surveillance maritime et l'e-Navigation. Cependant, l'espace entraîne des contraintes spécifiques que des algorithmes et un traitement avancés ont à surmonter. L'ESA et CLS, filiale du Centre National d'Etudes Spatiales (CNES), se sont très tôt impliqués, au niveau de l'OMI, de l'UIT et de l'AISM pour explorer les possibilités de l'espace. Ce rapport présentera les systèmes existants (en 2013), et la situation actuelle (2014) des activités de recherche et développement (traitement du signal, constellation des satellites et possibilités associées).

The European Satellite-AIS Data Processing Center (EU SAT-AIS DPC) developed by CLS for the European Space Agency (ESA) and European Maritime Safety Agency (EMSA)

How will such infrastructure support e-Navigation?

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The European Satellite–AIS Data Processing Center (EU SAT–AIS DPC) developed by CLS for the European Space Agency (ESA) and European Maritime Safety Agency (EMSA) – How will such infrastructure support e–Navigation?

Gaëtan Fabritius, Collecte Localisation Satellites (CLS), France

INTRODUCTION

The Automatic Identification System (AIS) is a short range coastal tracking system currently used on ships. It was developed to provide identification and position information to vessels and shore stations. Space-based, or SAT-AIS, will provide AIS data received via satellite, allowing for the detection of seafaring vessels equipped with AIS tracking devices outside coastal coverage.

WHO NEEDS WHAT?

Currently in Europe, the SafeSeaNet (SSN) operated by EMSA ensures the effective tracking of vessels and hazardous cargoes based on the data received by coastal stations around Europe. From the coastal stations, the AIS messages are transferred via national stations to four regional AIS servers that provide the data to the EMSA SafeSeaNet server. The SAT-AIS DPC is providing an additional data stream for EMSA's Integrated Maritime Data Environment (IMDatE). The provision of SAT-AIS data brings value added to existing maritime information services by providing ship detection capabilities at distances from coastlines that cannot be covered by land-based AIS. Additional benefits to the user communities lay in the validation of the positional information included in AIS messages which will provide an effective means to identify and counteract illegal (maritime related) activities.

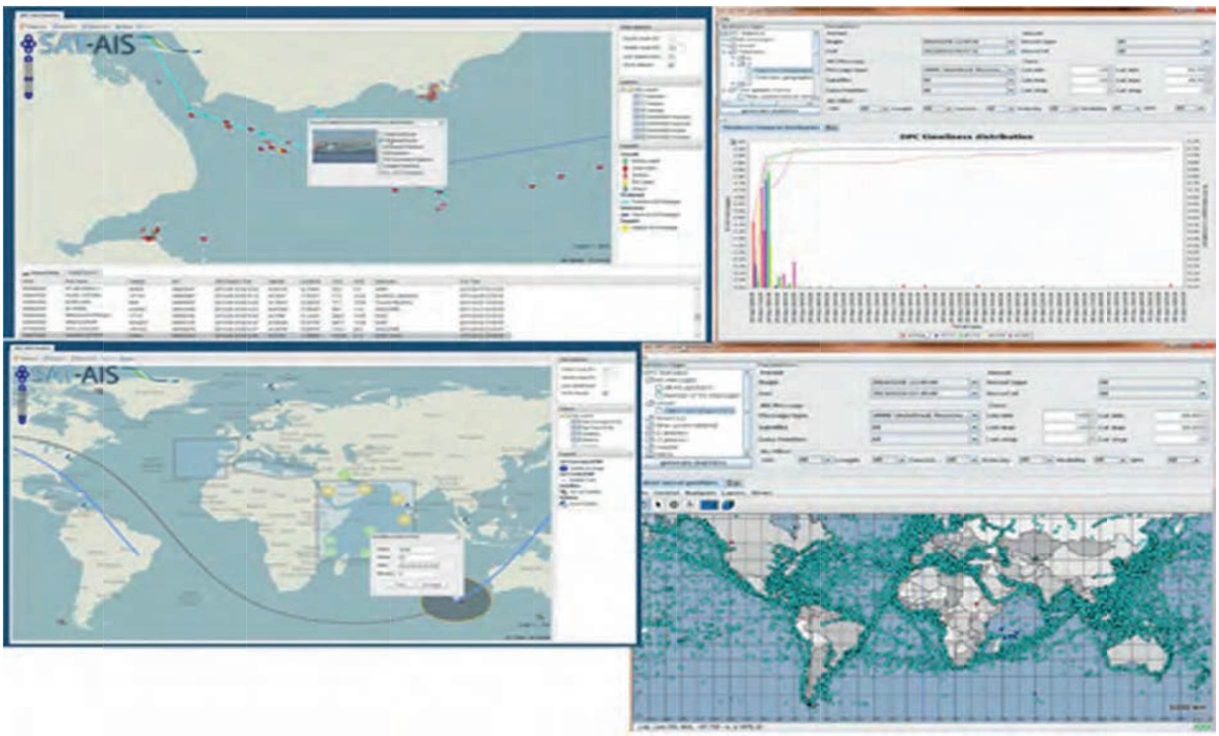
SAT-AIS information will support European entities and institutions in law enforcement, fisheries control campaigns, maritime border control operations, maritime safety and security issues including marine pollution response, search and rescue and anti-piracy.

The challenges into that system are related to the data retrieval, validation and fusion of huge volume of data in a timely manner. The SAT-AIS DPC performs the following functions: it retrieves SAT-AIS data, together with ancillary information such as the Doppler shift and ship detection reports derived from Earth Observation imagery, and validates AIS message position. Furthermore it generates forecasts of ship positions and expected ship visibility from the space segment. It is also capable of generating warning messages when AIS information has not been detected, or when the system has lost contact with a ship.

DATA EXCHANGE FOR E–NAVIGATION

In October 2013, CLS has been working, jointly with the Norwegian Coastal Administration (NCA) and Chilean Coast Guard (Directemar) on an e-navigation demonstration aiming at exchanging such enhanced information relying on existing "LRIT shore-based infrastructure" as per IMO/COMSAR 17 outcomes. ■

http://www.kystverket.no/en/About-Kystverket/International-work/enavigation/News/e-navigation-workshop-held-in-Chile/
http://www.lrit-services.com/news/more/?item=193



67 BEHAVIOR RECOGNITION ASSISTING MARITIME SITUATIONAL AWARENESS

Florian A Gruber. *Frequentis AG, Austria*

At the time being various tracking systems like Automatic Identification System (AIS) and Maritime Communication Systems (MCS) are globally in use on SOLAS Vessels. National and local authorities already established shore based AIS/MCS infrastructure, networks and services. This paper focus on analyse of additional possibilities for decision support of both centre operators with navigation and logistic tasks.

National administrations and operators welcome the potential of AIS/MCS and its capability to enhance the safety of life at sea. Nearly all countries and also some private companies are running already shore bases AIS/MCS networks with good experiences with the existing implementations. These experiences with new technologies in daily operation lead to new evolutionary ideas from our customers. Frequentis collects them among our Maritime User Group conferences and private workshops. This gives Frequentis the opportunity to offer innovative solutions for new services.
Logistic and Calamity-abatement services have different nature and needs never the less similar techniques can assist both sides operators, their authorities or logistic partners in their daily business. (E.g. VTS centres, national authorities, ports and shipping companies)

The paper is a discussion about those ideas and the technical possibilities behind them. The aspects taken into account are:

- The operators are the experts in analysing vessel behaviour
- The authorities decide which behaviour needs to be recognised
- Today's Systems mainly offer only passive decision support, by displaying traffic situations or only recording vessel behaviours for later analysis.
- Today's technologies mainly overload the operators with information and may be decreasing awareness of the current situation.
- Operators already stated their needs to define active sets of personalized user defined events based on traffic data in their systems.
- System integration is needed to replace unimportant automatic generated alarms with operator configurable smart behaviour analyses.
- Tracking&Tracing behaviour recognition needs to be harmonized with the existing local services for logistical and/or calamity abatement.

There are ideas from experienced user, available implementations as mentioned above the T&T behaviour recognition. Additionally taken into account is, how this could be used in combination with MCS voice communication to assist logistic- and calamity abatement services.

Actualmente se utilizan a nivel mundial en buques SOLAS diferentes sistemas de seguimiento como el Sistema de Identificación Automática (AIS) y los Sistemas de Comunicación Marítima (MCS). Las autoridades nacionales y locales ya han establecido infraestructuras, redes y servicios AIS/MCS en la costa. Esta ponencia se centra en el análisis de opciones adicionales para la ayuda en la toma de decisiones de operadores de centro con tareas de navegación y logística.

Las administraciones nacionales y los operadores dan la bienvenida al potencial del AIS/MCS y su capacidad para aumentar la seguridad de la vida en el mar. Casi todos los países y algunas empresas privadas utilizan ya redes costeras AIS/MCS con buenas experiencias con las implementaciones existentes.

Estas experiencias con nuevas tecnologías en el funcionamiento diario conducen a nuevas ideas evolucionarias de nuestros clientes. Frequentis las recoge de nuestras conferencias de Grupo de Usuario Marítimo y talleres privados. Esto permite a Frequentis ofrecer soluciones innovadoras para nuevos servicios.

Los servicios de reducción de logística y desgracias tienen una naturaleza y necesidades diferentes y, sin embargo, técnicas parecidas que pueden ayudar a operadores de ambos lados y sus autoridades o socios logísticos en su tarea diaria. (P. ej., centros VTS, autoridades nacionales, puertos y compañías de tráfico marítimo.)

La ponencia es un debate acerca de esas ideas y las posibilidades técnicas que albergan. Los aspectos tenidos en cuenta son:

- Los operadores son los expertos del análisis comportamental del buque
- Las autoridades deciden las necesidades comportamentales que hay que reconocer
- Los sistemas actuales ofrecen principalmente apoyo pasivo en la toma de decisiones mostrando situaciones de tráfico o grabando solo los comportamientos de los buques para un análisis posterior.
- Las tecnologías de hoy en día sobrecargan principalmente a los operadores con información y reducen probablemente el conocimiento de la situación actual.
- Los operadores ya declararon sus necesidades de definir juegos activos de eventos definidos personalizados por el usuario basados en datos de tráfico en sus sistemas.
- La integración del sistema es necesaria para sustituir las alarmas generadas automáticamente que no son importantes con un análisis comportamental inteligente configurable por el operador.
- El reconocimiento comportamental del seguimiento y rastreo tiene que combinarse con los servicios locales existentes para la reducción de logística y/o desgracias.

Hay ideas de usuarios experimentados, implementaciones disponibles como el anteriormente mencionado reconocimiento comportamental T&T. Además, hay que tener en cuenta cómo se podría utilizar esto en combinación con la comunicación por voz MCS para ayudar a los servicios de reducción de logística y desgracias.

A l'heure actuelle divers systèmes de suivi comme le Système d'identification automatique (AIS) et les systèmes de communication maritime (MCS) sont utilisés à bord des navires SOLAS. Les autorités nationales et locales ont mis en place des infrastructures, réseaux et services AIS/MCS à terre. Ce rapport se concentre sur l'analyse des possibilités supplémentaires d'aide à la prise de décision pour les opérateurs de centres chargés à la fois de la navigation et de la logistique.

Les administrations nationales et les opérateurs accueillent favorablement le potentiel de l'AIS/MCS et ses possibilités d'amélioration de la sécurité de la vie humaine en mer. Presque tous les pays et quelques sociétés privées gèrent des réseaux d'AIS/MCS à terre et ont acquis une bonne expérience avec les installations existantes.

Cette expérience des nouvelles technologies dans le fonctionnement quotidien conduit nos clients à formuler de nouvelles idées d'évolution. Frequentis les collecte auprès des conférences de notre Groupe d'usagers maritimes et de séminaires privés. Ceci offre à Frequentis l'occasion d'offrir des solutions innovantes pour de nouveaux services.

Les services logistiques et de gestion de crises sont de natures différentes mais des techniques similaires peuvent néanmoins aider leurs opérateurs, leurs autorités ou leur partenaires logistiques dans leurs tâches quotidiennes (par exemple les centres VTS, les autorités nationales, les ports et les compagnies maritimes).

Ce rapport revêt la forme d'un débat autour de ces idées et des possibilités techniques sous-jacentes. Les aspects pris en compte sont les suivants :

- *Les opérateurs sont des experts en analyse du comportement des navires*
- *Les autorités décident quel comportement doit être remarqué*

• Les systèmes d'aujourd'hui offrent essentiellement une aide à la décision passive, en affichant des situations de trafic ou en seulement enregistrant des comportements de navires pour une analyse ultérieure

• Les opérateurs ont déjà fait état de leur besoin de disposer d'ensembles dynamiques d'évènements personnalisés reposant sur les données de trafic de leurs systèmes

• Il faut une intégration de systèmes pour remplacer les alarmes sans intérêt, générées automatiquement, par des analyses de comportement intelligentes configurables par l'opérateur

• Le suivi et la détection du comportement doivent s'harmoniser avec les services locaux de logistique et de gestion de crises existants.

L'usager expérimenté a des idées, et il existe des possibilités, comme décrit ci-dessus, de mise en place de détection du comportement. On prend aussi en compte la façon possible d'utiliser ceci en combinaison avec les communications MCS pour aider les services logistiques et de gestion de crises.

Behaviour recognition assisting maritime situational awareness

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Behaviour recognition assisting maritime situational awareness

Florian A Gruber – FREQUENTIS AG, Austria

The goal to avoid distress, saving lives, nature, goods, and optimization of logistics could be supported by such a service. There is definitely the potential of T&T "Behaviour recognition" to assistance logistic- and navigational- oriented operators and personal in daily work.

Listed below some possibilities of improvements can be found:

- Operator defined traffic rules analysed by the behaviour recognition service that triggers specified notifications and/or actions will support the next generation of situation awareness tools.
- Fast and automatic recognition of traffic circumstances and behaviours in traffic situations done in the background don't disturb normal working.
- Recognition of suspicious behaviour, by performing filtering tons of normal behaviour multiplies operator's eyes. Even finding "Lost Targets" in specific areas is technically possible.
- Ships data interpretation helps, e.g. cargo, navigational status, persons on board and others, to find interesting vessel traffic situation for standard automatic ship reporting or to detect dangerous traffic constellation.
- An optimization process with focus on the "hit rates" including finding nearly misses is supported. Powerful filtering reduces unwanted alarms and warnings.
- Integration of available sensors and communication like AIS, LRIT, RepSys, Radar, DSC, Voice Communication, CCTV, etc. will improve the service.
- The use of different communication channels like AIS Safety Related Messages, MSI, DSC and MCS Voice Communication is helpful to actively influence the situation after a positive detection.

Nevertheless, in a safety critical system that uses automatic traffic recognition algorithms, the operator always has to be able to intervene automatic triggered actions.

Following figures illustrate selected examples:

T&T Services for AIS Networks in combination with MSC, DSC Services are powerful tools for all participants in the maritime environment.

T&T behaviour recognition features are:

- Suspicious lost of targets, check if accidentally or with criminal intent
- Passage, speed, track, routing, cargo, person on board -behaviour
- Maritime Safety Information function -event triggered
- Traffic separation scheme -monitoring
- Anchors zone management – including a trigger for Levy Service
- Active Infrastructure protection for e.g. Beacon, Boys, Bridges

There are lot more examples which could be established by using existing information in existing safety network environment.

The combination of AIS with MCS Voice radio networking will empower the benefit for the vessels and the authorities, enabling them to immediately warn or inform vessels before a critical situation even arises.

Such services have the potential to combine Navigation with Communication!

Accident avoidance is supported as well as the daily logistical work of VTS and MRCC operators. ■

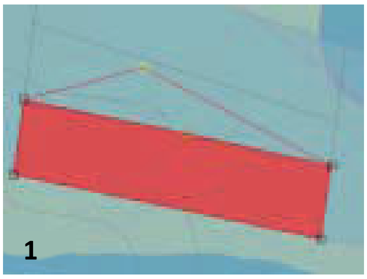
*The main functionality of a **T&T Behavior Recognition e.g. Logistics – Anchor Zone Management** system lies in the term of a Region of Interest (ROI) which is a representation of a geospatial polygon in context to maritime traffic.*

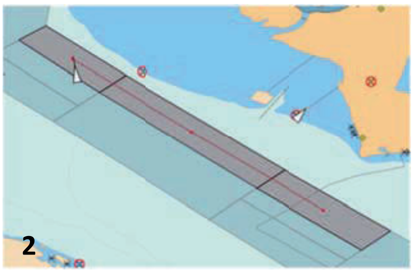
Spatial Analysis

Anchor zone Management will only work in connection with an implementation of a behaviour recognition module, because it needs to be able to get notified when a vessel (or in general, a maritime object) enters, leaves or updates within a region of interest. For this functionality, it needs to be aware of some geospatial functions, which can be either implemented in the DB or in an own service.

Fairways

Another important feature of an Anchor Zone Management module is Fairways. Fairways are connected region of interests. They also exist in the S-57 file format as an own layer. With fairways a user of the system can assign a vessels route to its berth or anchorage zone. Once assigned, the Anchor Zone module will monitor the behaviour of the vessel and check if it stays within the assigned route.





1. Operator defined Region of Interests for behaviour monitoring 2. Fairway routing and separation monitoring with automatic MSI 3. Traffic movement analysis with logistic event trigger

79 ACHIEVEMENT OF ATON IN TURKEY (FINALIZING SOTAS PROJECT)

Celalettin Uysal. Directorate General of Coastal Safety, Turkey

In addition to existing 85 remote controlled AtoN stations in Turkish straits, a new Project called SOTAS which includes the installation of 382 AIS AtoN stations as integrated with new LED type lanterns and the establishment of remote control for these stations over GSM/GPRS and ADSL network, has been completed by covering the whole Turkish waters. SOTAS aims to monitor and manage the AtoN stations, to collect information from navigational aids and, to observe the vessel traffic all over Turkish coast. Directorate General of Coastal Safety uses the collected information for both improving the system itself and benefitting from AIS for other purposes. The SOTAS system is also key position for e-navigation developments in Turkey.

By using the system, new highlighted fatures are,

a. Messages produced in RMC and automated AIS-AtoN messages can be broadcasted to AIS receiver units with in the range. Area broadcast message has been included to software for e-navigation.
b. Each units of SOTAS can be used as receiver and processed to determinate AIS slot usage on their coverage area.
c. SOTAS system has capable to call data from his storage and display historical track between selected dates.
d. New features included, maintenance software to improvere pair processing for technicans.

Además de las 85 estaciones AtoN existentes controladas de forma remota en los estrechos turcos, se ha completado un nuevo proyecto llamado SOTAS que cubre todas las aguas turcas e incluye la instalación de 382 estaciones AIS AtoN integradas con nuevas linternas de tipo LED y el establecimiento de control remoto para estas estaciones a través de GSM/GPRS y red ADSL. SOTAS pretende controlar y gestionar las estaciones AtoN, recopilar información de ayudas a la navegación y observar el tráfico marítimo en toda la costa turca. La Dirección General de Seguridad Costera utiliza la información recopilada para mejorar el propio sistema y beneficiarse del AIS para otros propósitos. El sistema SOTAS también es una posición clave para los desarrollos de la e-Navegación en Turquía.

Utilizando el sistema, las nuevas características destacadas son:

a.Pueden emitirse mensajes producidos en RMC y mensajes AIS-AtoN automatizados a unidades receptoras AIS dentro del alcance. El mensaje de emisión de área se ha incluido en el software para la e-Navegación.
b.Cada unidad del sistema SOTAS puede utilizarse como receptor y procesarse para determinar el uso de la ranura AIS en su área de cobertura.
c.El sistema SOTAS es capaz de recuperar datos desde su almacenamiento y mostrar un seguimiento histórico entre fechas seleccionadas.
d.Software de mantenimiento con nuevas características incluidas para mejorar el procesamiento de pares para los técnicos.

En plus des 85 aides à la navigation télécommandées des détroits de Turquie, on a achevé un nouveau projet appelé SOTAS, comprenant l'installation de 382 aides à la navigation AIS intégrées comprenant des lanternes LED, contrôlées à distance par GSM/GPRS et réseau ADSL et couvrant la totalité des eaux turques. Les buts de SOTAS étaient de contrôler et gérer les aides à la navigation, collecter leurs informations et observer le trafic des navires tout le long de la côte turque. La Direction Générale de la Sécurité de la Côte utilise l'information collectée pour, à la fois améliorer le système lui-même, et tirer bénéfice de l'AIS à d'autres fins. Le système SOTAS est aussi une clé pour les développements de l'e-Navigation en Turquie.

Les avantages de l'utilisation de SOTAS sont :

a. Les messages produits en MRC et les messages d'aides à la navigation AIS automatisés peuvent être transmis à des récepteurs dans la zone de couverture. Une zone d'envoi de message à été insérée dans le logiciel e-Navigation.

b. Chaque unité de SOTAS peut être utilisée comme récepteur et traitée pour déterminer une bande d'utilisation AIS dans sa zone de couverture.

c. Le système SOTAS est capable de retrouver dans sa mémoire et de montrer à l'écran des traces de suivi entre des dates sélectionnées

d. Les nouveaux aspects comprennent un logiciel d'entretien pour le traitement par les techniciens.

Achievement of AtoN in Turkey

Finalizing SOTAS project

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Achievement of AtoN in Turkey – Finalizing SOTAS Project

Celalettin Uysal, Aids to Navigation Department - Turkey

Introduction

Directorate General of Coastal Safety, Lighthouse Authority in Turkey, which makes arrangements for minimizing the damages of marine accidents which may occur in Turkey's maritime jurisdiction areas, internal waters and coasts, for the purpose of providing the safety of navigation, life property and environment based on recommendations, guides and practices of IMO and IALA regarding the issue, has put into service the Automatic Identification System (AIS Aton- based) for Navigational Aids in 2012 and completed its works for safety of navigation.

Initial efforts of Aids to Navigation Department, Lighthouse Authority in Turkey, for Automatic Identification System started in 1999. Navigational aids which are located at important positions such as Istanbul Strait, Çanakkale Strait and the entrance of Strait have been monitored within this system which could be rather used through regional solutions with respect to technology of the time. However, the development of technology, reduction of communication costs, implementation of electronic navigation in maritime sector, increase of tourism based on especially yacht traffic and the density of tanker, container and Ro-Ro ships in coasts of Turkey have further raised the importance of aids to navigation at every point.

From all reasons above, it became compulsory to make investments for Administration, and to proceed to systems which all data are used common and, can render service to both administration and users. Experts on this issue in Turkey studied for two years in 2006 by considering the needs of sector, the needs of Lighthouse Authority and, the view and opinions of people who did a scientific research for needs of other stakeholders to be benefitted from service. "**Automatic Identification System for Aids to Navigation**" (AIS AtoN) Project was established at the final report of this study.

At the implementation of Project, it is considered that it will cover the entire Turkish coasts in two steps. The purpose of this is to observe faults which may occur at newly established system, and to get results which are close to perfection at second step. Another reason is the ongoing discussions about conditions of AIS AtoN in international area. Mounting process was carried out for 185 AtoNs, between 2008-2010 and 215 AtoNs, between 2010-2012. All software and hardware were prepared in Turkey, and the contractor of Project is iDeal Technologies Inc. It has been targeted to provide the implementation of Project to AIS or GSM/data communication derivatives and all subsidiary lighthouses as required over the years.

At the preparation process of Project, the adaptation of historical lighthouses became a problem. Initially, the question was: "How could historical lighthouses become integrated without disrupting their structures". An expert team was formed for the adaptation of facilities having 16 AtoNs which were started to be established at late 1800's in the world and operate with this system in our coasts. As a result of research made by this expert team, a special gear was designed for each AtoN by an engineering calculation which can turn drum under lens and provide current light flashing character. Redactor and engine were designed for providing motion for these gears Sensors were placed at appropriate points to detect a fault which may occur during turning over time. Thus, the adaptation of historical lighthouses to the system was provided without disrupting their original structures. Historical lighthouses are protected by our Organization as an exceptional part of our Turkish Maritime history and they continue to serve to maritime world by merging technology and history into their structures.

Picture 1: Şile Lighthouse Rotating system

Picture 2: Şile Lighthouse

General Technical Specification of AIS AToN for Turkey

AIS AtoN system is prepared in accordance with relevant standards, performance requirements, rules and recommendations at national and international level and approved by accredited test institutions. The installed system consists of the following components:

a. AIS AtoN equipment (AIS AtON operating at FATDMA and RATDMA Access modes)
b. GPRS unit for each AIS AtoN equipment which will connect it to remote central server
c. If a problem occurs at GPRS communications, there will be DSL Router at 60 spots which will provide communications between central server and AtoN. If AtoNs become disconnected through GPRS, communications will be provided by connecting AtoN over VDL at locations which have DSL router. In the system, almost all information of AtoNs can be reached by these 60 DSL Routers.
d. AtoNs/ lights and control units,
e. Software operating at central server, and current monitoring, evaluation and control software modules Lighthouse authority obtains information needed by Central server through DSL and GPRS module/terminals and controls related functions.

System serves to over 200 remote users through Main Control Center (MCC) located at Directorate General of Coastal Safety in Istanbul and sub-centers located at ten local technical offices.

To the end that AtoNs can be cleaner, cost-effective and environment friendly, renewable energy sources were used. For this purpose, all optical navigation lights in AtoNs were replaced by modern systems with low-power consumption using L.E.D. technology. In addition, each station was equipped with AIS AtoN devices which have extremely low-power consumption for remote monitoring/management of these L.E.D lights, monitoring maritime traffic around related station, executing AIS operations. All AIS AtoN stations, key application and utilities used in Project were developed locally in line with requirements of Administration, and delivered in conjunction with interfaces which may provide two-way data flow with other current systems, similar software in other organization/institutions.

It has the capability of receiving all types of AIS message, *as defined in ITU-R M-1371*, sent through A and B channels of AIS AtoN and transmitting them to Center server. It is also possible to send automatic text based routine and safety messages by Center server to public. All inquiry and control functions, *described in IEC-62320-2 standards and which can be realized through VDL*, may also be interrogated by using AIS Message 6 and 25 working with devices in the RADTMA access mode. The structure used in the system for sending, interrogating and controlling of the special message through VDL to SOTAS devices, is designed in accordance with MCR (Manufacturer's AtoN Control) configuration at IEC-62320-2 standard. Information about SAR vehicles sent by Message 9 through AIS channel can be received and evaluated. Each of SOTAS devices in the system, *including 4 units of virtual aids to navigation*, can broadcast to public.

SOTAS project is prepared in compliance with AIS AtoN system, and therefore it has the capability of receiving dynamic and static information broadcasted by vessels in the area where the SOTAS devices are established. Information received:

- Static Information
  - IMO number
  - MMSI number
  - Call Sign and name
  - Type of vessel (ID no and clearly)
  - Vessel's width and length
  - GPS antenna location in the vessel
  - OTAS type of device
  - OTAS class of vessel
  - Cargo type of vessel
  - Draft
  - System type of defining position
  - The capability of displaying Message 12 and 14
- Dynamic Information
  - Position of vessel (latitude and longitude)
  - Time (UTC)
  - Course according to ground (COG)
  - Speed according to ground (SOG)
  - Heading
  - Rate of Turn (ROT)
  - Navigation situation of the vessel (like "at anchor", "not under command", " be en route")
  - Cargo type (like cargo, dangerous cargo)
  - Arrival port and estimated time of arrival
  - Position info accuracy

Static and dynamic information sent through AIS Message to SAR aircraft in order to use in Search and Rescue Operations:

- MMSI number

- SAR aircraft position (latitude and longitude)
- Height
- Routing according to ground (COG)
- Speed according to ground (SOG)
- Position info accuracy

The service quality rendered to mariners has been improved with the contribution of the other system's stakeholders. With the aim of providing instant information to mariners, cooperation has been made with the Organization responsible for gathering and sharing of Meteorological data, and 31 units of aids to navigation in critical points have been equipped with Meteorological sensors (at the end of 2014, total number of aids to navigation equipped with meteorological sensors will be 59) and they have been put into service for mariners over AIS Message 8. In addition, within the project, cooperation has been made with another State Organization responsible for monitoring fishing vessels movements and the same services have been provided for them too.

Picture 5: SOTAS with automatic meteorological D-OMGI

Picture 3-4: Marine Automatic Meteorological Observation Stations transmitting weather data from SOTAS. http://www.meteor.gov.tr/deniz/domgi.aspx) captured from Offical web site published by Turkish State Meteorological Service

SOTAS Stations

All of the AIS AtoN stations have IP65 class mechanical protection against severe environmental conditions. There is SOTAS capsule having GSM/GPRS communication interface and AIS AtoN device at the beneath of the protector in outermost which is preventing cables from negative impacts of sun and salt. Antenna pedestal, *including GPS – VHF and GSM antennas*, has been developed in order to ease installation and maintenance works of the stations. By means of Ethernet port and GSM module on communication interface device, the system uses

Picture 2: Şile Lighthouse

wire/wireless communication alternatives as back-up. If both communication infrastructure are available at the same time, principally communication has been provided over Ethernet with wire, and if there is an interruption, the system automatically switchovers to GSM/GPRS communication. Where both communications are not available, the system can reach other SOTAS stations within its coverage area with VHF-VDL messages. The system, *with the given on the spot access software*, can perform transactions needed, like self-test, configuration and embedded software updating during the installation and maintenance.

Picture 6: SOTAS equipped buoy

SOTAS Stations

All of the AIS AtoN stations have IP65 class mechanical protection against severe environmental conditions. There is SOTAS capsule having GSM/GPRS communication interface and AIS AtoN device at the beneath of the protector in outermost which is preventing cables from negative impacts of sun and salt. Antenna pedestal, *including GPS – VHF and GSM antennas*, has been developed in order to ease installation and maintenance works of the stations. By means of Ethernet port and GSM module on communication interface device, the system uses

wire/wireless communication alternatives as back-up. If both communication infrastructure are

Picture 7: SOTAS with LED Sector Light

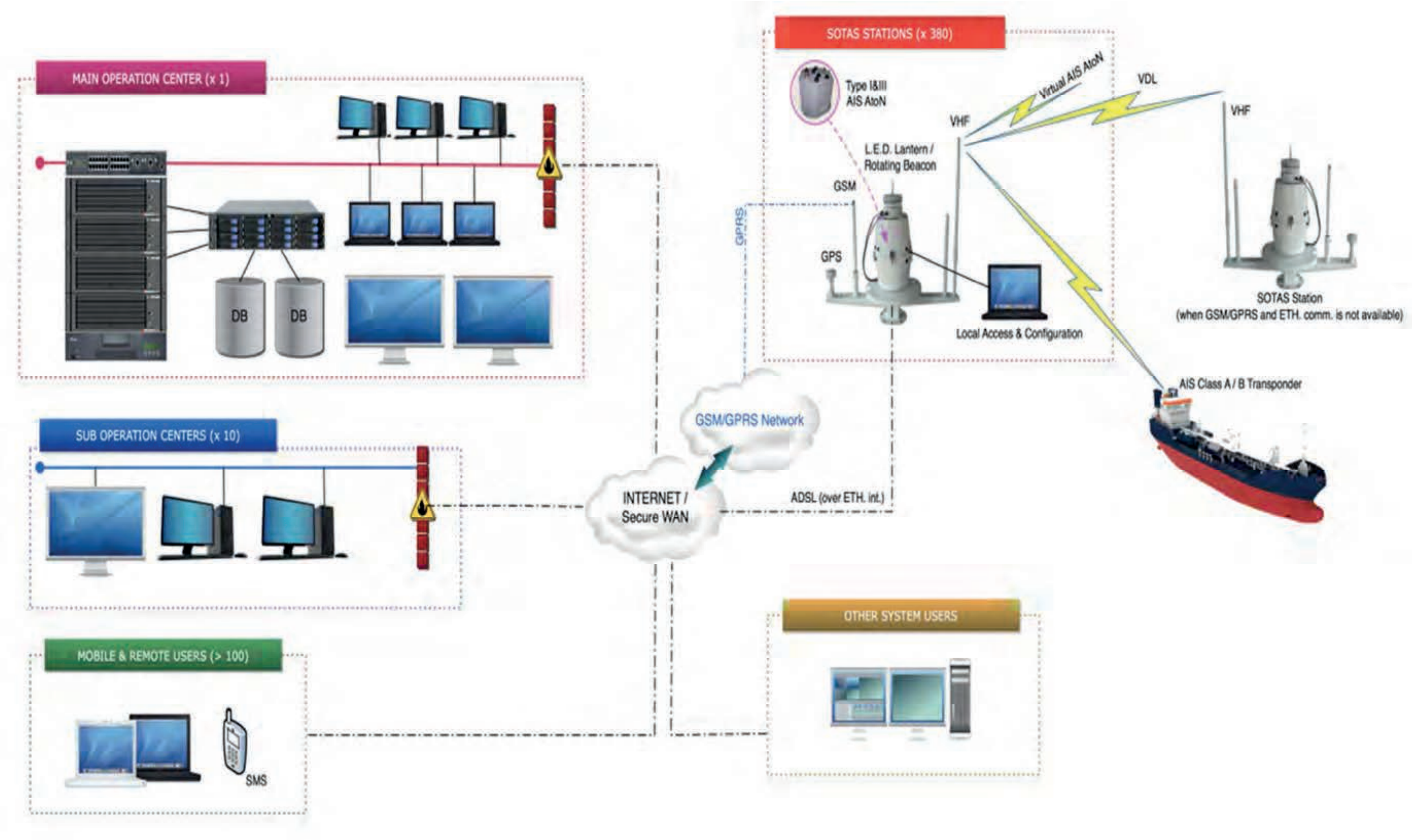
available at the same time, principally communication has been provided over Ethernet with wire, and if there is an interruption, the system automatically switchovers to GSM/GPRS communication. Where both communications are not available, the system can reach other SOTAS stations within its coverage area with VHF-VDL messages. The system, *with the given on the spot access software*, can perform transactions needed, like self-test, configuration and embedded software updating during the installation and maintenance.

SOTAS Center Software

The center application software, *developed modular and scalable*, are used by the users having different level of access authorization and access permission to system's functions is given to the degree of their level of authorization for each person, and all critical command and inquiry transactions realized are recorded.

With the help of developed center software, remote monitoring and control operations like:

a. Display of Aids to Navigation identity information



Picture 8: SOTAS System Architecture

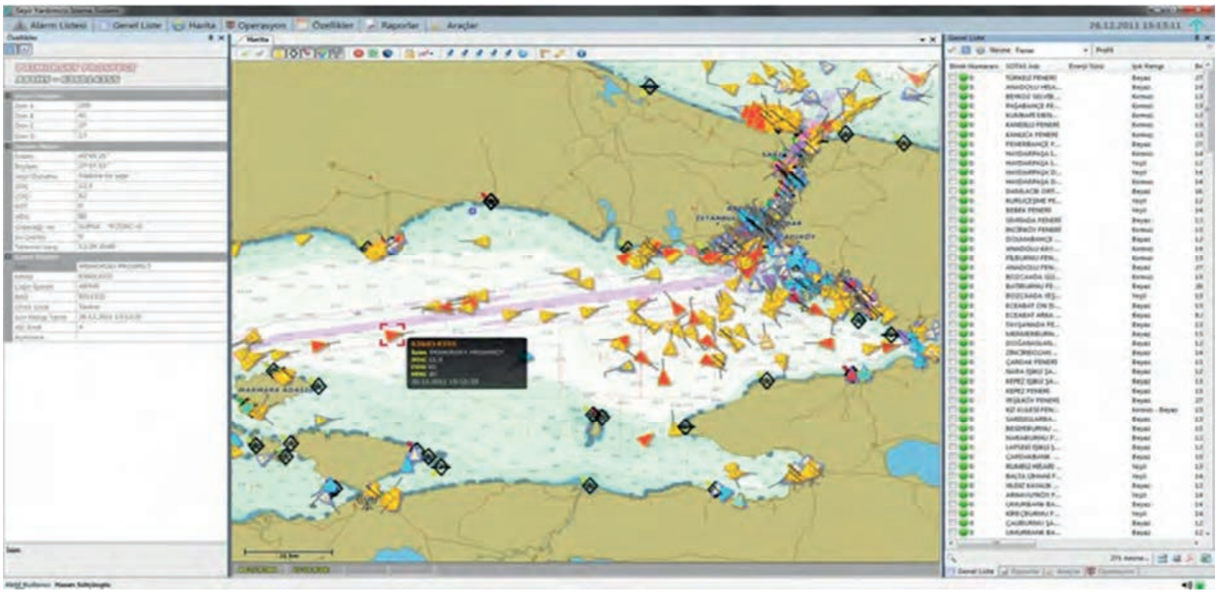
b. Collection of AIS data of vessels and message transmission
   i. IMO, MMSI number
   ii. Call sign and name
   iii. Type, width-length
   iv. AIS device type
   v. AIS class
   vi. Cargo type
   vii. Vessel Draft
   viii. Other AIS based information
c. Monitoring of light situation (on, off state)
d. Battery voltage (battery powered aids to navigation) and monitoring of instantaneous current taken from circuit
e. Position information of SOTAS station
f. Counter information for rotating lighthouses
g. Lantern fault alarm
h. L.E.D fault alarm (excluding rotating lighthouses)
i. Drifting alarm (for buoys)
j. Protective area warning (for buoys and aids to navigation at sea)

Picture 9: SOTAS station with 10 nm LED lantern

Picture 10: SOTAS Station with LED sector light

k. Low voltage warning
l. High voltage warning
m. No mains voltage warning (lighthouse operating with mains voltage)
n. Remote reset of SOTAS and interface card
o. RACON device fault alarm, are performed and recorded.

It is possible real-time monitoring of more than 3.000 vessels in covered area by the system in Turkish coasts, imaging of past route/track info, sending text messages to vessels, interrogating static, dynamic and special navigation data and filtering and ranging them according to criteria and interrogation specified by the user. S-57 types of maps are used as e-navigation map and they are updated regularly.



Picture 11- SOTAS Center Software Screen Captured

If buoy chain is broken and the buoy has been drifted, automatically activated warning alarm and AIS warning messages sent to vessels, which are inside of the buoy circle defined by user, are some of the prominent functions of the system.

If a failure has been occurred or alarm has been activated in any component of the system, voiced and visual alarm messages are composed and additionally, communication instruments like e-mail, SMS are sent automatically to preauthorized persons with regard to alarm type. After the mentioned failure alarm, technical team is directed via call opened on Maintenance-Repair module and status info about the failure and operations made can be monitored through the system.

Software features

Area Notices section

SOTAS software, *using Message 8 for each SOTAS,* can transmit the requested area notices by entering associated text and text description contents. These notices can be transmitted within specified time intervals through the chosen SOTAS's.

Area notices, associated texts and text descriptions which will be transmitted, are described by using special data entrance areas regarding to area information, *like position, sector, open area (line), range position or text,* with the area type, notice type, starting date and validity period.

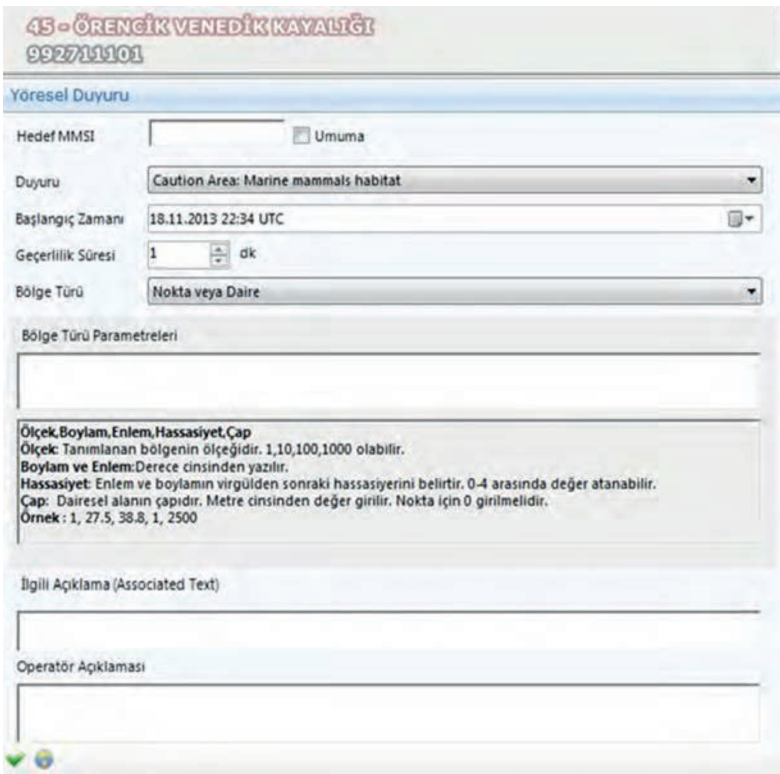
Picture 12: Area notice section screen captured.

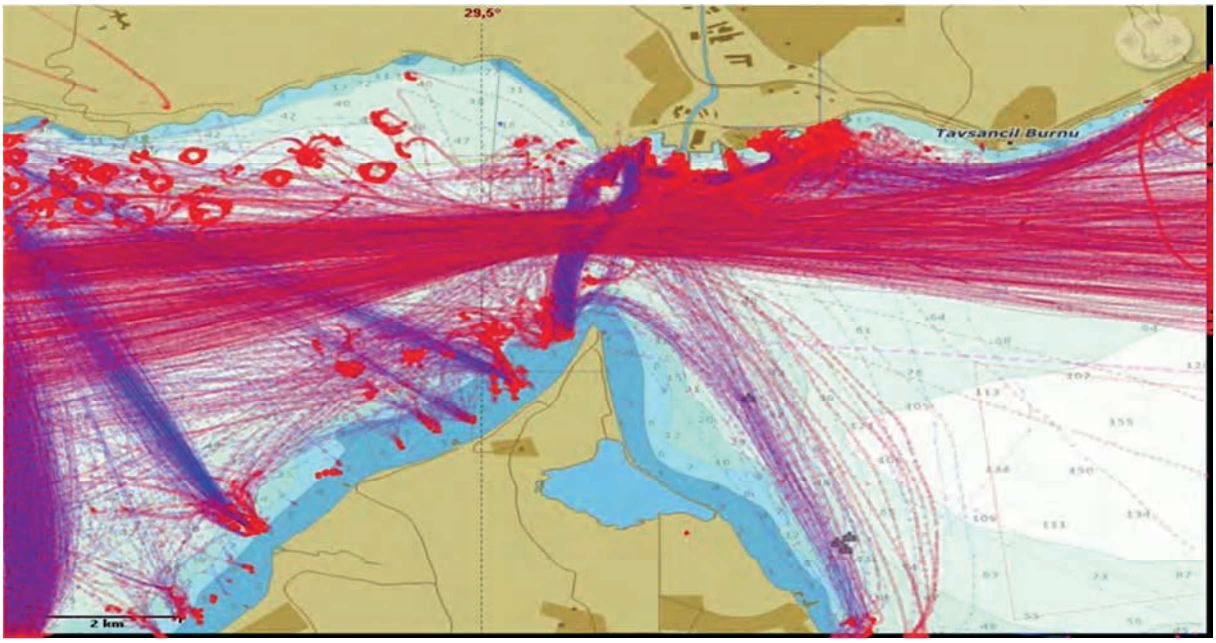
→

After numbering (linkage ID) the area notices and associated texts for each SOTAS, these notices and texts can be transmitted to publicity (to all) or to an accessible MMSI number.

The due date and time for SOTAS's area notices broadcasting and frequency of transmission can be selected by the user.

All broadcasted area notices and associated texts are demonstrated prominently on the map which is available on SOTAS's software with the comment text.





Picture 13- SOTAS Graphic Analyses Software Screen captured

Stack Trace (graph analyses) software

Beside of monitoring and control functions provided by the system, it is very important to analyze and report regularly collected data, in order to determine additional aids to navigations which will be required in the future, to define buoy locating points and to conduct the communication in a suitable way. For this purpose, data on database are analyzed and reported by Graphic Reporting involved within the project.

Slot tracing software which provides to monitoring the SOTAS's VDL.

For SOTAS that selected with the Slot Tracing Application, slot usage on real is screened to users in a "slot map". Also with this application, slot usage density statics is obtain by using data as "Slot reservation and usage", "Synchronization Faults", "Slot Collisions", "Improper use of VDL", "Faultier AIS messages", "VDL loads", "Slot usage for a selective user" in a selected time and criteria

Picture 14-SOTAS Slot tracing Software Screen Captured like VHF channel, AIS type, message type. SOLAS, as being selected to be use in Slot Tracing application, chance to a receiver position to monitor all slots used in VDL. Generated graphical data is recorded by transforming to PDF, PNG and JPG format.

WEB Inquiry and Information Sharing Services

Required section of information which was collected in system can be shared with authorized internet users in near real time manner through web-based inquiry and information sharing services.

A special web interface was prepared and secure access system in communications was used for product sharing and all inquiries to be made. Data history belonging to any vessel which was kept in UMS, has been accessed and inquired through web service to be prepared. Web service has prepared XML file which contains various information, selectable frequently and periodically.

Technician / Maintenance and Repair Tracking Application Software

Independent maintenance and repair module has been working as a database management tool, which provides evaluation, tracking, remote controlling, programming and recording of repair procedures, failures, routine control works and maintenance which have to be made for all Aids to Navigation periodically. This module also provides the transmission of SOTAS failure alarm and warnings with related Administration personnel to the personnel of organization, *where the service has been bought*, via Short Message Service, Electronic Mail etc.

For the software and Aids to navigation systems, geographical area based groupings and under these areas locations of AtoN are described. Importance rating, minimum service and alarm time threshold are identified for AtoN.

Chief Technician examines failure records with the help of filters which he/she will apply by using Maintenance Repair Module interface on existing failure service card, and can assign technician for the service and inform district chief technician and related personnel of organization which provides service about warnings and failures with Sort Message Service (SMS) and Electronic Mail(EM) by taking into account the priority of aids to navigation.

Conclusion

As a state organization, Directorate General of Coastal Safety takes the responsibility for minimizing accident risk possibility and improving the safety of navigation, life, property and environment in Turkish seas and territorial waters.

Directorate General of Coastal Safety establishes, operates monopoly and invests in any system and facilities intended to provide safety of navigation in Turkish Straits and territorial waters in accordance with the legislation regulated its functions. Our Organization uses tools like; “Turkish Straits Vessel Traffic Services System”, “Marine Communication Systems”, “Lighthouse, Foghorns and buoys”, “E-Navigation”, “dGPS Base Station”, “Automatic Vessel Identification Systems”.

In addition to them some other services like “Salvage Services”, “Search and Rescue Services at Sea”, “GMDSS and Merchant Marine Communication” are also rendered by the Directorate General of Coastal Safety.

The Directorate General of Coastal Safety efforts to maintain a high level of safety of navigation continues with our slogan “Your Own Safety is Our First Priority” at clean sea. ■

2 COMMUNICATION FOR E-NAVIGATION

Rolf Zetterberg. Swedish Maritime Administration, Sweden

In the early phase of the development of the e-Navigation concept, IALA stated that communication is, together with accurate positioning systems and electronic charts, the main pillars of e-Navigation. This initiated a comprehensive work within IALA and other organizations, in order to find the best ways to fulfill the communication requirements for e-Navigation.

This paper shortly describes this work, which still is ongoing, and the role of IALA in the process, from defining the communication needs, spectrum requirements, transmission technology and technical characteristics of the foreseen system. The results so far are, including The IALA Maritime Radio Communications Plan which is a supporting document for this this process, presented briefly.

The need for further development work, standardization and implementation on board and ashore, is discussed.

En la fase temprana de desarrollo del concepto de e-Navegación, la IALA declaró que la comunicación, junto con los sistemas de posicionamiento precisos y las cartas náuticas electrónicas, son los pilares centrales de la e-Navegación. Esto inició un trabajo exhaustivo dentro de la IALA y otras organizaciones para encontrar las mejores formas de cumplir los requisitos de comunicación para la e-Navegación.

Esta ponencia describe brevemente este trabajo, que todavía está en curso, y el papel de la IALA en el proceso, desde la definición de las necesidades de comunicación y las necesidades de espectro hasta la tecnología de transmisión y las características técnicas del sistema previsto. Se presenta un resumen de los resultados hasta el momento, incluyendo el Plan para las Radiocomunicaciones Marítimas de la IALA, que es un documento de apoyo para este proceso.

También se analiza la necesidad de fomentar el trabajo de desarrollo, normalización e implementación a bordo y en tierra.

Au début du développement du concept e-Navigation, l'AISM a déclaré que la communication était, avec les systèmes de positionnement précis et les cartes électroniques, l'un des piliers importants de l'e-Navigation. Cela a généré au sein de l'AISM et d'autres Organisations des travaux très importants, dans le but de trouver les meilleurs moyens de répondre aux besoins de communication de l'e-Navigation.

Le rapport décrit brièvement ces travaux, toujours en cours, et le rôle de l'AISM dans cette démarche, depuis la définition des besoins en communication et en spectres, la technologie de transmission et les caractéristiques techniques du système espéré. Les résultats obtenus jusqu'à maintenant sont brièvement donnés dans le rapport, notamment le Plan de Radionavigation de l'AISM qui est un document de référence pour ce travail.

Le rapport discute aussi de ce qui reste à faire : poursuite du développement, normalisation et installation à bord et à terre.

Communication for e-Navigation

Rolf Zetterberg

Swedish Maritime Administration

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

Communication for e–Navigation

Rolf Zetterberg, Swedish Maritime Administration

Background

The use of IT-systems both onboard and on shore are increasing and consequently the need for data communication between ship and shore and between ships is increasing. This trend has been going on for many years and is now, with the introduction of e-Navigation, accelerated.

When IMO Maritime Safety Committee, MSC 81, 2006 made e-Navigation to a joint work item for the sub-committees on Safety of Navigation (NAV) Radiocommunication and Search and Rescue (COMSAR) and Standards of Training and Watchkeeping (STW), IALA was well prepared to work on the communication for e-Navigation. The "old" IALA Radionavigation Committee had a Working Group on "Future Communication" and the IALA AIS Committee had a very important role in the development and implementation of AIS, which beside its main function have a limited data communication capability.

When the IALA eNavigation Committee was created in 2006 was, among others, Working Groups for Communication and for AIS established and continued the work to contribute to the development of communication for eNavigation.

MRCP

The Maritime Radio Communications Plan (MRCP) has been developed by IALA to assist in the selection of radio communication systems required to support e-Navigation.

The core objective of the document is to state the IALA vision for the efficient use of Radio Spectrum in the Maritime Mobile Service.

The document focuses on the need for an agreed infrastructure of communications between ships and ashore. It presents IALA's view on current, developing and future Radio Communication Systems for the maritime sector.

e-Navigation will require appropriately designed radio communication systems for robust and reliable services. The document is aimed at assisting in the formulation of policy for National and International spectrum allocation and usage.

The document is also provided for IALA members and other administrations to assist them in offering their proposed use of radio spectrum as part of the on-going studies at ITU. The MRCP provides guidance to IALA members regarding potential future developments, which will enable members to identify areas requiring resource allocation and research activity. It has also been used in the work on Maritime Communication by ITU.

The plan describes several systems that can be part of the communication solution for e Navigation and also potential system components for modernization of GMDSS.

Table 1 below is an example from the MRCP, indicating where existing (E) and possible future (F) communication systems may be used.

The work by IALA has focused on VHF communication, which is an area of interest for many of the IALA members and is, through the work by IALA on AIS, an area where IALA have experience and have produced good results.

Communication Requirements

Fundamental for the design of communication systems are the user requirements. IMO have expressed that the e-Navigation concept should be based on identified user needs. IALA assisted in identifying user needs by inputs to the IMO eNAV Correspondence Group and a long "wish list" was created. These needs have after discussions, gap analysis, grouping, cost/benefit analyses and prioritization, eventually boiled down to 5 so called "e-Navigation solutions", which now are described in general terms. The descriptions are not yet detailed enough to allow any calculation of the requirements on the communication systems.

IALA has therefore used another approach when trying to meet the communication requirements under e-Navigation. General requirements for safety of life, operational, and commercial applications have been considered, but the work has focused on a small set of known applications with the flexibility to grow, to encompass others in the future as necessary. It is obvious that we still are in a very early stage of the e-Navigation age and we don´t know what to expect in the future but the trend towards an increased use of data communication is clear.

Guidance is also given by the IMO eNAV Correspondence Group, which states in its report COMSAR 16:"The expectations to e-navigation are given in MSC 85/26/Add.1. Based on this description, the expectations to e-navigation are:

1. Onboard - harmonization of navigation systems, thereby actively engaging the mariner in the process of navigation to carry out his duties in a most efficient manner, while preventing distraction and overburdening.
2. Communications - providing an infrastructure which authorizes seamless information transfer on board ship, between ship and shore authorities and other parties with many related benefits."

Table 1 Geographical classification of e-Navigation data and voice communication techniques Ship-Shore

e-NAV Area Definitions	GMDSS Sea Area (approx)	Broadband phone line or cable. (When ship at berth)	Wi-Fi®	WiMax™	Mobile phone technology	AIS	VDE	Digital VHF voice and data	Data by modulated RADAR	Geostationary Satellite	Commercial MEO/LEO satellite comms	MF & HF (including Navtex / MSI)	DGPS beacon data broadcast service	Current MF & HF NDBP	HF digital data service	MF/HF digital data services for MSI (incl NAVDAT)
1 – Inside port	A1	E	F	F	E	E	F	F		E	E	E	F			F
2- Approaching port area	A1			F	E	E	F	F	F	E	E	E	F			F
3A – Coastal navigation out to cell phone coverage (approx. 5nm)	A1			F	E	E	F	F	F	E	E	E	F		E	F
3B - Coastal navigation VHF coverage range (approx . 25nm)	A1			F		E	F	F	F	E	E	E	F		E	F
4 - Coastal approach (approx. 100nm)	A2									E	E	E	F	E	E	F
5 - High seas	A3									E	E	E		E	E	F
6 - Polar regions	A4										E	E		E	E	F
Legend:																
Existing technology			E													
Future: Not existing or not widely used			F													
Possible preferred technology (Existing, Future)			E		F											

Similar statements with the same effect are used in other IMO documents. A complicating factor is that there are also requests to achieve this without introduction of new carriage requirements for additional equipment.

IALA and VDES

The IALA involvement in the development of VDES has its background in the leading role of IALA in the development, introduction and maintenance of AIS. ITU World Radio Conference 2007 invited IALA (along with IMO and IEC) to contribute to studies on future use of the spectrum. In a liaison to ITU 2008 IALA expressed its vision:

"IALA's vision and strategy for maritime systems propose a significant shift from analogue to digital communications in the VHF maritime band (Radio Regulations Appendix 18), as well as advanced AIS technologies, which IALA believes will greatly contribute toward the modernization of the GMDSS."

In a liaison to ITU Working Party 5B, IALA proposed 2010, a number of provisions within the Radio Regulations:

1. The protection of AIS1 and AIS2 channels for the safety of navigation as well as distress and safety communications. In addition, allow AIS transmissions by SAR aircraft.
2. AIS channels for satellite tracking (channels 75 and 76).
3. Additional channels for the next generation of AIS (AIS V2).. IALA envisaged the necessity of a next generation of AIS (AIS V2), which would require two additional channels for low volume TDMA digital communications using AIS techniques
4. Spectrum resources for application of the VHF data service as described in Recommendation ITU-R M.1842-1 annexes 3 and 4. IALA envisaged e-Navigation would require a minimum capacity of 150 kHz equivalent to six 25 kHz channels
5. IALA supported the retention of the spectrum around 500 kHz for future maritime digital data systems to support e-Navigation and expressed that allowing secondary use around 500 kHz by amateur service would impact the safety of navigation for the maritime mobile service.

IALA liaised with and sent proposals to ITU, IMO, IEC and RTCM as appropriate to support decisions for these improvements.

When ITU allocated frequencies for satellite detection of AIS, IALA proposed an update of the AIS Technical Characteristics to include the new frequencies and a new message (Msg 27). It was accepted by ITU as Recommendation ITU-R M. 1371-3.

During the period up to WRC-12 IALA produced various inputs to ITU and IMO to support the development.

In an input to ITU WP5B 2011, IALA had become more specific: " IALA requests that ITU designate RR Appendix 18 channels 27 and 28 for AIS 5 and AIS 6 and the contiguous group of the 6 channels 24, 84, 25, 85, 26 and 86 for the VHF data exchange of safety and security related information"

In another input, to the IMO eNavigation Correspondence Group, IALA mentioned the importance of an improved AIS, called "Next Generation AIS". This was not well received by some of the Contracting Governments of IMO, who protested and declared that there was no decision by IMO on any further development of AIS. As a consequence, IALA decided to not use that term and introduced "VHF Data Exchange" (VDE) as the term for the anticipated new communication functionality. In the following discussions, it soon appeared obvious that it would be beneficial to consider AIS and VDE as two parts of one system, both using frequencies in the same band and both facilitating exchange of data. A new term "VHF Data Exchange System", VDES, was created and has become widely accepted. It is something very close to what once was called "Next Generation AIS", but with a new name.

The outcome of ITU WRC 2012 was quite positive:

- VHF Appendix 18 was modified to permit digital systems on channels: 24, 84, 25, 85, 26 and 86 for Region 2 from 1st Jan 2013 and 80, 21, 81, 22, 82, 23, 83, 24, 84, 25, 85, 26, 86 worldwide except Region 2 and specific countries (footnote D1)) from 1 Jan 2017;
- Testing of future AIS applications on channels 27, 28, 87 and 88 is permitted from 1January 2013;
- 160.9 MHz (channel 2006) is reserved for experimental use for future applications or systems, e.g. MOB and AIS from 1 January 2013.

Based on this decisions, IALA has continued its work by demonstrating the need for communication, proposing possible technical designs and started the work on a "Preliminary

Draft New Recommendation ITU-R M on VDES". It is presently mainly a placeholder, showing the interest from IALA to contribute in this work.

Through the participation in the IALA work of organizations involved in development of satellite systems has IALA also got the competence to consider the possibility to include a space segment in VDES. The design proposals from IALA allows for two way communication via a Low Earth Orbiting satellite system. If and when such a system will be built is presently not known.

Future work

At its last meeting for the work period 2010-2013, the eNAV Committee developed the document eNAV14-17.1.3.6, "Demonstration objectives in support of the development of VDES. "The document describes the present status of the VDES development, outlines a possible roadmap for the development of VDES (***Figure 1***) and identifies areas which need further test and studies and when the results are required for a timely implementation of the development plan.

The roadmap indicates that there must be cooperation between several organizations and that a VDES-system could be operational in 2020. However, to make it a wide spread system on board ships will require additional time, perhaps of a similar length as the development. Critical factors for the implementation are, among others:

- The applications and range of services that can be offered via VDES
- Possible Carriage Requirements from IMO
- A timely implementation of a shore infrastructure and possible space segment
- Cost and characteristics of the system

The members of IALA, administrations and industry, have a very important role in the continued work on definition, development and implementation of VDES and the services that can be provided via VDES. The cooperation within IALA gives us all the opportunity to contribute to the optimal solution for the communication part of the e-Navigation concept. ■

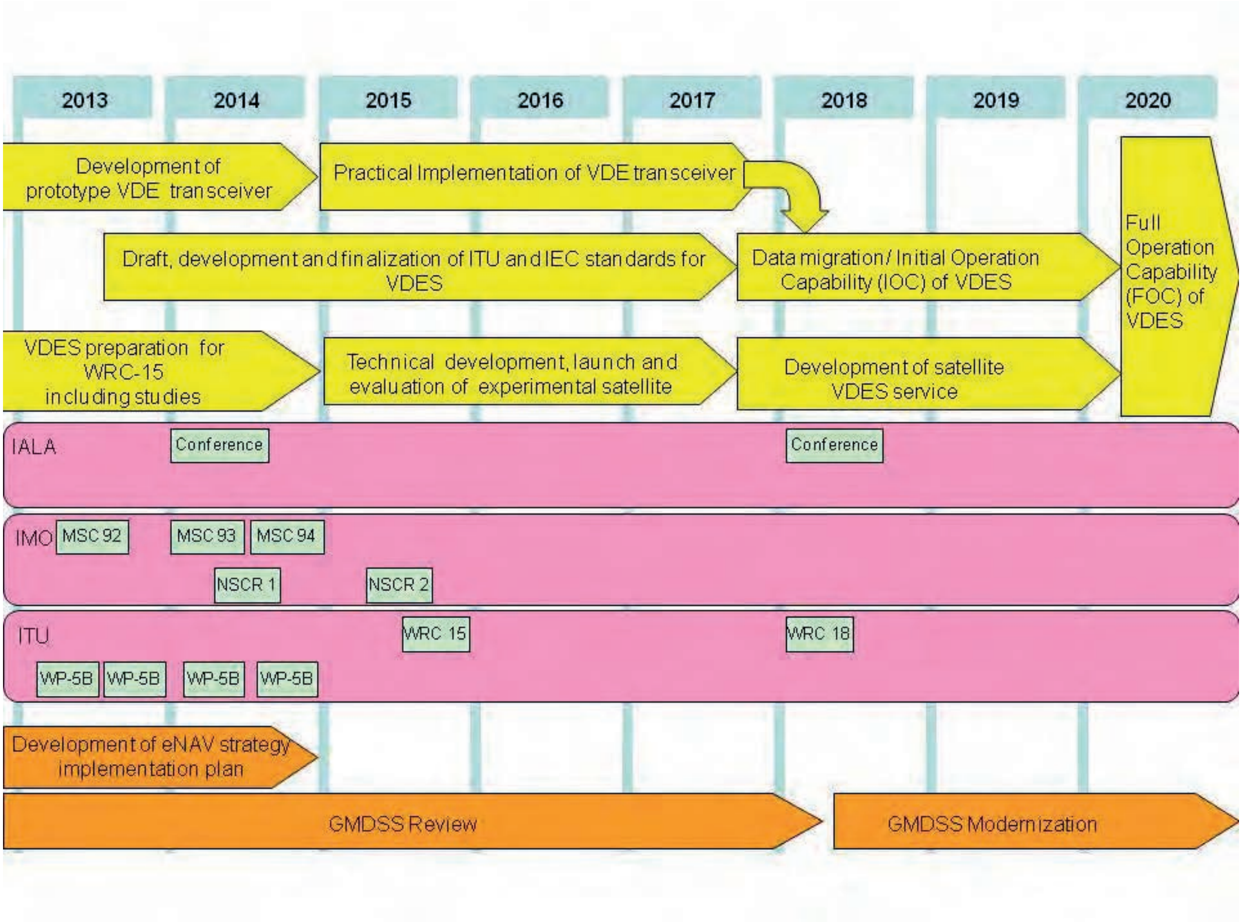


Figure 1: Possible roadmap for development of VDES

63 IALA'S VHF EXCHANGE SYSTEM (VDE). A FOUNDATION FOR E-NAVIGATION COMMUNICATIONS AND GMDSS MODERNIZATION

William D. Kautz. U.S. Coast Guard, USA

VHF data communications will provide the core for robust high-speed/large volume data exchange amongst ships, shore stations, and satellites. AIS has significantly contributed to the safety of navigation, and the carriage and use of AIS onboard vessels is expanding. Various applications of AIS such as AIS-AtoN, Class-B AIS, AIS-SART, AIS-MOB, EPIRB-AIS, and satellite detection of AIS, are useful and valuable for not only the safety of navigation but also safety of life, marine environment protection, assurance of maritime security, assistance of search and rescue missions and efficiency of shipping; however, the AIS, as a navigation safety system, not a communications system, is not capable of handling, nor was it ever intended for high-speed/large volume data exchange.

E-Navigation requirements for robust and efficient communications coupled with the need to protect AIS for its original purpose of safety of navigation, while making use of the broad AIS capabilities formed the basis of IALA's e-Navigation committee's decision to develop a concept known as VHF Data Exchange System (VDES). The VDES is a VHF maritime data communication system that includes functions of AIS, facilitates e-navigation, supports GMDSS modernization, and general maritime communications. VDES uses Recommendation ITU-R M.1842-1 techniques to solve the limitation of AIS data exchange. The VDES has great capabilities for robust and fully automated communications and will influence the whole maritime society with enhancement of safety, security, protection of the environment and logistics.

The World Radio Conference in 2012 (WRC-12) allocated two new frequencies for long-range detection of AIS, allowed additional frequencies for experimental use of AIS, and authorized channels for VHF Data in accordance with Recommendation ITU-R M.1842-1.

Because of its advanced capability for AIS technology with robust high-speed/large volume data exchange between ships and between ship and shore, the VDES will be able to become the core element in e-navigation and could also significantly contribute to the modernization of GMDSS.

This paper will focus on technology for new AIS-like TDMA data exchange and high speed/high volume VHF data exchange applications for e-Navigation as well as VDES/AIS possibilities in vessel distress, GMDSS and SAR.

Las comunicaciones de datos VHF formarán el núcleo para el intercambio estable de datos de alta velocidad/gran volumen entre barcos, estaciones costeras y satélites. El AIS ha contribuido significativamente a la seguridad de la navegación, y el transporte y el uso de barcos con AIS a bordo está aumentando. Diversas aplicaciones de AIS como AIS-AtoN, AIS Clase B, AIS-SART, AIS-MOB, EPIRB-AIS y detección por satélite de AIS, son prácticas y valiosas no solo para la seguridad de la navegación, sino para la seguridad de la vida, la protección del medio ambiente marino, la garantía de seguridad marítima, la asistencia a las misiones de búsqueda y rescate y la eficiencia del tráfico marítimo; sin embargo, el sistema AIS, como sistema de seguridad de navegación, y no como sistema de comunicación, no es capaz de gestionar ni fue pensado para gestionar el intercambio de datos de alta velocidad/gran volumen.

La necesidad de comunicaciones eficientes y estables para la e-Navegación, junto con la de proteger el AIS para su propósito original de seguridad de navegación al tiempo que se hace uso de las amplias capacidades del AIS, formaron la base de la decisión del comité de e-Navegación de la IALA de desarrollar un concepto conocido como Sistema de Intercambio de Datos VHF (VDES). El VDES es un sistema de comunicación de datos marítimos VHF que incluye funciones del AIS, facilita la e-Navegación, admite modernización del GMDSS y comunicaciones marítimas en general. El VDES utiliza técnicas de la Recomendación ITU-R M.1842-1 para resolver la limitación del intercambio de datos AIS. El VDES tiene grandes capacidades para las comunicaciones estables y completamente automatizadas e influirá en toda la sociedad marítima con mejoras en la seguridad, protección del medio ambiente y logística.

La Conferencia Mundial de Radiocomunicaciones de 2012 (WRC-12) asignó dos nuevas frecuencias para detección de largo alcance del AIS, permitió frecuencias adicionales para uso experimental del AIS y autorizó canales para datos VHF de acuerdo con la Recomendación ITU-R M.1842-1.

Debido a su capacidad avanzada para tecnología AIS con intercambio estable de datos de alta velocidad/gran volumen entre barcos y entre barco y costa, el VDES podrá convertirse en el elemento fundamental de la e-Navegación y también podría contribuir significativamente a la modernización del GMDSS.

Esta ponencia se centrará en la tecnología para nuevas aplicaciones de intercambio de datos TDMA tipo AIS y de intercambio de datos VHF de alta velocidad/gran volumen para la e-Navegación, así como posibilidades VDES/AIS en buques en dificultades, GMDSS y SAR.

La communication de données en VHF fournira la base d'un échange de données de gros volumes et à haute vitesse entre navires, stations à terre et satellites. L'AIS a beaucoup contribué à la sécurité de la navigation et l'emport et l'usage à bord de l'AIS est en expansion. Diverses applications de l'AIS comme l'aide à la navigation AIS, l'AIS Classe B, l'AIS SART, l'AIS MOB, l'EPIRB-AIS et la détection satellite sont utiles et valables, non seulement pour la sécurité de la navigation, mais aussi pour la sécurité de la vie humaine, la protection de l'environnement, la sûreté maritime, les missions de recherche et de sauvetage et l'efficacité de la navigation ; cependant l'AIS, en tant que système de sécurité de la navigation – pas système de communication – ne peut pas et n'a jamais été prévu pour un échange de données volumineuses à haute vitesse.

Les besoins de l'e-Navigation en communications robustes et efficaces, ainsi que la nécessité de protéger son but original de sécurité de la navigation, tout en utilisant toutes ses possibilités, ont abouti à la décision de la Commission e-Navigation de l'AISM de développer un concept de Système d'Echange de données VHF (VDES). C'est un système de communication de données maritimes en VHF qui comprend les fonctions de l'AIS, facilite l'e-Navigation, aide la modernisation du SMDSM et les communications maritimes en général. Le VDES utilise les techniques de la Recommandation ITU-R M1842-1 pour parer aux limites de l'échange de données AIS. Le VDES a de grandes possibilités de communications robustes et totalement automatiques et influencera toute la communauté maritime par l'amélioration de la sûreté et de la sécurité, la protection de l'environnement et la logistique. La Conférence mondiale des Radiocommunications de 2012 (CMR-12) a alloué deux nouvelles fréquences pour la détection de l'AIS à grande distance, des fréquences additionnelles pour l'utilisation expérimentale de l'AIS, et autorisé des canaux pour les données VHF conformément à la Recommandation ITU-R M.1842-1.

En raison de la possibilité de la technologie AIS d'échanger à haute vitesse un grand volume de données entre navires et entre navires et terre, le VDES pourra devenir l'élément central de l'e-Navigation et contribuer aussi à la modernisation du SMDSM.

Le rapport se concentrera sur le nouvel échange de données « AIS-like » TDMA, les applications d'échange des données de gros volumes à haute vitesse et sur les possibilités du VDES/AIS pour les navires en détresse, SMDSM et SAR.

IALA's VHF Exchange System (VDE)

A foundation for e-Navigation communications and GMDSS modernization

Bill Kautz

United States Coast Guard

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

IALA's VHF Data Exchange System (VDES) – A foundation for e–Navigation communications and GMDSS modernization

Bill Kautz – United States Coast Guard

The History of Data Transmission in the VHF Marine Band

The VHF marine band (Appendix 18 of the International Radio Regulations) was initially used for transmission of voice communications by FM (frequency modulation of the carrier) on 25 kHz channels, which is the most-inefficient means of communications in the international maritime service because voice speech is slow and lacks intelligibility, especially with varying languages and accents in the noisy marine radio environment. For this reason, the ITU (International Communications Union) introduced the first marine data transmission system, DSC (Digital Selective Calling) in accordance with Recommendation ITU-R M.493, to help ensure that calling and distress communications attempts were successful. VHF DSC transmits data at 1200 bits per second using digital two-tone FSK modulation, slow by modern data standards, but very robust. At the request of the IMO (International Maritime Organization), to improve safety of navigation, ITU introduced another VHF data transmission system, the AIS (Automatic Identification System) in accordance with Recommendation ITU-R M.1371, which provides navigation and identification data for ships, shore stations, aids to navigation and search and rescue devices at 9600 bits per second using digital GMSK modulation. At the request of some Administrations, to improve spectrum efficiency for VHF Data Exchange (VDE), ITU introduced a standard, Recommendation ITU-R M.1842, with options for 25 kHz, 50 kHz and 100 kHz channels at data rates up to 307.2 kbps using digital modulation waveforms that had been proven by ETSI (European Technical Standards Institute). Appendix 18, in its current revision by the World Radio Conference 2012 (WRC-12), approves all three data transmission methods in accordance with the approved ITU standards (Recommendations ITU-R M.493, M.1371 and M.1842) and designates channels for their use. Consequentially, both voice and data communications now coexist in the VHF marine band.

The Introduction and Purpose for the VDES (VHF Data Exchange System)

VHF Data Exchange System (VDES) is a technological concept developed by the IALA e-NAV Committee and now widely discussed at ITU, IMO and other organizations. VDES was originally developed to address emerging indications of overload of VHF Data Link (VDL) of AIS and simultaneously enabling a wider seamless data exchange for e-Navigation, potentially supporting the modernization of GMDSS, both processes that are currently developed by IMO. VDES is capable of facilitating numerous applications for safety and security of navigation, protection of marine environment, efficiency of shipping and others. VDES will prospectively have a significant beneficial impact on the maritime information services including Aids to Navigation and VTS in the future. Functional aspects of VDES utilize two-way VHF data exchange communications in ship-ship, ship-shore and ship-satellite modes.

In collaboration with IALA, the ITU-R has further developed the basic VDE concept into a more comprehensive concept of VDES. The VDES now integrates the function of AIS, ASM and VDE and includes the channels for these functions with satellite transmission and reception.

In the May 2013 meeting of ITU-R Working Party 5B (WP5B), several Administrations and IALA introduced and proposed the concept of VDES, intending to address AIS VDL loading problems and future data communications requirements identified by IMO. The VDES was envisioned as an integrated system (to include AIS, Application Specific Messages (ASM) and VHF Data Exchange (VDE), in ship-ship and ship-shore communications, including satellite uplink and downlink) that would utilize the resources and provisions of Appendix 18 and the applicable ITU standards. WP5B agreed, sent affirmative liaison statements to IMO, IALA and other affected ITU-R Working Parties and produced working documents on VDES which were further developed at its meeting in November 2013.

VDES Functions include:

AIS (As originally intended for navigation and collision avoidance)

AIS is now well recognized and accepted as an important tool for safety of navigation and is a carriage requirement for SOLAS vessels (Class-A). However, because of its effective and useful technology, the use of AIS is expanded to vessels not compliant with the carriage requirement (Class-B) and other applications such as Aids to Navigation (AtoN), Application Specific Messages (ASM), Search and Rescue Transmitter (SART), Man Over-Board unit (MOB) and EPIRB-AIS.

This expanding use of AIS technology has caused significant increase in VHF Data Link (VDL) loading which has become an active concern in IMO and ITU. To address this growing problem, the World Radio Conference in 2012 (WRC-12) adopted Resolution 360 [COM6/21] (WRC-12) "Consideration of regulatory provisions and spectrum allocation for enhanced Automatic Identification System technology applications and for enhanced maritime radiocommunications" and decided to discuss the matter at WRC-15 under agenda item 1.16.

At its November 2013 meeting, ITU-R-WP 5B approved a report on AIS VDL loading which identified significant VDL problems and demonstrated the need for additional channels under agenda item 1.16 to protect AIS and to make provisions for expanding requirements for data communications.

Long Range AIS (satellite detection)

WRC-12 authorized Channels 75 and 76 for long range AIS. Long range AIS will be used for long range identification and tracking of AIS.

ASM

The function of Application Specific Messages (ASM) is included within the existing AIS. ASM provides data, which are supplied by external applications. The data structure and its interpretation must be known by the recipient to be able to decode and understand the content of the ASM. IMO has defined several international Application Specific Messages like meteorological and hydrographical data, area notice or route information. The basic weakness of AIS-ASM is that AIS was designed primarily as a navigation safety system with an emphasis on repetitive broadcasting of identification and position, while ASM is a non-repetitive communications exchange (two-way) or broadcast (one-way). The AIS function depends on continuous reporting and allows an increasing loss of reception with increasing distance and increasing loading, while the ASM function depends on 100% reception by the intended recipient or recipients. Thus, the IALA initiative to solve the "AIS VDL loading problem" is focused on separating the AIS function (which is navigation, repetitive transmissions of position reports) from the ASM function (which is communications, not necessarily repetitive) by adding two channels to be designated for ASM that will utilize efficient digital communications technology.

VHF Data Exchange

Digital data exchange can be achieved using a whole multitude of commercially available data links, however global availability and interoperability is an issue. Since VDES is an opportunity for a globally interoperable capability of significantly higher speed and larger volume data exchange than AIS or DSC, and potentially with world wide coverage, VDES can become one of core facilitating elements for both implementation of e-Navigation and modernization of GMDSS.

VDES Communications including AIS, ASM and VDE

Table 1 provides a summary of the proposed technical assignment of various VHF channels for communication including protocol and types of messages to meet the functionality required by user needs.

Technical Considerations for Successful VDES Implementation

It should be noted that the ITU standards for data transmission in Appendix 18 identify the specific channels for data transmission and specify the timing of and maximum time durations for data transmissions. This level of specificity, e.g., the selection of the channels, the timing for the transmissions and the maximum durations of the transmissions, etc., is needed to preserve the integrity of both the data service and the other services in Appendix 18, including the GMDSS. Noting that AIS, DSC and voice communications have been successfully operating in Appendix 18 along with the GMDSS for many years, it is expected that VDES will also be successful if it is implemented in accordance with ITU standards. For example, the current working document toward a preliminary draft revision of Recommendation ITU-R M.1842-1 provides a draft new Annex 5 to specify the channel access scheme, transmission timing and maximum transmission duration on the channels specified for VDE in Appendix 18. These specifications are designed to ensure that GMDSS VHF voice radio communications[1], DSC calls[2] and DSC distress alerts[3] are successful during VDES transmissions. To mitigate consequential instantaneous receiver desensitization from each opposite VHF transmitter, it is important to follow the installation guidelines provided by IMO, e.g.,

	VHF Data Communications (including ASM and VDE)		*AIS*	
VDES FUNCTIONS	***Data communications for ASM***	***Data communications for VDE***	***AIS for safety of navigation***	***AIS long range***
Radio channels	• *Channels 27 and 28* • *World-wide dedicated channels (WRC-15 target)*	• *Channels 24, 84, 25, 85, 26, 86 for VDE* • *Channels 2024/2084 for VDE satellite communications*	• *AIS-1 & AIS-2 (simplex)*	• *Channels 75 and 76 (simplex)*
Functionality	• *Marine safety information* • *Marine security information* • *Short safety related messages* • *General purpose information communication*	• *General purpose data exchange* • *Robust high speed data exchange* • *VDE satellite communications*	• *Safety of navigation* • *Maritime locating devices*	• *Satellite detection of AIS* • *Locating during SAR*
Message types for AIS protocol	• *IMO SN.1/ Circ.289 international application specific messages* • *Regional application specific messages* • *Base Station*		• *Vessel identification* • *Vessel dynamic data* • *Vessel static data* • *Voyage related data* • *Aids to Navigation* • *Base Station*	• *Satellite detection of AIS* • *Message 27*
Applications	• *Area warnings and advice* • *Meteorological and hydrographic data* • *Traffic management* • *Ship-shore data exchange* • *Channel management*	• *High message payload* • *Satellite communications*	• *Ship to ship collision avoidance* • *VTS* • *Tracking of ships* • *Locating in SAR* • *VDL control (by Base Station)*	• *Detection of vessels by coastal states beyond range of coastal AIS base stations*

COMSAR/Circ.32 for antenna installations. For example, one manufacturer who supplies both GMDSS VHF voice radios and AIS specifies a minimum separation of 4m vertical distance between the two VHF antennas at the same horizontal position or more than 17m separation when the antennas are at the same horizontal level, which provides about 41 dB of isolation between the two VHF antennas. By contrast, a separation of only 1.5m provides only 20 dB of isolation.

Selection and Use of Frequencies for VDES

At its meeting in May 2013 (Document 5B/304, Annex 5, Section 3/1.16/3.3), WP5B provided the following description and selection of frequencies for VDES:

VHF data exchange system (VDES) considers both WRC-15 Agenda item 1.16 and WRC-12 revisions to RR Appendix 18, including both terrestrial and satellite components, which address the need to protect the integrity of the AIS VDL by moving AIS applications and ASM to other channels and the designation of some of the duplex channels previously designated for VHF public correspondence (VPC) for digitally modulated emissions in accordance with Recommendation ITU-R M.1842 (which describes VDE). The VDES integrates the functions of AIS, ASM and VDE and includes the channels used for these functions. An arrangement of the globally available channels and functional designated usage is shown in ***Table 2***.

The various functionalities of VDES and their uses by ships, shore stations and satellites are illustrated pictorially in ***Figure 1***, using the frequencies from ***Table 2***.

Note from ***Figure 1*** that the AIS-VDE ship receiving range is 161.800-162.025 MHz, which includes channels 2024 to AIS2. This arrangement makes it possible to prevent VDES receiver blocking from the VHF voice radio transmitter by means of a bandpass filter at the input of the VDES receiver (refer to ***Figure 2***).

IMPORTANT FOR ADMINISTRATIONS TO CONSIDER:

The plan to protect the VDES receiver with a bandpass filter is potentially conflicted (in the future) by the WRC-12 revision of Appendix 18 in which the four simplex channels 2078, 2019, 2079 and 2020 were added (covering the range of 161.525-161.600 MHz), which would permit VHF voice radios to transmit on the upper side of the 4.6 MHz separation shown in Figure 1. Heretofore, marine VHF voice radios were not permitted to transmit above 157.425 MHz. Administrations who are concerned about this potential impact on the AIS should consider proposals for appropriate revision of Appendix 18 by the WRC-15.

Channel number in RR Appendix 18		**Transmitting frequencies (MHz) for ship and coast stations**	
		Ship stations (ship-to-shore) **(long range AIS)** **Ship stations (ship-to-satellite)**	**Coast stations** **Ship stations (ship-to-ship)** **Satellite-to-ship**
AIS 1		161.975	161.975
AIS 2		162.025	162.025
75 (long range AIS)		156.775 (ships are Tx only)	N/A
76 (long range AIS)		156.825 (ships are Tx only)	N/A
2027 (ASM 1)		161.950 (2027)	161.950 (2027)
2028 (ASM 2)		162.000 (2028)	162.000 (2028)
24/84/25/85 (VDE 1) 100 kHz channel	24/84/25/85/26/86 (SAT 2) 150 kHz channel	100/150 kHz channel (lower legs merged) Ship to shore Ship to satellite	100/150 kHz channel (upper legs merged) Ship to ship, Shore to ship Satellite to ship
24	24	157.200 (1024)	161.800 (2024)
84	84	157.225 (1084)	161.825 (2084)
25	25	157.250 (1025)	161.850 (2025)
85	85	157.275 (1085)	161.875 (2085)
	26	157.300 (1026)	161.900 (2026)
	86	157.325 (1086)	161.925 (2086)

TABLE 2: EXAMPLE CHANNEL DESIGNATIONS
Appendix 18 channels and frequencies for the VHF data exchange system (AIS, ASM and VDE) as illustrated in Figure 1

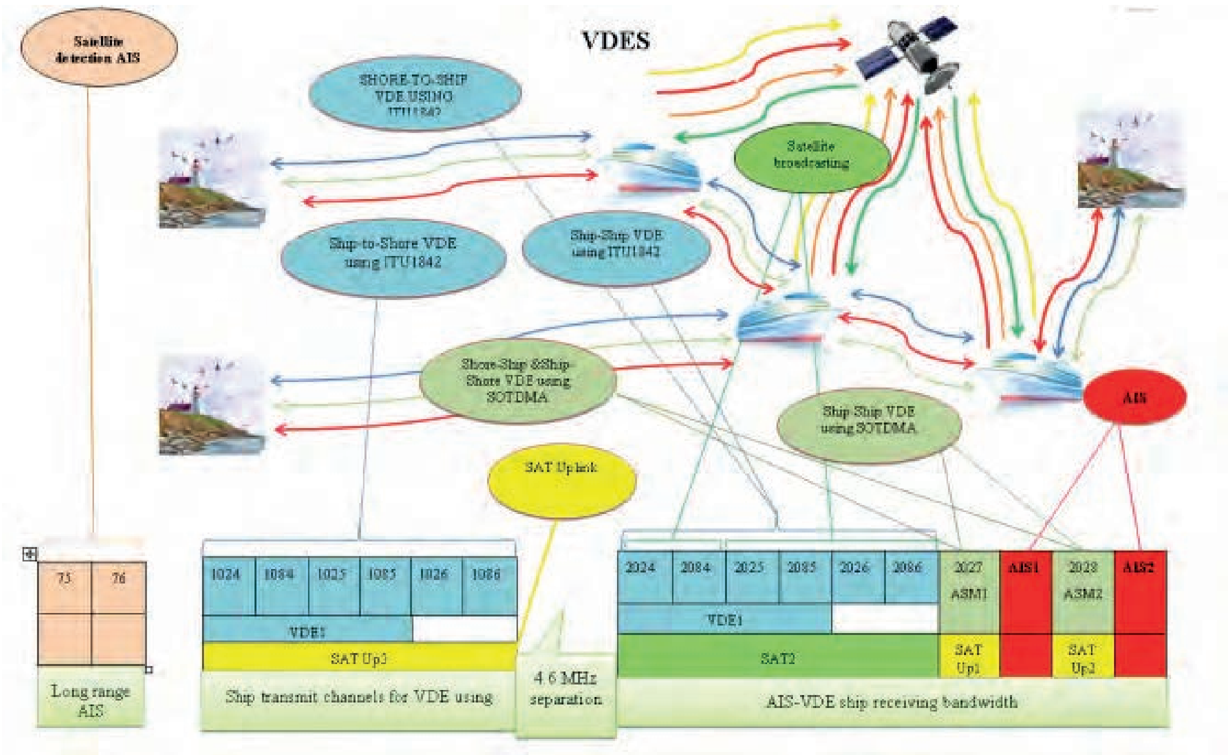


FIGURE 1: VDES Functions and Frequency Usage

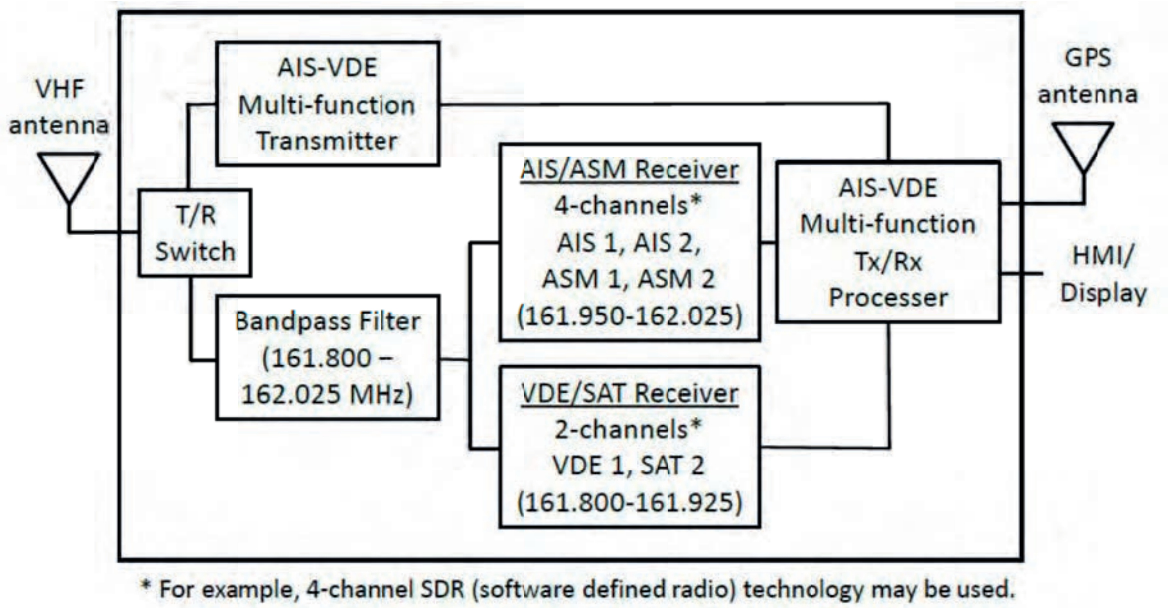


FIGURE 2: Example VDES Functional Diagram

An example VDES internal architecture

An example VDES internal architecture (to support ***Table 2*** and ***Figure 1***) is shown in ***Figure 2***. Note that the VDES is protected from receiver blocking by the 161.800-162.025 MHz bandpass filter.

It should be noted that the AIS-VDE transmitter will need to be designed to support the complex waveforms used in Recommendation ITU-R M.1842-1, e.g., QAM waveforms have peak-to-average power ratios of over 10 dB. To minimize the receiver desensitization effects on the VHF voice radio from the VDES transmitter broadband noise floor, the power level in the resonant circuit of the VDES transmitter frequency source, e.g., the Tx VCO, should be as high as practical, e.g., a power level of +10 dBm or higher is recommended (refer to the note in Figure 3 concerning a lower noise floor).

Analysis of Signal Levels between VDES and VHF Voice Radios

Figure 3 is a graphical representation of the transmission spectrum of a typical VHF marine voice radio transmitter, referred to the antenna connector of the radio, based on measurements taken from several manufacturers of these radios. Note that the power level at the VDES antenna connector will have to account for transmission losses in the antenna cables, isolation between the VDES antenna and the VHF radio antenna, and must also consider the different frequencies of interest between the VDES and the VHF radio transmitter. ***Table 3*** shows the power levels delivered to the VDES (***Figure 2***) from the VHF marine voice radio transmitter (***Figure 3***). This table illustrates the need for the protection of the VDES receiver with the bandpass filter (which is absent in the current AIS) and for the installation of the two VHF antennas to achieve the highest practical isolation. Note that protection of the VDES is considered here and is achieved in this manner because voice communications by the VHF voice radio require it to be keyed for much longer duration than the VDES, whereas protection of the VHF voice radio from the VDES is achieved by controlling the timing and maximum durations of the VDES transmissions. Fortunately, the duty cycle of each transmitter is low.

VHF Tx Output	Antenna Isolation	VDES Input (2 cable losses = 3db)	VDES Rx Input (Rx Filter = 40dB/2dB)
+44 dBm @157.4 MHz	20 dB	+21 dBm	-19 dBm
+44 dBm @157.4 MHz	41 dB	0 dBm	-40 dBm
-66 dBm @162.0 MHz	20 dB	-89 dBm	-91 dBm
-66 dBm @162.0 MHz	41 dB	-110 dBm	-112 dBm
-71 dBm @162.0 MHz	20 dB	-94 dBm	-96 dBm
-71 dBm @162.0 MHz	41 dB	-115 dBm	-117 dBm

TABLE3: Power levels delivered to the VDES (refer to Figure 2) from the VHF radio transmitter (refer to Figure 3)

GMDSS Modernization

The current GMDSS system was designed over 25 years ago. There has not been a full review since its full implementation in 1999 and technology has developed significantly in that time. Significant technology elements within the GMDSS have also evolved, although the functions have not been altered. The current system is seen to be relatively sound, but it is known that there are GMDSS elements where improvement could be made, e.g. managing the cessation of international telex, and to examine the continued use of narrow-band direct-printing in certain sea areas.

The elements that will be identified may need to be examined and reviewed as a matter of some urgency. The 14th session of IMO Sub-Committee on Radiocommunications and Search and Rescue (COMSAR 14, held on March 2010) initiated a Scoping Exercise and a Work Plan to define the requirements for the GMDSS Review and Modernization. The Scoping Exercise was finalized at COMSAR16 (March 2012) and the Review will be take place over a three-year period (2013-2015).

A further two-year period is envisaged (2015-2017) for the GMDSS modernization plan. This will be followed by development of legal instruments, revision/development of relevant performance standards and an implementation period.

VDES/AIS has the potential to play a significant role in GMDSS modernization by modernizing delivery and reception of Maritime Safety Information and as a providing a modern efficient means for the distress alerting, locating and communications functions.

The potential use of VDES/AIS for Distress

The use of VDES/AIS for distress communications shows great potential in improving safety and allowing for the eventual replacement of VHF DSC on vessels subject both to SOLAS, and non- SOLAS vessels. There are technical issues which require solutions in order for VDES/AIS to replace VHF DSC and two primary guiding principles for considering VDES/AIS in this role: a) AIS has existing shipboard and shore based infrastructure, currently in daily use worldwide; b) in developing the AIS system for Distress, "do no harm to the existing functions of the AIS system."
The shipborne Automatic Identification System

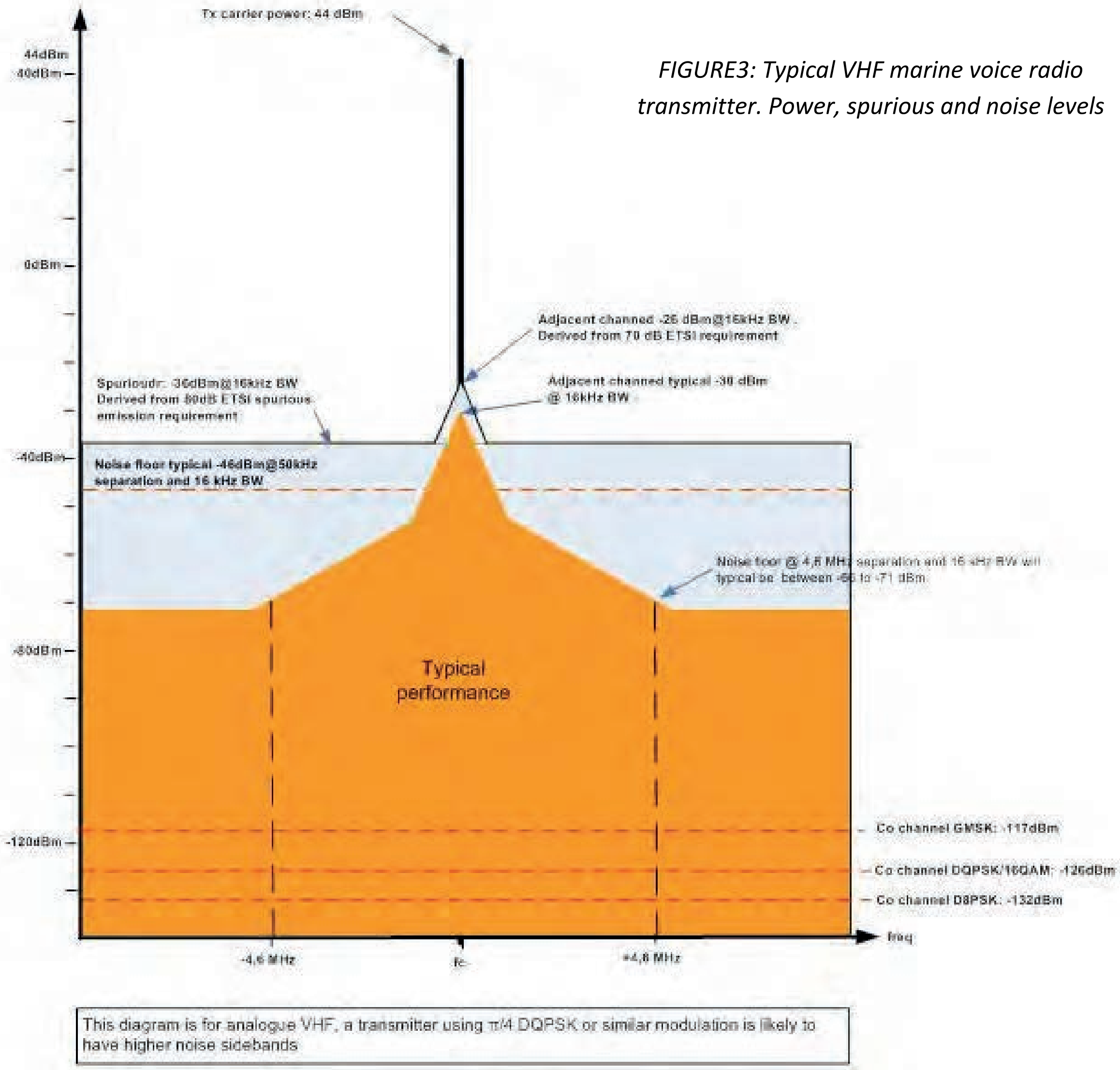


FIGURE3: Typical VHF marine voice radio transmitter. Power, spurious and noise levels

(AIS) mandated under SOLAS Chapter V has become well accepted by the maritime community and is being used by thousands of ships not subject to the SOLAS Convention. Its application has been expanded to address additional needs, such as distress locating consequential to IMO's adoption of the AIS search and rescue transmitter (AIS-SART) as an equivalent to the radar SART mandated under SOLAS IV. Several years ago manufacturers, noting that a market demand existed for mariners to have a simple distress alerting capability integrated into equipment used every day for navigation, began including a distress alerting capability in the predefined AIS safety related messages offered on both Class A and B AIS equipment. IMO COMSAR 12, "agreed that … it could not be considered to be a part of the GMDSS at the present time, … (and) concluded that it was crucial to assess the compatibility with the GMDSS and that a possible inclusion of AIS in GMDSS should therefore be a proposal for future work … to add AIS distress alerting as a component to the GMDSS and as a part of the wide-ranging review of the GMDSS"[4].

While the use of AIS for distress alerting will be considered further in GMDSS Modernization development, if the IMO agrees to put that effort on its work plan, users not subject to the SOLAS Convention, manufacturers and other international organizations, such as the ITU, may consider the matter and possibly implement such a system before revisions to SOLAS IV are completed. There are many reasons that justify AIS use for maritime distress communications, but there also are equally valid reasons for proceeding cautiously and deliberately before allowing AIS to be used in this way. VDES is intended to augment AIS in order to provide the communications capability needed to perform the full functionality required by these applications.

Concept of VDES/AIS distress

AIS is commonly used by all classes of vessels, has ashore VHF infrastructure, and can be detected by satellite. VDES/AIS distress implementation could be accomplished with minimal cost to shipping. It could allow for the eventual replacement of VHF DSC both on ships and ashore. Training problems inherent in DSC could be avoided since AIS is routinely used by ships for navigation, whereas DSC is primarily used only in distress.

Because of the widespread use of AIS on ships and AIS navigational chart displays on ships and ashore, a vessel in distress could be immediately identified and located and then tracked by those in a position to assist that vessel. Since AIS position reports are immediately identifiable and verifiable, false alert problems inherent in DSC could be dealt with immediately and therefore should largely be avoided. Even satellites are available capable of detecting, locating and tracking AIS-equipped vessels, if AIS were to be used to identify and locate vessels in distress. VDES would then, by its various functions (refer to Figure 1), provide the necessary means for distress communications globally.

VDES/AIS Distress, as an eventual replacement for VHF DSC, would need to be carefully transitioned over a period of time, for both ship and shore infrastructure. This transition could be accomplished through IMO's GMDSS Modernization Program.

Technical issues and possible solutions for VDES/AIS distress

AIS messages can be sent with a priority #1 (highest) through #4 (lowest).[5] If used for distress, message priority should be of the highest available (i.e. #1), and provisions may need to be considered to protect the transmission. In contrast, the use of safety related messages for distress purpose considered by COMSAR 13, would be of priority #2, and would not be transmitted at all if sufficient consecutive slots were not available for the purpose. A possible solution to this "priority problem" would be to indicate the distress status of a vessel within the priority #1 AIS position reports as follows:

In November 2013, ITU-R WP5B approved Rec. ITU-R M1371-5, which now utilizes all of the possible "Navigation status" states (0 to15) except one (Navigation status = 13 is reserved for future use). If this could be used, in the future, for distress communications purposes, it would provide a means for the AIS Class A to indicate a distress condition with position reports on the AIS 1 and AIS 2 channels using Messages #1, 2 or 3 and on the Long Range AIS channels using Message #27. Since other AIS devices or classes of AIS are not permitted to use Message #27 or the Long Range AIS channels, other provisions would be needed to include them.

Existing AIS shore facilities would need to be capable of displaying a detected AIS distress status and relaying that information to an MRCC. Since most AIS shore facilities are currently used primarily for vessel traffic service or maritime domain awareness purposes, often managed by agencies having no maritime search and rescue responsibilities, this problem may be the most difficult one for administrations to address. Nevertheless resolving this problem, e.g., by upgrading from AIS to VDES/AIS, could allow for the eventual elimination of a requirement for a VHF DSC coastal network, at cost savings to administrations.

When VDES/AIS is used for distress purposes, appropriate symbol and alarm capability would need to be included in any AIS shipboard navigational display (prospectively, and better, upgraded to VDES/AIS), with the training to ensure appropriate action.

As use of VDES/AIS for distress communications is considered, several technical issues would have to be addressed. For example, how should responsible stations which receive the distress message transmit an acknowledgement message? Should a distress and certain safety or urgency communications directly enable voice communications, and if so, how should that be achieved? VDES/AIS provides both the means and the opportunity to address these issues.

Persons ashore or on vessels who operate equipment capable of transmitting or receiving distress communications incur certain obligations, particularly when receiving an unacknowledged distress alert, or when transmitting a distress alert. When VDES/AIS is used for distress purposes, those obligations must be considered and appropriate action taken.

Currently, AIS frequencies include AIS 1, AIS 2, and AP 18 channels 75 and 76 for satllite detection. Studies are needed to determine the proper AIS channeling requirements for distress transmission. Careful review of the AIS channels and the prospective new channels for ASM and VDE is required before changes to the message structures are finalized. The technical work provided by IALA, e.g., solutions utilizing VDES, for consideration by ITU-R WP 5B provide a basis and a means for this analysis.

Conclusion

ITU, IMO, and IALA have recognized the efficiency and the necessity for digital communications. ITU has produced technical standards, has revised the VHF marine band (RR Appendix 18) to designate channels for VHF data exchange, and authorized channels for testing AIS-like applications and protecting the AIS data link. It is recognized that both analog voice communications and digital communications will share the band. This document illustrates how the design and installation of the new VDES (Figure 1) should address the compatibility and interoperability of both systems. The VDES, as envisioned by IALA and presented to ITU, addresses the identified improvement for the AIS along with essential digital communications contributions for E-Navigation and GMDSS Modernization. ■

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1 Report ITU-R M.2169 refers to a study of the effects of data burst transmissions on voice radio communications which concludes that the consequential loss of intelligibility of human speech is tolerable if the frequency of occurrence and the length of the data bursts are appropriately limited, e.g., as in AIS. Considering the successful implementation of AIS in the VHF marine radio environment, similar timing limits to AIS are proposed for VDES.

2 DSC calls are repeated if they are not acknowledged, since it is understood that a single call may be blocked.

3 DSC distress alerts are repeated until acknowledged. Each transmission is 1500ms long and contains five repetitions of the DSC distress call.

4 *COMSAR 13-14, Section 7.1.*

5 See Rec. ITU-R M.1371-4 Table 43.

9297 COMMON MARITIME DATA STRUCTURE FOR E-NAVIGATION & THE MARITIME CLOUD

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The Usability of e-Navigation depends on harmonization of information presentation and generic standards for equipment, allowing familiarization and simplification of training. These goals will only be achieved through the introduction of a Common Maritime Information System and Data Structure.

Mariners require information for planning and execution of voyages, assessment of navigation risk and compliance with regulation. Information should be accessible from a single integrated system. Shore-based users require information for the maritime domain of interest, static and dynamic information on vessels and their voyages, in an internationally agreed common data structure.

The IHO Registry has been adopted as a common baseline, providing a framework for a Common Maritime Data Structure (CMDS).

Product specifications, based on data models and conforming to the IHO S-100 standard are being prepared in the fields of Aids to Navigation (AtoN), Vessel Traffic Services (VTS) and Automatic Identification Systems (AIS), for example AtoN Information exchange and the Inter VTS Exchange Format (IVEF).

The IHO Registry contains the following subordinate registers: Feature Concept Dictionary (FCD) register; Portrayal register; Metadata register; Product Specifications register; Data Producer Code register.

S-100 provides the data framework for the development of the next generation of Electronic Navigation Charts (ENC) products, as well as other related digital products required for hydrographic, maritime and Geographic Information Systems (GIS) applications. An S-100 online registry has been established for the registration, management and maintenance of the items recognised under the S-100 framework.

The benefits for end-users, operators and service providers of standardized exchange of information are increased efficiency, fewer errors, simpler training and common equipment and interfacing.

The ways in which the CMDS will be used are still being explored. Maritime Service Portfolios provide an organized presentation of technical and operational services and the concept of a Maritime Cloud is being developed by the Danish Maritime Authority as an all-embracing information system that can serve the whole maritime sector.

La usabilidad de la e-Navegación depende de la armonización de la presentación de información y de estándares genéricos para el equipamiento, permitiendo la familiarización y simplificación de la formación. Estos objetivos solo se conseguirán mediante la introducción de un Sistema de Información Marítima y Estructura de Datos Común.

Los marineros necesitan información para la planificación y realización de viajes, la evaluación del riesgo de navegación y la conformidad con la regulación. La información debe ser accesible a través de un sencillo sistema integrado. Los usuarios en tierra necesitan información sobre el espacio marítimo de interés e información estática y dinámica sobre buques y sus viajes en una estructura de datos común acordada internacionalmente.

Se ha adoptado como base común el Registro IHO, proporcionando un marco para una Estructura de Datos Marítimos Común (CMDS).

Se están preparando especificaciones de producto, basadas en modelos de datos y conformes con la norma S-100 de la IHO en los ámbitos de las Ayudas a la Navegación (AtoN), Servicios de Tráfico de Buques (VTS) y Sistemas de Identificación Automática (AIS), por ejemplo, el intercambio de Información AtoN y el Formato de Intercambio VTS Inter (IVEF).

El Registro IHO contiene los siguientes registros subordinados: registro de Diccionario de Conceptos de Características (FCD), registro de Descripción, registro de Metadatos, registro de Especificaciones de Producto y registro de Código de Productor de Datos.

La norma S-100 proporciona el marco de datos para el desarrollo de la próxima generación de Cartas de Navegación Electrónicas (ENC), así como otros productos digitales relacionados requeridos por aplicaciones de los Sistemas de Información Geográfica (GIS), hidrográfica y marítima. Se ha establecido un registro S-100 en línea para el registro, la gestión y el mantenimiento de los elementos reconocidos bajo el marco S-100.

Los beneficios del intercambio normalizado de información para los usuarios finales, operadores y proveedores de servicios son una mayor eficiencia, menor número de errores, formación más sencilla y equipos e interconexión común.

Todavía se están explorando los modos en que se usará la CMDS. Los Catálogos de Servicios Marítimos proporcionan una presentación organizada de servicios técnicos y operativos y la Autoridad Marítima Danesa está desarrollando el concepto de una «Nube Marítima» como un sistema de información global que pueda servir a todo el sector marítimo.

La facilité d'utilisation de l'e-Navigation dépend de l'harmonisation de la présentation de l'information et de normes génériques d'équipements permettant la familiarisation et la simplification de la formation. Ces buts ne seront atteints que par l'introduction d'un système d'informations maritimes commune et une structure de données commune.

Les marins demandent des informations pour prévoir et exécuter leurs voyages, évaluer le risque de navigation et se conformer aux réglementations. Les informations devraient être accessibles à partir d'un seul système intégré.

Les utilisateurs à terre demandent des informations sur le domaine maritime qui les intéresse, des informations statiques et dynamiques sur les navires et leurs voyages avec une structure de données commune, internationalement acceptée.

La base de données de l'OHI (IHO Registry) a été adoptée comme base de départ commune, donnant un cadre pour une Structure de Données Maritimes Commune (CMDS).

Les spécifications de produit basées sur des modèles de données, conformes à la norme S-100 de l'OHI, sont en préparation pour les divers types d 'aides à la navigation, VTS, AIS, par exemple échange d'informations d'aides à la navigation et format d'échange entre VTS (IVEF).
La base de données de l'OHI comprend les sous titres suivants : Dictionnaire des concepts (FCD), Descriptions, Métadonnées, registre de Spécifications du produit, registre du Code du producteur de données.

La S-100 fournit un cadre de données pour le développement de la nouvelle génération de cartes électroniques (ENC), ainsi que d'autres produits numériques concernant l'hydrographie, les Systèmes d'Informations Géographiques (GIS). Une version en ligne du registre 100 a été créée pour l'inscription, la gestion et l'entretien des éléments reconnus dans le cadre de la S-100.

Les avantages pour les utilisateurs, opérateurs et services fournisseurs d'échanges d'informations standardisés sont : plus d'efficacité, moins d'erreurs, une formation plus simple, et des équipements et interfaces communs.

La façon dont le CMDS sera utilisé est toujours est encore en cours d'exploration. « Maritime Service Portfolios » fournit une présentation organisée des services techniques et opérationnels et le concept d'un Cloud maritime est développé par le Service de signalisation maritime du Danemark comme système incluant tous les systèmes d'informations pouvant être utiles au secteur maritime.

Common Maritime Data Structure for e–Navigation & the Maritime Cloud

Nick Ward
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&

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

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1. INTRODUCTION

e-Navigation is the future, digital concept for the maritime sector. Integration and harmonization are keywords in the definition of e-Navigation:

> *"e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment"*

Key objectives of e-Navigation include: safe and secure navigation of vessels, facilitating communications, including data exchange between vessels and shore, integration and presentation of information onboard and ashore to maximize navigation safety benefits and minimize risk of confusion. Systems should have global coverage with consistent standards and interoperability.

2. USABILITY

The Usability of e-Navigation depends on harmonization of information presentation and generic standards for equipment, allowing familiarization and simplification of training.

These goals will only be achieved through the introduction of a Common Maritime Data Structure.

3. REQUIREMENT FOR MARITIME INFORMATION

Mariners require information for planning and execution of voyages, assessment of navigation risk and compliance with regulation. Information should be accessible from a single integrated system.

Shore-based users require information for their maritime domain of interest, including static and dynamic information on vessels and their voyages, in an internationally agreed format.

Data needs to be organised or formatted in a standard way to exchange and present the required information. This is the purpose of the Common Maritime Data Structure.

4. IHO REGISTRY

The IHO Registry has been accepted by the International Maritime Organisation (IMO), IALA and other international bodies as a baseline for this Common Maritime Data Structure. The IHO Geo-spatial Information Registry provides a framework for product specifications in different fields. Within IALA's remit, these include AtoN, VTS and AIS. The product specifications are based on data models, produced using generally accepted methods, such as Unified Modelling Language

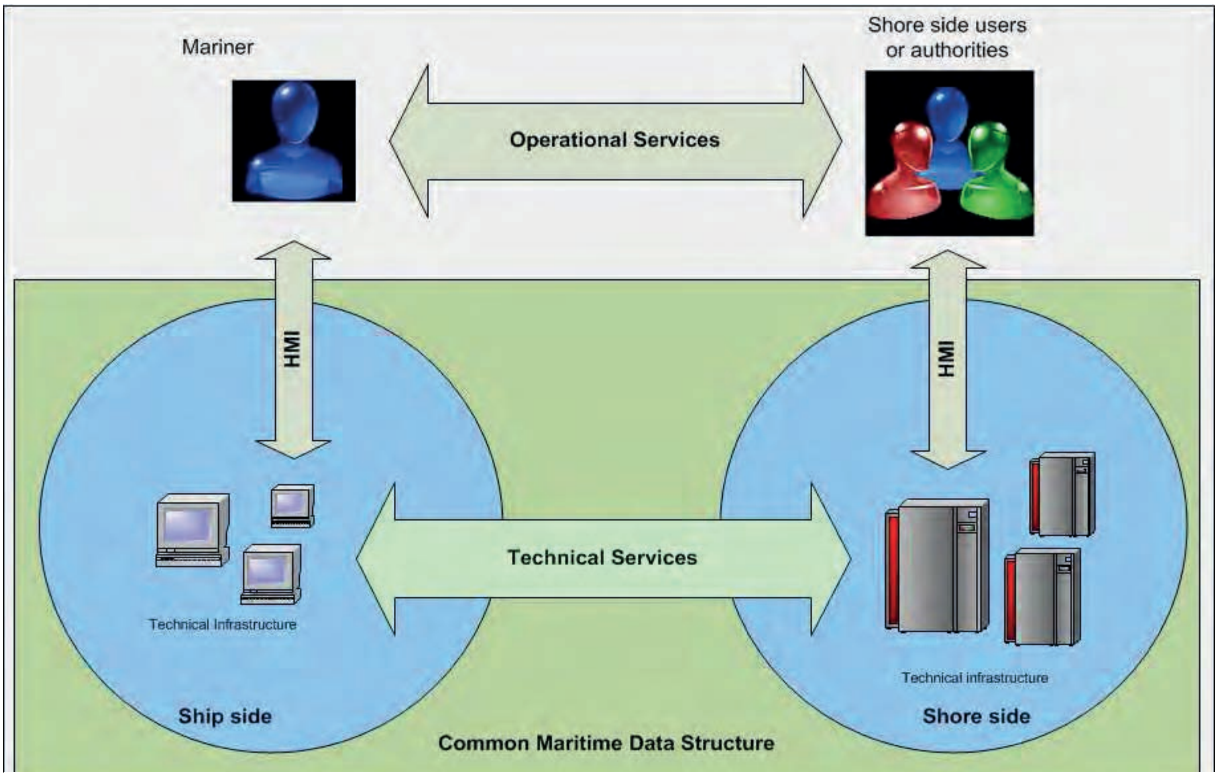


Figure 1: Common Maritime Data Structure

Nick Ward, General Lighthouse Authorities for the UK and Ireland
Thomas Christensen & O Bakman Borup, Danish Maritime Authority

(UML) and employ standard data exchange formats, for example XML or GML (Extensible/Geography Markup Language).

The registry contains the following principal subordinate registers: Feature Concept Dictionary (FCD) register; Portrayal register; Metadata register; Product Specifications register; Data Producer Code register.

IALA is committed to participation in the IHO Registry, as a first step towards the Common Maritime Data Structure that is necessary for e-Navigation. The resulting standardization of information exchange should lead to increased efficiency, fewer errors and simpler training, with common equipment and interfacing.

5. IHO S–100

The IHO Standard S-100 provides the data framework for the development of the next generation of Electronic Navigation Chart (ENC) products, as well as other related digital products required by hydrographic, maritime and Geographic Information System (GIS) users. The S-100 online registry allows for the registration, management and maintenance of items recognised under the S-100 framework.

In practice, this means standardised methods for exchanging information between VTS authorities, between AtoN Service providers and Hydrographic Offices (HO), between service providers and ships and between ships. Potentially, generic standards could be developed for presentation and handling of information. For example, the AtoN Information Product Specification was prepared from a spreadsheet used by the Australian Maritime Safety Authority (AMSA) and Australian Hydrographic Office (AHO), converted to a Data Model (in Unified Modelling Language) and uses Geography Markup Language (GML) as a data exchange format between AtoN authorities & HO. The Inter VTS Exchange Format (IVEF) was based on a data model already developed, in Extensible Markup Language (XML) used for data exchange between VTS authorities.

6. TIMETABLE

Under the IMO timetable for e-Navigation development, the Strategy Implementation Plan is due to be approved by the end of 2014 and Maritime Service Portfolios and the corresponding

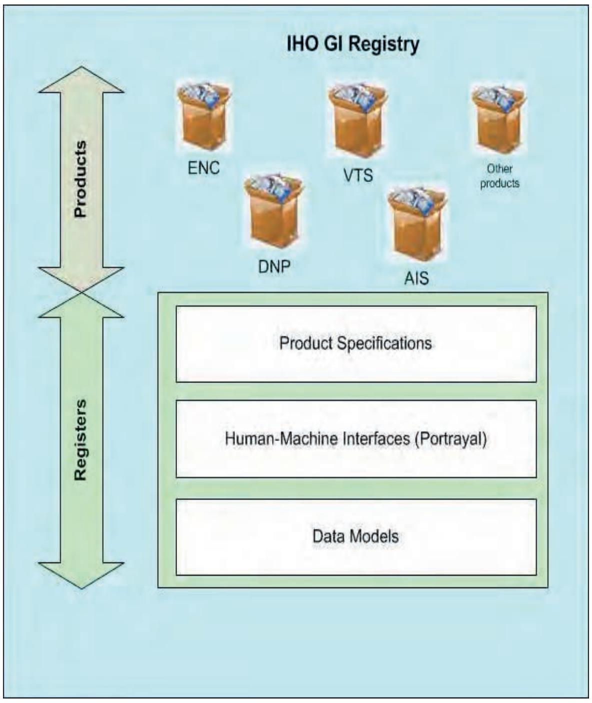


Figure 2: IHO Registry

S-100 Product Specifications are likely to be developed over the period 2014-18. Implementation dates will depend on the maturity of each application, but the product specifications mentioned above could be introduced any time after 2014.

7. BENEFITS

The benefits of standardized exchange of information are increased efficiency, fewer errors, simpler training and common equipment and interfacing. These benefits will apply to the end-users, principally mariners, as well as shore-side operators and navigation service providers.

8. MARITIME CLOUD

The CMDS fits into the concept of e-Navigation, as shown in Fig 1. There are other related developments taking place, in particular the Maritime Cloud and Maritime Service portfolios.

The Maritime Cloud concept being developed by the Danish Maritime Authority is defined as: A communication framework enabling efficient, secure, reliable and seamless electronic information exchange between all authorized maritime stakeholders across available communication systems.

Nick Ward, General Lighthouse Authorities for the UK and Ireland
Thomas Christensen & O Bakman Borup, Danish Maritime Authority

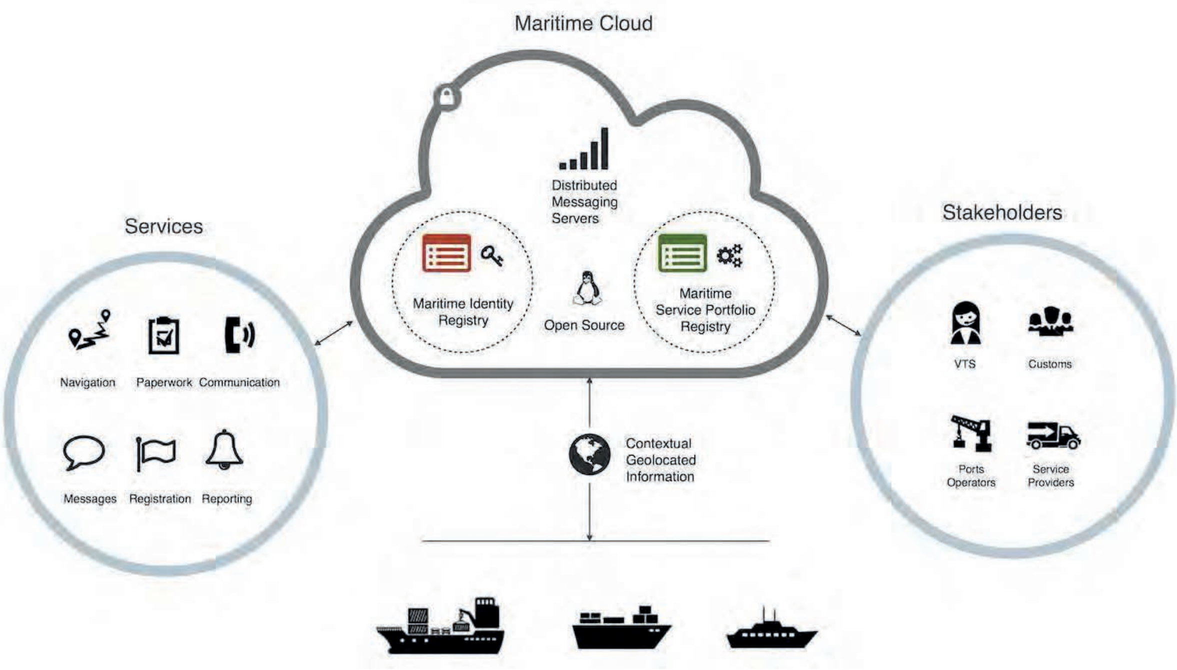


Figure 3: the Maritime Cloud (Image: DMA)

The Maritime Cloud is not a 'storage cloud' containing all information about every ship or cargo. Nor is it referring to 'cloud computing'. The Maritime Cloud is the realization of the defined communication strategy for e-navigation as described in the IMO strategy for e-navigation.

The Maritime Cloud consists of standards, infrastructure and service reference implementations, that together with governance enable the efficient exchange of information between qualified maritime parties via interoperable information services, utilizing highly automated interfaces to different communication options, enhancing general communications related to berth to berth navigation and related services for safety and security at sea and protection of the marine environment.

The core of the Maritime Cloud will be a cluster of servers, providing the three core services:

- A Maritime Identity Registry
- A Maritime Service Portfolio Registry
- A Maritime Messaging Service

The Maritime Identity Registry gives each maritime actor a unique identity code not tied to any specific role (e.g. IMO number for vessels) or technology (e.g. MMSI number tied to radio equipment). Attributes like contact information will be tied to each identity. Furthermore each identity will have a digital certificate allowing authentication and integrity checking, and when appropriate facilitate encrypted data transfer and digital signing of documents.

The Maritime Service Portfolio Registry will provide a digital version of the 'yellow pages' directory of where instances of information services are available. Service providers will be able to register provided services and service consumers will be able to locate provided services at their current position or along planned route.

The Maritime Identity Registry and the Maritime Service Portfolio Registry will enable the publication of an offline digital publication called the Almanac, which will function as a 'white pages/yellow pages phonebook' of registered maritime actors and information services.

The Maritime Messaging Service (MMS) within the Maritime Cloud is intended to ensure seamless information transfer across different communication links. The Maritime Messaging Service offers a geo-aware messaging protocol making it possible to send and receive messages that are relevant to vessels within an area.

The MMS within the Maritime Cloud will be based on Internet connectivity, yet any number of alternative communication services may be connected to and utilized by the Maritime Messaging Service via dedicated gateways. This way, a message sent by one specific ship using INMARSAT access to the MMS, may be received via a VSAT terminal on another ship, a HF data connection on yet another ship, or a VTS operator on a DSL landline Internet connection.

The Cloud will be built on existing proven technology and can therefore be cost effective. The Maritime Cloud is currently used as the testbed infrastructure in the ACCSEAS project. The concept has also been submitted to the IMO e-navigation process as a proposed infrastructure supporting e-navigation.

9. CONCLUSIONS

A Common Maritime Data Structure is essential to e-Navigation. The IHO registry has been adopted as a common baseline, with the development of Product Specifications conforming to IHO S-100, bringing benefits of harmonization, usability and effectiveness.

The Maritime Cloud and Maritime Service Portfolios are practical forms that this structure could take. ■

31 IMPROVEMENT OF MARITIME INFORMATION AND COMMUNICATION SYSTEM (MICS): E-NAVIGATION FOR SMALL SHIPS

Hideki Noguchi. Navigational Safety System Development Office, Aids to Navigation Engineering Division, Maritime Traffic Department, Japan Coast Guard, Japan

In Japan, about 40% of maritime accidents are caused by pleasure crafts and about 30% are caused by fishing boats. Many of these crafts and boats do not have communication equipment other than a mobile phone and can not get necessary information such as weather warning, navigation warning. This lack of information becomes one of the causes of the accident.

The Japan Coast Guard (JCG) has operated the Maritime Information and Communication System (MICS) since 2001. The MICS uses internet and provides information needed for safe navigation to mainly owners or users of small boats and crafts. However, the MICS is useable only on land and is a passive system which can not provide necessary information unless the user connects the internet.

In order to solve these defects, the JCG has improved the MICS from 2010. The major subjects of the improvement are (1) introduction of automatic e-mail delivery system for mobile phone, (2) connection of MICS to the Automatic Data Editing and Switching System (ADESS). The ADESS is operated by the Meteorological Agency and automatically provides data of weather warning, earthquake warning, tsunami warning, etc. If the user registers the MICS, the user can get necessary navigational information automatically and immediately within the range of mobile phone. At present time, more than 10,000 users registered and already received the important information.

En Japón, aproximadamente un 40 % de los accidentes marítimos están causados por embarcaciones de recreo y aproximadamente un 30 % están causados por barcos de pesca. Muchas de estas embarcaciones y barcos no poseen equipos de comunicación salvo un teléfono móvil, y no pueden obtener información necesaria como avisos meteorológicos y avisos de navegación. Esta falta de información se convierte en una de las causas de los accidentes.

La Guardia Costera Japonesa (JCG) dirige el Sistema de Información y Comunicación Marítima (MICS) desde 2001. El MICS utiliza Internet y proporciona información necesaria para una navegación segura principalmente para los propietarios o usuarios de pequeños barcos y embarcaciones. Sin embargo, el MICS solo puede utilizarse en tierra y es un sistema pasivo que no puede proporcionar la información necesaria a no ser que el usuario se conecte a Internet.

Para resolver estos defectos, la JCG ha mejorado el MICS desde 2010. Los principales aspectos de la mejora son (1) introducción de un sistema automático de envío de correos electrónicos para teléfono móvil, (2) conexión del MICS al Sistema Automático de Edición y Conmutación de Datos (ADESS). El ADESS es operado por la Agencia Meteorológica y proporciona automáticamente datos de avisos meteorológicos, terremotos, tsunamis, etc. Si el usuario se registra en el MICS, puede obtener la información de navegación necesaria de forma automática e inmediata dentro de la cobertura del teléfono móvil. En la actualidad, hay más de 10 000 usuarios registrados, y ya han recibido información importante.

Esta ponencia presenta el nuevo MICS y considera la e-Navegación para pequeñas embarcaciones.

Au Japon, environ 40% des accidents maritimes sont dus aux bateaux de plaisance et 30% sont dus aux bateaux de pêche. Beaucoup de ces bateaux n'ont comme moyen de communication qu'un téléphone portable et ne peuvent pas avoir des informations de première importance telles que les alertes météo et les avis aux navigateurs. Ce manque d'information devient l'une des causes des accidents.

La Garde côtière japonaise (JCG) a mis en place en 2001 le Système de Communication et d'Information Maritime (MICS). Ce système utilise Internet et donne les informations nécessaires à la sécurité de la navigation, principalement aux propriétaires ou utilisateurs de petits bateaux. Cependant le MICS n'est utilisable qu'à terre et il est passif, à moins que l'utilisateur ne se connecte à Internet

Pour remédier à ces insuffisances, la JCG a amélioré le MICS en 2010 de la façon suivante : 1) Introduction d'un système d'envoi automatique de messages électroniques pour téléphones portables, 2) Connexion du MICS à ADESS (Automatic Data Editing and Switching System), géré par le service météorologique et qui donne automatiquement les conditions météorologiques, les alertes de tremblements de terre, de tsunamis, etc... Si un utilisateur s'enregistre sur MICS, il reçoit automatiquement et immédiatement les informations de navigation dans la zone de couverture de son téléphone portable. Actuellement, plus de 10 000 utilisateurs sont enregistrés sur MICS et ont reçu les informations importantes.

Le rapport présente le nouveau MICS et l'e-Navigation pour les petits bateaux.

Improvement of Maritime Information and Communications System (MICS): e-Navigation for small ships

Hideki Noguchi

Japan Coast Guard

IALA·2014·AISM

XVIII Conference · A Coruña · Spain

Hideki Noguchi, Japan Coast Guard

1. Maritime accidents in Japan

Japan is island country and therefore maritime activity such as shipping, fishing, marine leisure is very active. Although the recent numbers of maritime accident has been gradually decreasing by reflecting the recent economic trend, more than 2,000 accidents are happened in a year in Japan. Of those accidents, more than 70 % is caused by non-SOLAS ships such as fishing boats, pleasure crafts as shown in ***Figure 1***. Most of those small non-SOLAS ship or craft does not have adequate radio communication and have difficulty to access necessary information for the safety of navigation.

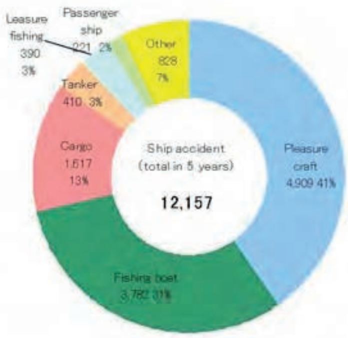


Figure 1: Ship accident by type of ships

One of the reasons of these non-SOLAS maritime accident is lack of adequate information such as weather, tidal information. Generally, sea weather is prone to change suddenly and drastically. Furthermore, Japanese sea weather, especially wave and tidal movement is very complicated due to the geographical features of Japanese coast line. Because of its size, small boats are very weak with rough weather and easily capsized which frequently resulted in a fatal accident. It therefore is very important to obtain weather warning or advisory from the Meteorological Agency and real-time local weather condition for preventing the non-SOLAS maritime accident.

2. Old MICS

The JCG had provided weather information that was observed at several lighthouses through JCG radio broadcast and telephone information service. This weather information service from a lighthouse was so popular among mariners, since due to the complicatedness of Japanese coast line, the local weather was sometimes so different from wider area weather information that was provided by the Meteorological Agency through TV or commercial radio broadcast. However, there were some disadvantages of utilizing the JCG weather information service. One was that there was a need of special radio for receiving the JCG radio broadcast service and other was that user had difficulty to call the service when needed due to the busy line.

After entering new millennium, it became possible to provide more information easily with various providing tools by emerging and expanding new information and communication technology. In 2001, the JCG started the establishment of Maritime Information and Communication System (MICS) and expanded MICS to nation wide service in 5 years.

This MICS was aimed to provide local navigational information and to mariners. Each local Coast Guard (CG) office including Vessel Traffic Service Center had its own old MICS. The old MICS provided mainly the following information.

- Local weather information observed at AtoNs in the area of the CG office and the neighboring CG office
- Local Maritime Safety Information (MSI) such as navigational warning, notice to mariners
- Live camera image captured at AtoNs in the area of the CG office

In order to provide the information, the old MICS used the local CG homepage, telephone information service, MF radio broadcast, type 16 of Differential GPS (DGPS) and AIS (VTS center only). ***Figure 2*** shows the conceptual framework of the old MICS and ***Figure 3*** shows the system flow of the old MICS. The weather data at each AtoNs were automatically collected, edited and uploaded in every 30 minutes, while other information such as local MSI were manually inputted and uploaded at each time.

The use of the old MICS was measured by number of access to the MICS homepages. When the old MICS was started, 2013, the average number of access per month through internet at each homepage was 4,593. When the old MICS was finished its establishment of nation wide service, 2018, the number was almost steady, 4,387. On the other hand, the average number of access through mobile phone in 2013 was 1,785 and the number in 2018 was drastically increased to 4,667. A comparison of these numbers, access by internet and access by mobile phone, shows that the users became familiar to use the old MICS on the sea by mobile phone because of its easiness.

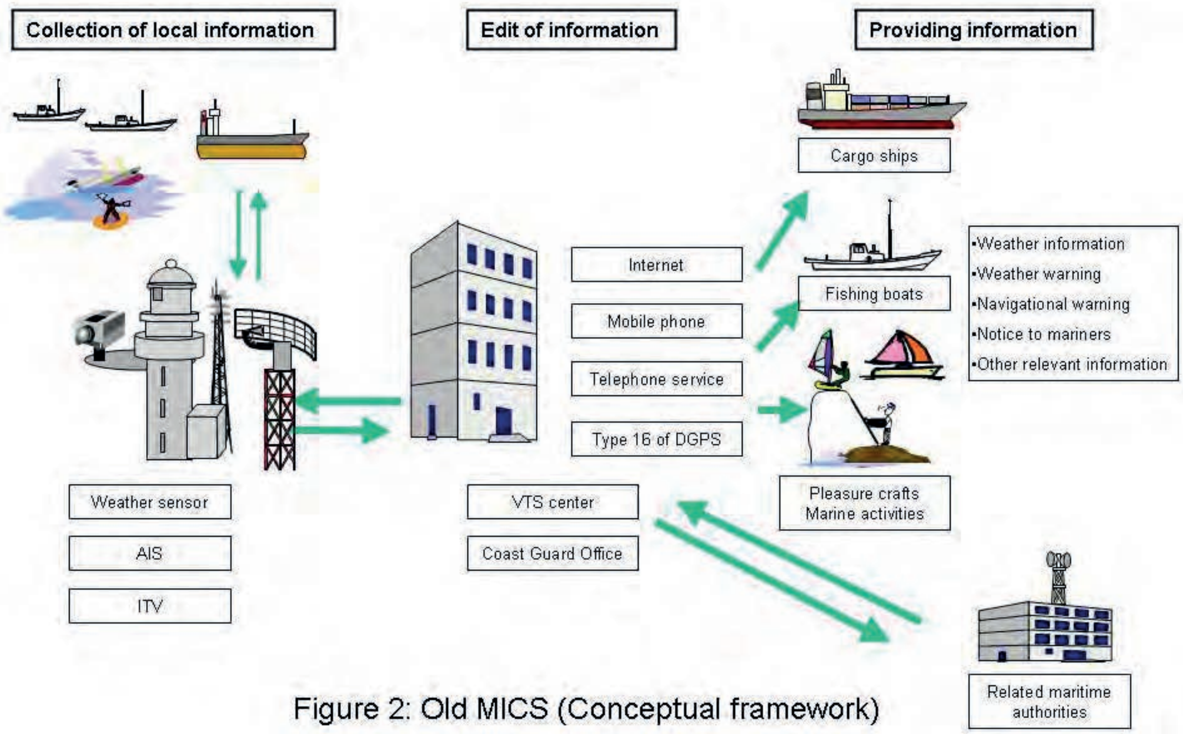


Figure 2: Old MICS (Conceptual framework)

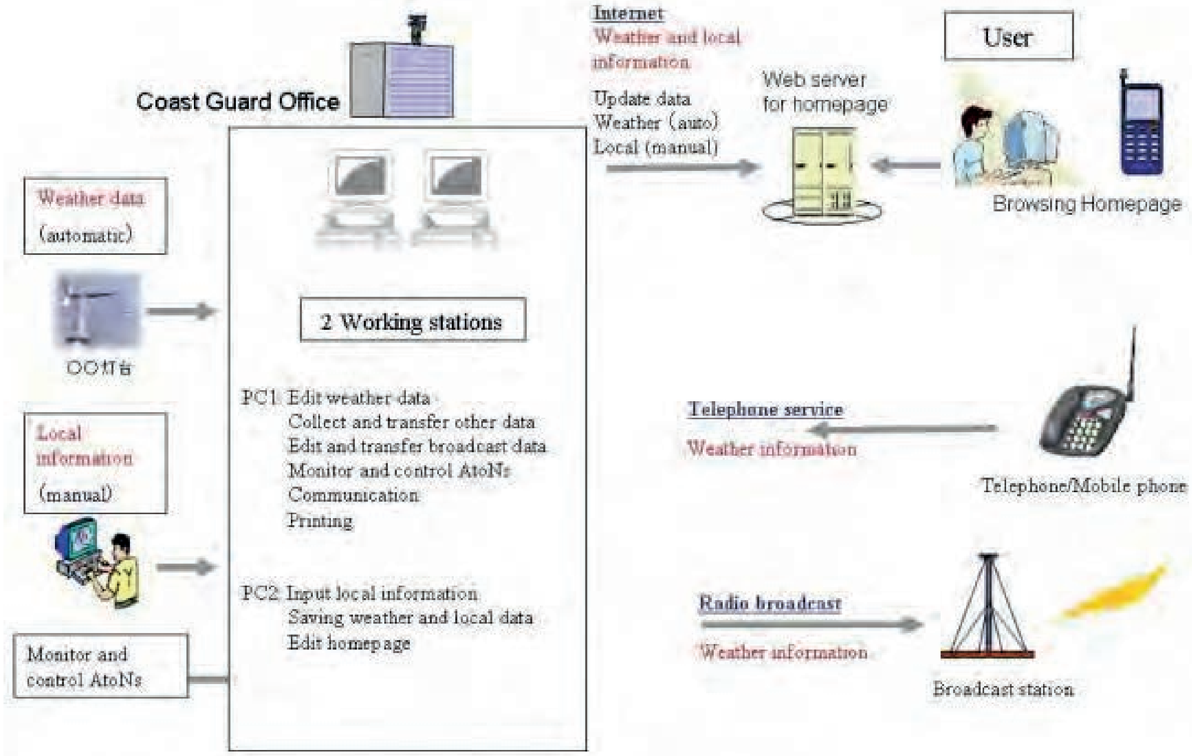


Figure 3: Old MICS (system flow)

3. Improvement

The old MICS was very effective tool for providing information to mariners, especially non-SOLAS ships, pleasure crafts and fishing boats that are not required internationally recognized radio communication equipment and thus a mobile phone becomes a useful communication tool. However, after more than 5 years of operation, lack of some capabilities were emerged. Such capabilities were

a. active information providing capability
   As ***Figure 3*** shows, user needs to access the old MICS homepage in order to obtain necessary information. However, emergency information such as navigational warning, weather warning should be provided actively and immediately.

b. wider level warning providing capability
   The old MICS was established as local information service. However some information or warning, for example tsunami warning and falling debris information should be provided widely or nationally.

c. and easier access capability
   Although some sort of design was standardized, each old MICS homepage was designed locally and thus user sometimes felt difficulty when accessing a different MICS homepage. The homepage design should be user friendly and accessible.

In order to provide active information providing capability, e-mail delivery system that had been already commercially available at that time was adopted. In addition to the e-mail delivery system, since some information such as tsunami warning requires promptness, the weather warning delivery system named Automatic Data Editing and Switching System (ADESS) that automatically provides weather warning, caution and other information from Meteorological Agency, was also adopted. Because ADESS is operated by the Meteorological Agency, the JCG exchanged the memorandum regarding the operation of ADESS and MICS with the Meteorological Agency. User who wants to receive this mail service needs to register the e-mail address with the e-mail delivery system.

For wider level warning providing capability, the system architecture was decided to be changed. The old MICS system was composed of local Coast Guard offices and unable to handle a regional level or national level warning. Therefore, considering the frequency of regional level warning and national level warning, the system was centralized to the regional Coast Guard Headquarters and the national level warning system wad added to the DGPS Center located in JCG Headquarters. In order to ensure the promptness of the warning, the new MICS operation console was put in the regional operation room that handles every regional and local emergency information within the region.

In parallel with the centralization of MICS, the unified MICS homepage was developed for easier access. In addition to the easier access, the new MICS homepage was designed to provide intuitive information portrayal that user can easily recognize what warning is issued at what area.

Figure 4 shows the comparison of old and new MICS.

4. New MICS

The first new MICS was established at 3rd Regional Coast Guard Headquarters in 2011. Then the second MICS was established at 4th, 5th ,6th and 7th Regional Coast Guard Headquarters in 2012 and the final MICS was established at the remaining 1st, 2nd, 8th, 9th, 10th and 11th Regional Coast Guard Headquarters in 2013. As new MICS has expanded its service to nation wide, the number of users registered with the e-mail delivery service has also been increased. As of 1st July 2013, nearly 15,000 users registered with the system.

Figure 5 illustrates the information flow of the new MICS. From operational point of view, in each regional headquarters, the MICS operation officer who is on duty of the MICS operation console at the regional operation room gathers emergency information and other information from the local Coast Guard offices in the region. The officer edits the information to the defined format and inputs the information to the console in order to send by the mail delivery system or update the MICS homepage. While this regional information is processed manually, weather information observed at lighthouses in the region is processed automatically by the weather information editing console.

The staff of local Coast Guard offices gathers information such as local marine event, harbor work and reports the information to the regional headquarters by the JCG own network. Using this console, the Coast Guard office can monitor and control a lighthouse that is equipped with the weather sensor for MICS service.

Figure 4: Comparison of old and new MICS

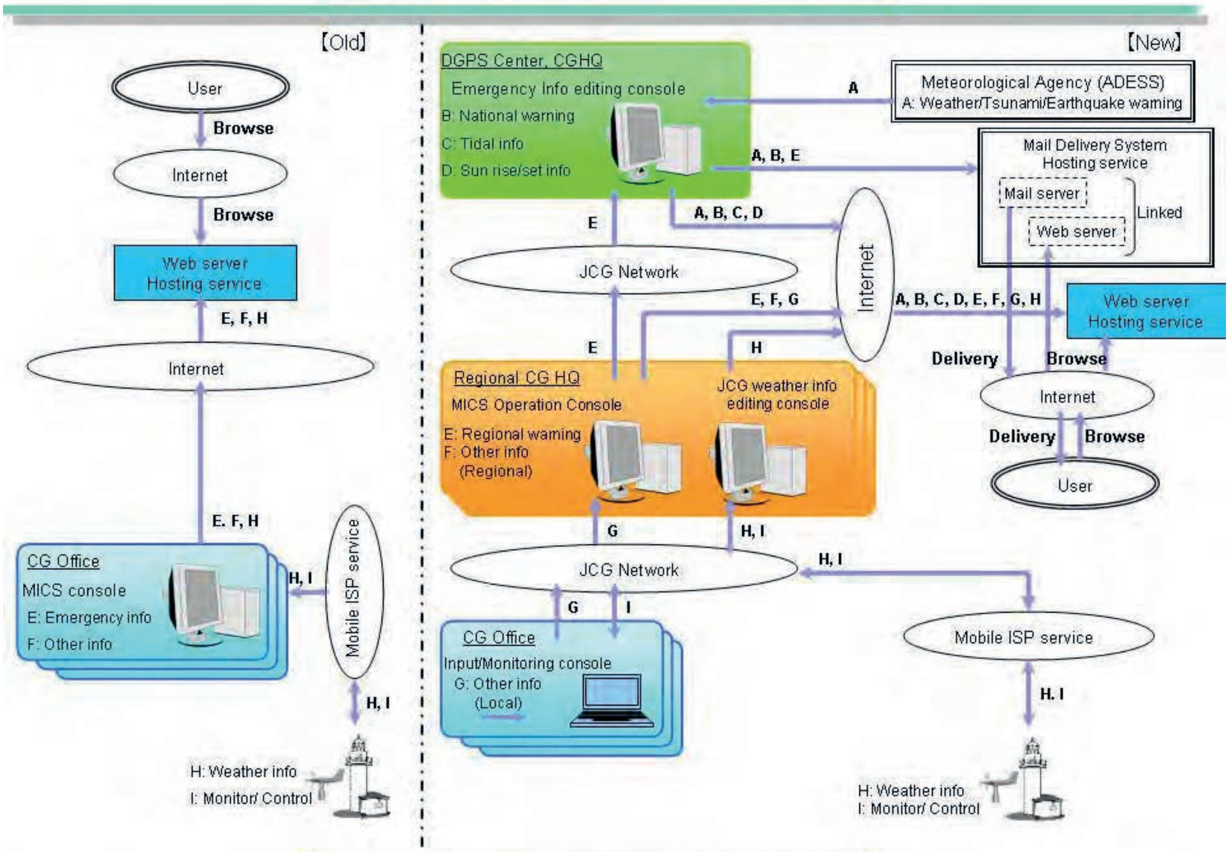
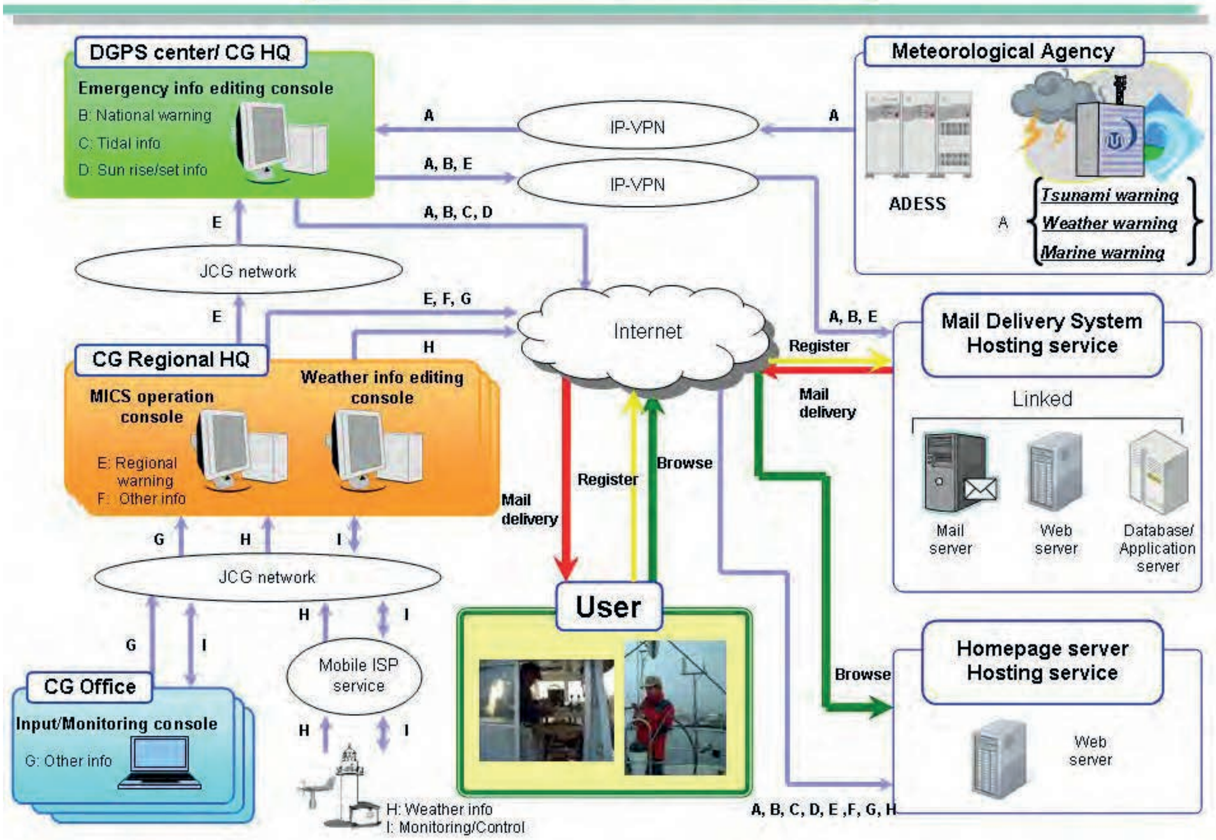


Figure 5: Information flow of new MICS



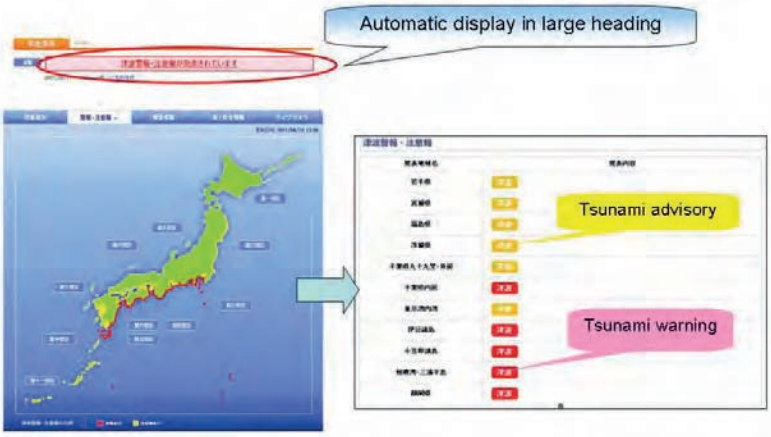


Figure 6: Example screenshots of tsunami warnings and advisories

In the Maritime Traffic Department of the JCG headquarters, only the DGPS center has 24/7 watch system. Therefore, wider area warning or national level warning from the JCG Operation Center is gathered to the DGPS Center and the OOW of the DGPS center inputs the warning information to the emergency information editing console for the mail delivery system. The weather warning and other warning from the Meteorological Agency is automatically transferred to the emergency information editing console through ADESS and sent to the users by the mail delivery system.

User can access the MICS homepage through internet. The first page appeared is a costal map of Japan and the user can intuitively find what and where warning or other emergency information is issued. *Figure 6* shows the example of the tsunami warning and advisories on the MICS homepage. The user who wants to know more detailed information can move to a regional or local map from the national costal map. *Figure 7* shows the example of the weather warning and advisory on each level of MICS homepage. The user can also obtain weather information observed at lighthouses in the same manner of the emergency information. In addition, the user can access the weather data of the specific lighthouse in the latest 12 hours so can grasp the weather trend at the lighthouse. *Figure 8* shows the example of the weather information.

If a user wants to use the mail delivery service of the emergency information, the user needs to register his or her e-mail address with the mail delivery system. At the registration, the user selects the type, area and time of the emergency information in accordance with his or her needs. The information is provided by text message only considering the size of display of the ordinary mobile phone. *Figure 9* shows the example of the mail delivered by the system with English translation.

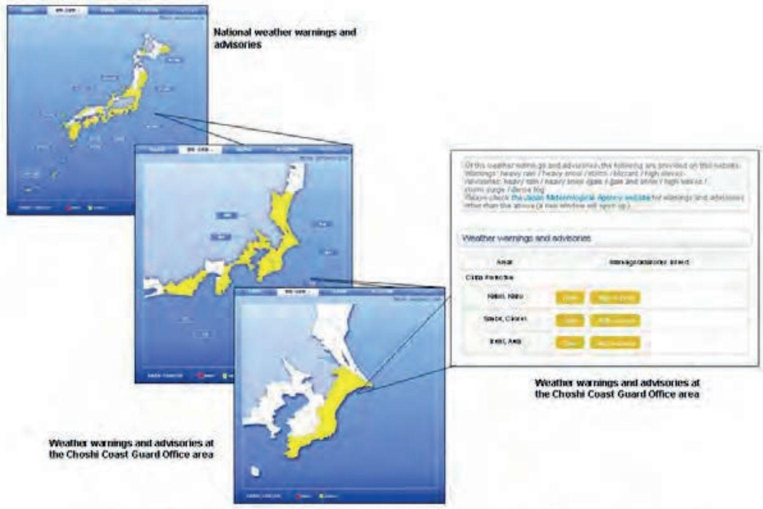


Figure 7: Example screenshots of weather warnings and advisories

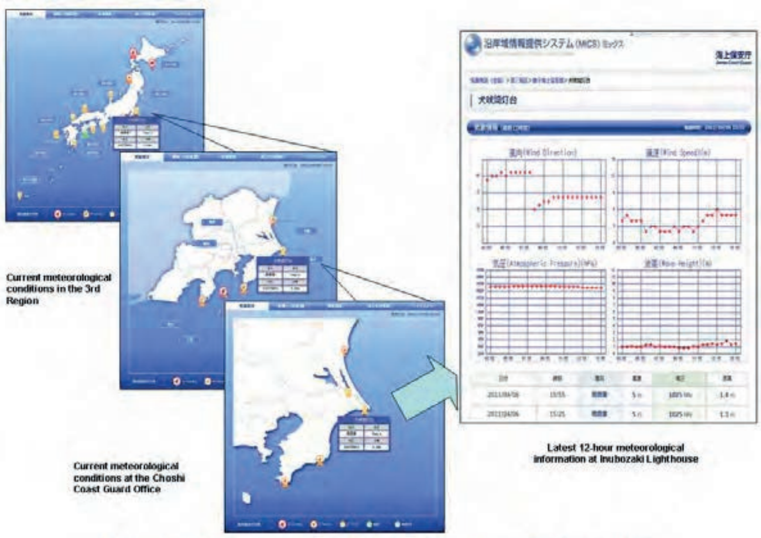


Figure 8: Example screenshots of current weather conditions

5. MICS in e-navigation

E-navigation is the IMO led and developed concept for enhancing safe and secure navigation of vessels by facilitating communication. Although IMO has responsibility for shipping engaged in international trade, e-navigation could or should be applied to all ships without regard for engaged in international shipping or not. Non-SOLAS ships do not need to be equipped with communication system regulated by SOLAS such as NAVTEX but

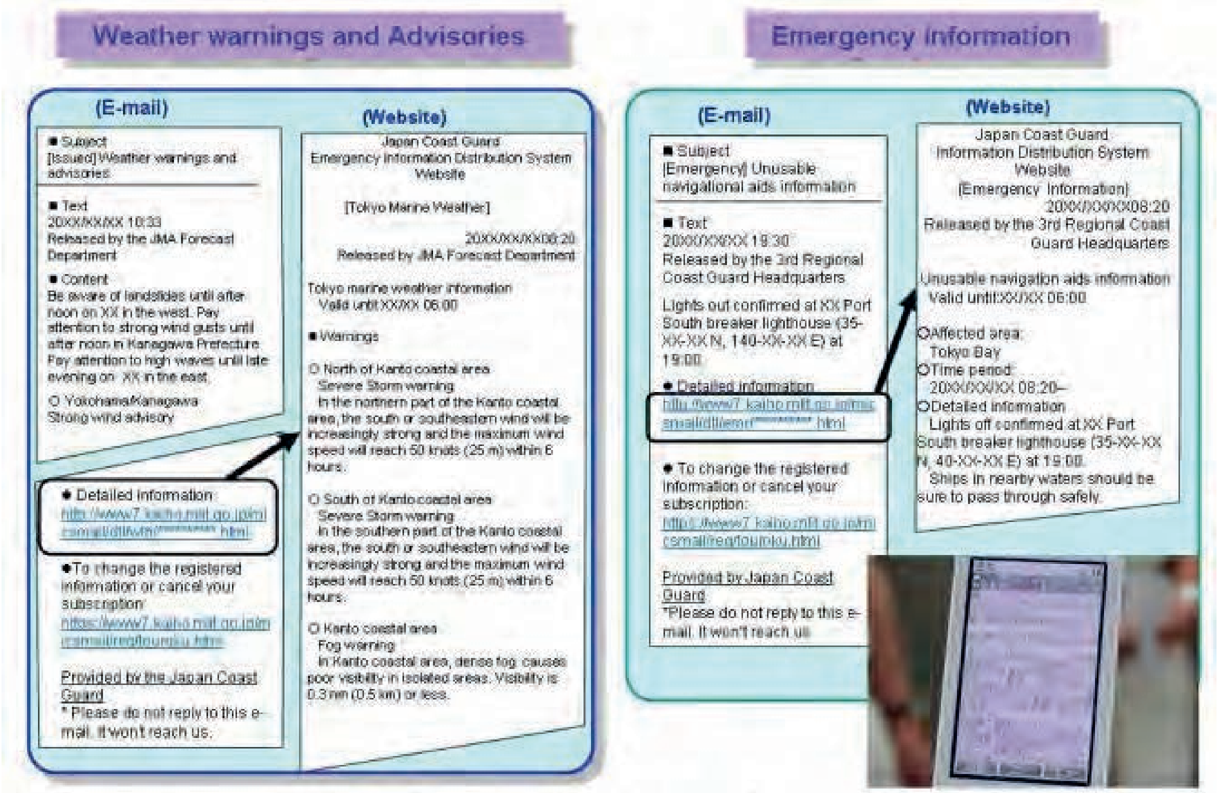


Figure 9: Example of e-mail delivery service

(Translated into English)

this does not mean that they do not need Maritime Safety Information (MSI) such as navigational warning, weather warning or tsunami warning. In fact, considering the size of ship, the proficiency of crew and others, many non-SOLAS ships really need such information.

MICS was originally developed to provide such information to non-SOLAS ships using Information and Communication Technology (ICT). However due to the technological limitation at that time, MICS was limited to be a passive system that required access from user. Technological development after that has enabled MICS to be improved and became an active system that provides necessary information at the necessary time. But the improved MICS still has the following limitations.

- Narrow coverage
  The mail delivery system does not cover the whole coast of Japan and even in the area where the system is available, the coverage is only few miles from the coastal line.
- Vulnerable commercial link
  The mail delivery system relies upon commercial mobile phone service and thus is vulnerable to natural disaster such as earthquake or tsunami because of the capacity and redundancy of the service.
- Text only portrayal

  The mail delivery system delivers only text information and thus the portrayal of information is not intuitive.

In order to overcome those limitations, the JCG is now considering the next improvement of MICS. It is expected that the recent rapid spread of smart-phone including tablet computer will significantly contribute to the information portrayal of e-navigation for non-SOLAS vessels. Therefore the next generation MICS will surely have a capability of graphical portrayal mail delivery system.

On the other hand, the first two limitations are more difficult than the last one because of the reliance upon the commercial mobile phone service. However, after the Great East Japan Earthquake, many commercial mobile phone service providers have made efforts to establish the resilient service network. For example, many mobile base station's facilities have become anti-seismic and the power sources have also become independent. Consequently, the mail delivery system is now less vulnerable than before, though the coverage limitation still remains.

Since MICS was designed for non-SOLAS vessels, especially fishing boats and pleasure craft, the information delivery tools for the system heavily relies upon commercial services such as internet providers and mobile phone service providers. Compared with communication system defined by SOLAS, MICS is apparently less robust, less capable and less reliable. Therefore, utilization of commercial service in e-navigation for SOLAS vessels should require careful consideration and verification. However, the use of MICS does not require dedicated equipment and proficiency. Even week-end mariner can easily use MICS. This advantage should not be neglected when considering e-navigation for non-SOLAS vessels.

6. Conclusion

E-navigation certainly benefits safety and security of navigation of SOLAS ships and protection of marine environment. On the other hand, since non-SOLAS vessels share the same marine environment, non-SOLAS vessels should not be left from the benefit of e-navigation.

However, because of difference between SOLAS and non-SOLAS, the approach and implementation e-navigation is not same. MICS was designed for non-SOLAS vessels, especially fishing boats and pleasure crafts that are relatively small and usually navigating in coastal area. It is aimed to facilitate the exchange of information and data using ICT that is the similar concept of e-navigation but the difference is that MICS utilizes commonly available tool such as internet or mobile phone while SOLAS vessels use mostly dedicated tool. Therefore, when implementing e-navigation for both SOLAS and non-SOLAS ships, it is very important to choose appropriate and available tool taking advantages and disadvantages in consideration..■

11 MARITIME DOMAIN AWARENESS, THE CHILEAN EXPERIENCE

James Crawford. Directorate General of the Maritime Territory and Merchant Marine, Chile

Oceans are global pathways that maintain national prosperity and are vital to national security. The maritime domain awareness is defined as all areas and things of, above, under, down, in relation to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances. Terrorist organizations recognize this and also realize the importance of exploiting the maritime domain.

The basis for effective prevention measures is to be alert and aware of the threat, along with a credible deterrent and interdiction capabilities. The environment of the XXI century maritime threats demand a holistic vision, with a broad scope, which is pursued which through the MDA.

Los océanos son rutas globales que mantienen la prosperidad nacional y que son vitales para la seguridad nacional. La conciencia del dominio marítimo se define como todas las áreas y cosas de, por encima, por debajo, abajo, en relación con, adyacentes a, o que limitan con un mar, océano u otra vía navegable, incluyendo todas las actividades, infraestructuras, personas, cargamento, barcos y otros transportes marítimos. Las organizaciones terroristas reconocen esto y se dan cuenta de la importancia de explotar el dominio marítimo.

La base para adoptar medidas de prevención efectivas es estar alerta y ser consciente de la amenaza, además de tener una capacidad de interdicción y disuasión creíbles. El marco de las amenazas marítimas del siglo XXI requiere una visión holística, con un amplio alcance, lo que se persigue a través de la Conciencia del Dominio Marítimo (MDA).

Les océans sont des chemins universels qui assurent la prospérité nationale et sont essentiels pour la sûreté nationale. La connaissance du domaine maritime se définit comme l'ensemble des zones et objets se situant dans, au-dessus, au-dessous, au fond, en relation avec, adjacent à ou en bordure d'une mer, d'un océan ou de toutes autres voies navigables: infrastructures, personnels, fret, navire ou autre transporteur. Les organisations terroristes savent cela, mais aussi réalisent l'importance d'exploiter le domaine maritime.

La base de mesures de prévention efficaces est d'être en éveil et conscient des menaces, et doté de moyens crédibles d'intervention et d'interdiction. Dans l'environnement du XXIème siècle, ces menaces maritimes demandent une vision holistique de grande envergure que l'on peut atteindre par le MDA.

Maritime domain awareness: the Chilean experience

James Crawford

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

Introduction

The oceans are global pathways that maintain national prosperity and are vital to national security. Following this concept, the maritime domain awareness has been defined by the International Maritime Organization as the effective understanding of anything associated with the maritime domain that could impact the security, safety, economy, or environment.

The maritime domain is defined as all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, ships and other means of transport.

Terrorist organizations recognize this and also realize the importance of exploiting the maritime domain.

The basis for effective prevention measures is to be alert and aware of the threat, along with a credible response which considers deterrence and interdiction capabilities. The environment of the XXI century maritime threats demands a holistic approach, with a broad scope, which is pursued through the MDA.

Data collection to apply the MDA concept in Chile

Inside the Chilean Navy, the MDA concept has been adopted as "surveillance, monitoring, warning and response" of the national maritime area of responsibility, which is implemented by the Directorate of Maritime Safety, Security and Operations (DIRSOMAR), Technical Direction dependent of DIRECTEMAR, which embraces all areas related to maritime safety and security.

The information provided by surveillance and monitoring activities considers all the means that DIRECTEMAR owns, displayed in different layers of a computer application called Grafimar. These layers are organized as follow: the basic

information that feeds "Grafimar" is related to meteorological, geographic and hydrographic conditions. At this step, it is possible to visualize weather conditions that affect the national maritime jurisdiction, visualize temperature of the sea, information related to tsunami events, winds, currents, etc.

The second layer of information is provided by the national aids to navigation network, through data received by VTS stations and AIS sensors located along our coast, as well as, administrative information provided by local maritime authorities, such as ships' ETA / ETD, crew name list with nationalities, type of cargoes, etc. With this information, it is possible to visualize the location of ships sailing within the maritime jurisdiction, providing valuable information to analysts, to assist in decision making process related to local maritime operation departments, search and rescue and marine environmental protection operations.

The third layer is conformed by information from electronics systems, such as radar and radio stations, cctv, etc., that enhances the surface picture developed with the basic data obtained from maritime authorities.

The fourth layer is composed by information provided by open sources, as well as, operative means, such as patrol boats, aerial devices and human patrols. Finally, the last layer is conformed by data provided by other organizations or purchased from service provider companies, such as AIS data exchange with other maritime organizations authorities, AIS data and satellite image providers, etc.

With all the information sources, "Grafimar" is capable to generate information according to different levels of access, set by different interests, to facilitate the decision making process related to the awareness of the maritime jurisdiction. In this way, it is possible to know a huge number of variables that affect each ship within the maritime jurisdiction, from meteorological to security aspects, in order to apply an effective understanding of everything associated with the maritime domain that could impact the security, safety, economy, or environment.

The MDA concept in action

No matter the level of threat, information that feeds the maritime surface picture, is always kept at their highest level of availability.

At peace time, usually this information is used to develop operations regarding safety and marine environmental protection and drug control operations at Chilean maritime boundaries.

All the information that feeds "Grafimar" is available along the country through maritime authorities, giving vital information for decision making process related to all activities taking place in the maritime, river and lake areas of responsibility, which could affect national security and the development of its maritime interests, in order to alert, prevent, protect and provide the appropriate response required by the national interest. This is an inclusive concept regarding the actions of DIRECTEMAR as a backbone, thus introducing a higher systemic framework that allows subordinate commanders to understand and guide their work at different levels and stages. ■

129 R-MODE USING TRANSMISSIONS FROM EXISTING IALA RADIO BEACON INSTALLATIONS

Michael Hoppe. Federal Waterways and Shipping Administration, Germany

Position fixing systems are identified as one strategic key element of e-navigation. Existing and future Global Navigation Satellite Systems (GNSS) like GPS, GLONASS and GALILEO are fundamental infrastructures for global determination of PNT data. IALA has introduced the term "integrated PNT device" to describe the on-board part of a maritime integrated PNT system. Additionally, terrestrial services are used to improve performance or to ensure backup functionality to overcome the vulnerability of GNSS. As a contribution to the development of redundant positioning, a terrestrial backup navigation system based on ranging signals (R-Mode) transmitted from MF radio beacons and/or AIS base stations was proposed by the German Federal Waterways and Shipping Administration. To further develop the new system idea it was decided to perform a feasibility study as well as a practical field demonstration within a transnational EU project named ACCSEAS (Accessibility for Shipping, Efficiency, Advantages and Sustainability). One aim within the ACCSEAS project is the implementation of a test bed at the Dutch Coast which should enable a proof of concept for the proposed R-Mode using MF transmission from an IALA radio beacon station. The full paper will generally explain the R-Mode system concept and various implementation methods.

Los sistemas de fijación de posición se identifican como un elemento clave estratégico de la e-navegación. Los Sistemas Globales de Navegación por Satélite (GNSS) como GPS, GLONASS y GALILEO son infraestructuras fundamentales para la determinación global de datos PNT. IALA ha introducido el término "dispositivo PNT integrado" para explicar la parte a bordo de un sistema PNT marítimo integrado. Además, se utilizan servicios terrestres para mejorar el rendimiento o garantizar la funcionalidad de respaldo para superar la vulnerabilidad del GNSS. Para contribuir al desarrollo del posicionamiento redundante, la Administración Alemana de Navegación Fluvial y Transporte Marítimo propuso un sistema de navegación de respaldo terrestre basado en señales de rango (modo R) transmitidos desde balizas de radio MF y/o estaciones base AIS. Para desarrollar más la idea del nuevo sistema, se decidió realizar un estudio de viabilidad así como una demostración práctica de campo dentro de un proyecto transnacional UE llamado ACCSEAS (Accesibilidad para transporte marítimo, eficiencia, ventajas y sostenibilidad). Un objetivo dentro del proyecto ACCSEAS es la implementación de un banco de pruebas en la costa holandesa que debería permitir una prueba del concepto del modo R propuesto mediante el uso de transmisión MF desde una estación de baliza de radio IALA. La ponencia completa explicará en general el concepto del sistema de modo R y los diferentes métodos de implementación.

Les systèmes de localisation ont été identifiés comme un élément stratégique clé de l'e-Navigation. Les systèmes mondiaux de navigation par satellite (GNSS) existants ou bien futurs, comme le GPS, GLONASS et GALILEO sont des infrastructures fondamentales pour la détermination des données PNT. L'AISM a introduit le terme « appareil de PNT intégré » pour désigner la partie embarquée d'un système de PNT maritime intégré. En outre, des services à infrastructure terrestre sont utilisés pour améliorer la performance ou en tant que secours pour remédier à la vulnérabilité du GNSS. Pour contribuer au développement d'un système de localisation parallèle, un système de navigation à base terrestre reposant sur des signaux en mode R émis par les radiophares en moyenne fréquence et/ou des stations AIS à terre a été proposé par l'Administration fédérale allemande des voies maritimes. Pour faire avancer cette idée de nouveau système il a été décidé de mener une étude de faisabilité et une démonstration pratique sur le terrain dans le cadre du projet européen ACCSEAS (accessibilité pour la navigation, efficacité, avantages et durabilité). L'un des objectifs du projet ACCSEAS est la mise en place d'un site d'essai sur la côte néerlandaise, qui permettrait de démontrer le concept d'un mode R utilisant des émissions MF à partir d'un site de radiophare AISM. Le rapport expliquera le concept du système mode R et les diverses méthodes de mise en œuvre.

Paper not available

105 'TO INFINITY AND BEYOND' BROADBAND VHF – THE FUTURE OF E-NAVIGATION COMMUNICATIONS?

Jillian Carson-Jackson. Australian Maritime Safety Authority, Australia

You must be dreaming! Texting, e-mails and more over analogue VHF?
e-navigation – both ship and shore – will depend on communication capabilities. Radiotelephony has been the cornerstone of maritime communications for decades – but what role might it have in a modern e-navigation world?

The Automatic Identification System (AIS) was a breakthrough in sending digital information over analogue VHF radio channels. AIS has a specific purpose clearly identified in the Safety of Life at Sea Convention (SOLAS) Chapter V. The design of the system and the speed of transmission of information meet this existing need, but what about future requirements?

How might we be able to address the increasing need for communications ship shore / shore ship and ship ship? Are we 'dreaming' that this information can be sent within the framework of existing, analogue, maritime radio frequency spectrum?

¡Estás soñando! ¿SMS, correo electrónico, y más por VHF analógico?
La e-navegación (tanto en barcos como en costa) dependerá de las capacidades de comunicación. La radiotelefonía ha sido el pilar de las comunicaciones marítimas durante décadas; pero ¿qué papel podría tener en un mundo moderno de e-navegación?

El Sistema de Identificación Automático (AIS) fue un avance en el envío de información digital a través de canales de radio analógicos VHF. El AIS tiene un objetivo concreto claramente identificado en la Convención de Seguridad de la Vida Humana en el Mar (SOLAS), capítulo V. El diseño del sistema y la velocidad de transmisión de la información cumple esta necesidad existente, pero, ¿qué pasa con los requisitos futuros?

¿Cómo podríamos abordar la necesidad creciente de comunicaciones barco-tierra / tierra-barco y barco-barco? ¿Estamos "soñando" con que esta información se puede enviar dentro del marco de un espectro de frecuencia de radio marítimo análogo ya existente?

L'e-Navigation – à bord du navire comme à terre – va dépendre des possibilités de communication. La radiotéléphonie a été la pierre angulaire des communications maritimes pendant des décennies – mais quel rôle a-t-elle encore dans un monde moderne d'e-Navigation?

Le Système d'identification automatique (AIS) a été une avancée dans l'envoi d'informations numériques par canaux radio VHF analogiques. L'AIS a une fonction spécifique clairement identifiée dans le Chapitre V de la Convention pour la sauvegarde de la vie humaine en mer (SOLAS). La conception du système et la vitesse de transmission répondent à ce besoin, mais qu'en est-il des exigences futures?

Comment pourrons-nous répondre au besoin croissant de communications navire-terre/ terre-navire et navire-navire? Est-ce un rêve qu'imaginer que ces informations puissent être transmises dans le cadre du spectre de fréquence radio maritime, analogique, existant?

To infinity and beyond…

What is the future for maritime communications?

Jillian Carson-Jackson
&
Peter Pokorny

Australian Maritime Safety Authority

IALA·2014·AISM
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1. INTRODUCTION

The Oxford dictionary defines communication as:

The imparting or exchanging of information by speaking, writing, or using some other medium;

Means of sending or receiving information, such as telephone lines or computers

In a maritime sense, communication needs to occur over different mediums from ship-to-ship, ship- to-shore and shore-to-ship. We communicate with words (voice and printed); we send signals digitally and we expect, always, to be understood… This paper will attempt to look at some developments in maritime communication, and see what the future may (or may not) hold.

There is some really interesting science related to maritime communications so let's start by getting our grey cells working …

Q - Who said 'To infinity and beyond'? Was it:

a) *Flik from 'A Bugs Life?*

b) *Buzz Lightyear from 'Toy Story'?*

c) *Capt. Picard from 'Star Trek, the next generation'?*

d) *Capt. Malcolm Reynolds, from 'Firefly'?*

Did you get it right? While any of these folks could have said it, the phrase was a one that became popular with the movie 'Toy Story'. Yep, the right answer is B) Buzz Lightyear. Now Buzz had a hard time coming to grips with what he really was. While he had lasers in his arms, lots of great buzzing and whistling noises, and he could 'fly' – which was really 'falling with style' – he had to realize that he was a child's toy and not a space explorer. Now, you might be asking, what does an animated character from a popular children's movie have to do with maritime radio communications. Well, amidst all the gadgets and gizmos that Buzz had, he did have to come to terms with his limitations. Infinity is defined as *the state or quality of being infinite; Infinite is limitless or endless in space, extent, or size; impossible to measure or calculate. So, 'to infinity and beyond'* is really something that can't be reached, and flying just wasn't in the cards. It isn't possible to go counter to the laws of nature. In the case of Buzz Lightyear gravity continues to exert its force.

But what Buzz did is make the very best of what he had. The character acknowledged his limitations, but didn't let them inhibit his ability to 'think outside the box'. (Well, in as much as an animated character can actually do any of this.)

In this age of instant messaging, constant contact and access to what appears to be an 'infinite' amount of information through the internet, we have high expectations of communications technology. Hands up if you have a multi-function 'smart phone', or an iPad or other tablet device? Well, don't actually put your hands up or you will have a hard time holding onto the tablet, or e-book, or whatever you are reading this on. Do you always check for the nearest Wifi when you are waiting at the airport, the train station or even the doctor's office? For those of you still plying your trade at sea, do you hang out in the common room to watch a movie, or do you watch movies in your own cabin? Who has had to deal with dial-up internet connection instead of broadband? Communications is an expected part of our day-to-day life. (Some may even say essential, but that can be debated)

Maritime communications is really in the same boat (pun intended). Those at sea have the experience with the communications capabilities ashore. With all the requirements for information from ship / shore and vice versa we have some pretty high expectations, and increasing demands, on communications. In the maritime environment, however, it is not always possible to have a WiFi link or mobile phone coverage. We have to deal with what we have – and that means working with the finite resource of radiofrequency spectrum and the physical properties of how we pass data over that resource. So, what might be the future of maritime communications?

2. TECHNOLOGY AND COMMUNICATIONS

It used to be we could communicate over distance with flags (semaphore) or lights (aldis lamps). With technology we discovered the use of radio waves to transmit sound – first dits and dahs (Morse code) and then voice. These radio waves are pretty dependable, with reliable ranges using different frequencies. For example, we all know that VHF (Very High Frequency) is basically 'line of sight' and gives a range, depending on the height of the antenna (e.g. for two antennas, each located at 16 m in height above sea level, the approximate range is 20 nautical miles). This is, of course, for standard voice communications over VHF using an analogue modulation scheme (see science content – modulation schemes). These existing VHF frequencies can also be used with digitally modulated emissions, which we will look at later. VHF frequencies are identified in the ITU Radio

Regulations, Appendix **18,** often called the 'VHF maritime mobile band' which is sandwiched between portions of the land mobile service.

MF (Medium Frequency) and HF (High Frequency) bands are also used in the *maritime mobile service,* but they haven't had as much attention paid to them lately (see Science content on frequency bands). Although they are required by certain ships in specified sea areas as part of the GMDSS distress and safety functions, commercial data services have been available for many years now, but widespread use on a multi-channel basis has not been adopted. The Radio Regulations were revised at the World Radiocommunication Conference 2012 to allow - for HF (Radio Regulations, Appendix **17**) this revision enables multiple channels to be combined and a re-organization of the channel plan by removing unused Morse channels and unnecessary radio-telex (NBDP) channels. The new plan comes into effect from 1 January 2017. For MF, from 495 to 505 kHz is now available for digitally modulated emissions in the maritime mobile service.

Another radiofrequency spectrum used at sea is UHF (Ultra High Frequency). Although UHF is in widespread use at L-band (1.5/1.6 GHz) for maritime mobile-satellite services, there very little spectrum in the popular 400 MHz band for maritime communications. An increase in the 400 MHz spectrum would be difficult to achieve, which lends weight to making best use of the VHF maritime spectrum already available.

Science content – radio frequency bands

Abr	Stands for	Frequency range
EHF	Extremely High Frequency	30-300 GHz
SHF	Super High Frequency	3 GHz-30 GHz
UHF	Ultra High Frequency	300-3 000 MHz
VHF	Very High Frequency	30-300 MHz
HF	High Frequency	3-30 MHz
MF	Medium Frequency	300-3 000 kHz
LF	Low Frequency	30-300 kHz
VLF	Very Low Frequency	3 - 30 kHz

2.1 Analogue or Digital

It seems everyone is talking 'digital' these days. In Australia we made the 'jump' from analogue to digital TV a couple of years ago, and the last analogue TV service what shut down in 2013. That meant you either had to buy a new TV or get this fancy box to hook up to your TV so you could get the signals. I don't think many folks really understand the change, but I know we get a whole lot more channels now without having to sort out the antenna…

In maritime communications we are also seeing the introduction of 'digital' communications. The initial move to digital happened some years ago when Digital Selective Calling (DSC) was introduced as part of the Global Distress and Safety System (GMDSS). In the GMDSS, DSC is used as paging system that uses digital signals composed of 10 'bit' (binary digit) characters from an error-detecting code to automate the transmission of distress, urgency or safety calls via MF, HF or VHF radio.

The maritime world came a long way into the digital era when they introduced the Automatic Identification System (AIS). Apart from satellite communications, AIS was the first SOLAS radio system to actually make real use of the capabilities offered by 'going digital'. AIS uses two existing VHF channels (AIS 1 – 161.975 MHz, and AIS 2 – 162.025 MHz), but then changes how data is transferred across the spectrum. These are frequencies that were used for analogue voice in the past. Basically, you can think of them as 'analogue channels' that now have 'digital data' through a change in the modulation protocol that is being used. (see Science content – modulation schemes)

With modern digital data techniques, combined with developments in electronic fabrication and computing, we can transfer a whole lot more data at a time, using the same frequency and spectrum allocation already available in the Maritime Mobile Band, at MF, HF and VHF.

2.2 Sharing the Spectrum – AIS

In order for many users to share radio spectrum, a time division multiple access scheme (TDMA) is used so that each user can access the spectrum in an organized way by a system of slot reservations. There are various types of access schemes (or algorithms) used in AIS for different user needs, including self-organizing TDMA (SOTDMA), carrier-sense TDMA (CSTDMA), fixed access TDMA (FATDMA), random access TDMA (RATMDA) and incremental TDMA (ITDMA).

TDMA has been used for many decades in telephone systems, microwave and satellite systems. TDMA was used in the first maritime communications satellite system, MARISAT, for the telex component (which became part of Inmarsat-A). In this system, the timeslots that a ship used for its telex "bursts" was allocated via a common-signalling channel by the coast earth station. Each coast earth station operated its own TDM telex carrier. Various forms of digitally modulated systems have been used in the land mobile service for many years.

The advantage with AIS is that all users share the same spectrum, using essentially the same protocol, making it suitable for SOLAS vessels, non-SOLAS vessels; AIS aids to navigation; AIS on search and rescue aircraft and more (**Figure 1**).

With VHF, we have an opportunity to further expand this feature for data exchange at a much higher rate than with AIS using radio channels already allocated to the maritime mobile service world-wide. Currently, the only piece of radiocommunication equipment that is common to vessels is the VHF radio. A modification to this piece of equipment to an international data standard(s) could allow a much greater data throughput potentially to all vessels that wish to use it. Combining this terrestrial VHF data capability with satellite VHF communication will then allow potentially true global data communication with ships at sea, using a frequency band with good propagation characteristics, not only supplementing existing satellite capability, but perhaps making high-speed data communication accessible to all vessels on the water, irrespective of size, type or activity. This developing capability is called the VHF Data Exchange System or VDES – but more on this a bit later.

Science content – AIS data transfer / dial-up vs broadband

AIS data is transferred using packets of data that are transferred over 'slots' in time, and transmitted in "bursts". Each (time) slot is 26.667 ms in length, with 2 250 slots available each minute (called a 'frame') on each of the two AIS channels. The start of an AIS frame is synchronised to the start of a UTC minute. Using a modulation scheme called GMSK/FM, this means that the data can be transferred at up to 9.6 kbits/s on each AIS 25 kHz radio channel.

Each slot contains 256 bits, giving a bit rate of 576 000 bits per minute (or 576 000/60 = 9 600 bits/s). However, the data content on a timeslot is not 256 bits, but 168 bits. AIS uses a 6-bit code for each character/symbol, so that the maximum information symbol rate per channel is 28 symbols/slot or 63 000 symbols/min/channel.

To put that in context, a home 'dial up' internet connection using a PSTN (Public Switch Transfer Network) transfers data at a theoretical transfer speed of 56 kbits/s (or about 5.8 times faster than AIS). However, dial-up lines can be as low as 20 kbits/s in noisy environments. Broadband internet connection, using DSL (Digital Subscriber Line) can have data throughput from 256 kbit/s to 20 Mbit/s depending on the DSL technology, line conditions and service-level implementation. There can also be different speeds – 'upstream' (in the direction from the user to the service provided) is lower than 'downstream' (to the user) – which gives an asymmetric digital subscriber line or ADSL.

2.3 Maritime Communications 'needs' and e–navigation

So, why do we need to communicate in the maritime environment? What do we need to communicate, and to whom?

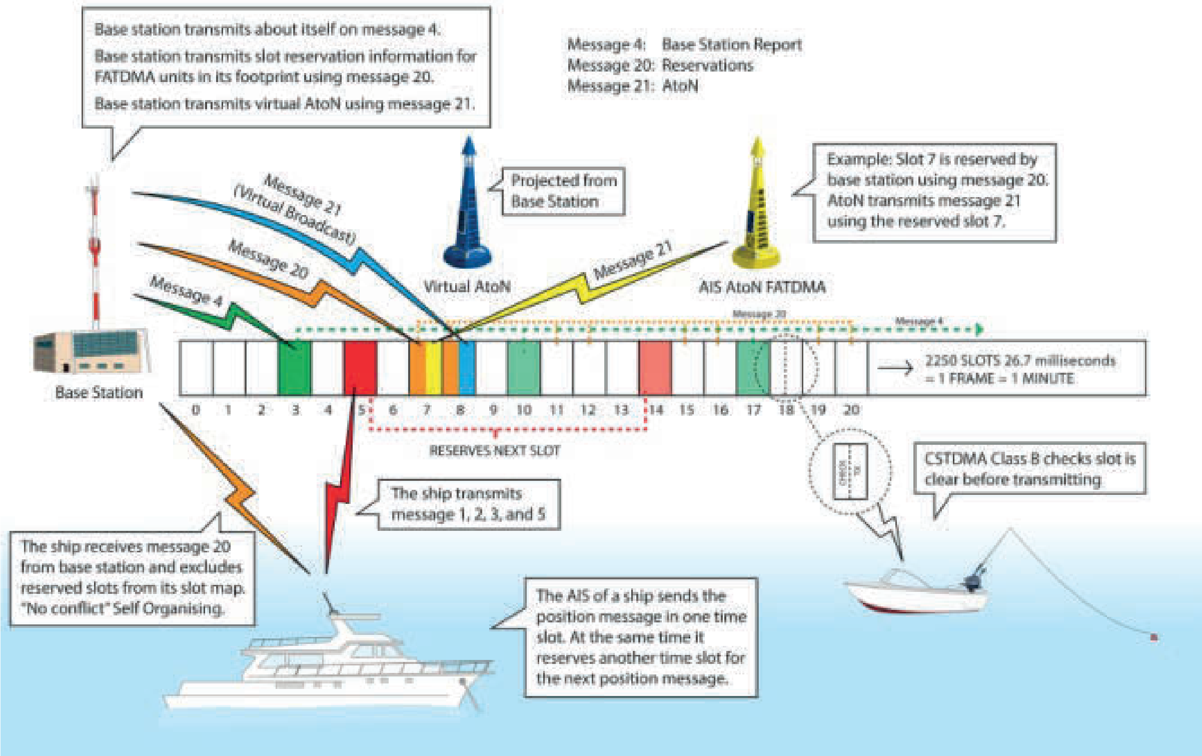

Figure 1: AIS slot management

Well, we communicate only when there is information to be conveyed or transferred. Data becomes information when it is correctly received and understood at the receiving end. Seems pretty obvious, doesn't it? If we are looking to the future of maritime communications, we need to look ahead to what the maritime communications needs will be in the future. This is where the work of the e-navigation comes in. The need to communicate information, in some manner, is identified in the user needs analysis and forms aspects of the Strategic Implementation Plan (SIP) for e-navigation.

The "shipping industry" is, in its broadest sense, a large network of entities and activities. These entities and activities are seen as centred about a ship, with the ship being considered self-contained. However, to support the sea transport of any sort, a large network of interested parties is necessary – and the role of shore entities in shipping is core to the overall industry. The need to become more efficient in cost, time and fuel consumption, the need to reduce pollution, and to operate and navigate with increasing safety in a 'zero tolerance' environment requires increasing flows of information between all parties - at sea and ashore In addition, the international nature of shipping means that the increasing need for communication is on a global scale. Communication needs are also highlighted in the review of GMDSS, where search and rescue authorities are also looking to 'work smarter' reduce costs (where possible), improve effectiveness, and increasingly share information and a 'common operating picture (COP)' with mobile assets.

There have been many attempts to improve communications via radio to and from ships at sea, and between ships. On the HF bands, commercial digital communications has been available for many years, but has not made it into common use. Maritime digital data communications on HF are described in Recommendation ITU-R M.1842, and there are developments to include digital data communications on VHF as additional annexes to the Recommendation.

Many ships now operate their own local area networks on board, store documents electronically, and can communicate ashore and with other ships via satellite links. Coastal phone networks have made it possible for ships in range to have broadband 'wireless' access in many areas.

Just like the virus checker software on our home or work computers, software on shipboard equipment requires updates, often via the internet. This means there is a need for some sort of connection – most likely a satellite or coastal mobile data network. However, not all coasts have mobile phone networks, or networks suitable for such data transfer. These updates can include downloading chart updates, notices to mariners, software updates for systems used on board, not to mention e-mail. Studies[1] have shown that at least 200 bit/s is required for a typical ship (not including 'info-tainment') to cover all predicted e-navigation requirements. This formed the basis of the recommendation from IALA to ITU-R WP 5B on how many channels would be necessary to support an international data system on VHF - that is: six 25 kHz channels (or 150 kHz).

At the World Radio Conference 2012, six channels are made available internationally, with more available in some regions. The ITU has now laid the groundwork for the use of digitally modulated emissions in the maritime frequency bands at MF, HF and VHF - the challenge to the maritime community now is to use this resource effectively. Like Buzz Lightyear, we have a chance now to make the very best of what we have…

2.4 Maritime Radio Spectrum

What is radiofrequency spectrum, really? Well, radiofrequency spectrum can be defined as the portion the electromagnetic radiation emitted or absorbed by an object that is used for radiocommunication. In a way, spectrum is the highway (or the country road) over which 'stuff' flows – voice communications, analogue data, digital data. To make it easier, this spectrum has been divided up into frequency allocations (consisting of channels or ranges of radiofrequency or wavelength) for various services. In our case, this is the maritime mobile service. In the VHF maritime mobile band, the allocations are currently each 25 kHz wide. It is interesting to note that, on the land mobile side, this has been halved to 12.5 kHz in many cases, or even 6.25 kHz – providing for more communication 'channels', but within the same amount of total spectrum. While there is a plan[2] for using 12.5 kHz channel spacing for VHF maritime mobile service, this has not been yet identified as a requirement.

Now, just like Buzz Lightyear trying to be something other than a toy, we can't really change the spectrum – it is what it is - a finite resource, and will behave in the same way and give the same results each time you use it (within parameters – there are, of course, ways spectrum can appear be fooled – including so-called 'anomalous' behaviour such as 'ducting' in the troposphere (the region from the earth's surface to about 7-20 km altitude, where most weather effects occur). We have to make the existing spectrum work smarter – we have to learn to 'fall, with style'.

2.5 A digital approach to VHF – the VDES

The development of the VHF data exchange system could well lead to a revolution in maritime communications. Taking the best of our current understanding of digital VHF communications from both DSC and AIS, along with the developments of digital HF and digital data development for land users, we have an opportunity to make the existing VHF radio spectrum work smarter.

As we saw, AIS can transfer data on a 25 kHz channel with a data rate of 9.6 kbits/s. But we need a whole lot more data if we are to meet the requirements identified for e-navigation. We can do this by grouping channels together (25 kHz X 2 = 50 kHz; 25 kHz X 4 = 100 kHz; or 25 kHz X 6 = 150 kHz) and changing how the data is sent over the spectrum (the 'modulation' scheme – see Science content for more information).

In addition to the modulation, there is what is called the 'waveform' – how the input data is coded prior to transmission. There are different 'waveforms' that could be used, and there are studies underway at the moment to suggest the most applicable waveform for the VDES. With VDES we have the opportunity to work from the 'ground up', optimizing for the maritime environment with a system that is robust in operation and, potentially, suitable for secure communication.

In AIS, no forward error correction is used for the input data, however a frame check sequence (FCS) is used with cyclic redundancy check (CRC) remainder calculated after multiplying the data with a mathematical code (polynomial), and transmitted in each data 'packet'. The scheme is part of what is called a Layer-2 function[3], the error-free transfer of data, but if the data itself is already in error, then erroneous data is faithfully reproduced. Wider bandwidths envisaged for VDES will allow more complete forward error correction to be used.

So, why is VDES a good thing? The VDES is envisaged to be used in confined port areas with many physical obstructions such as buildings, etc, and at sea subject to multi-path propagation from the sea when communicating with shore, other vessels and the slant satellite path. The change in radio path characteristics can affect the phase of components of complex signals, and these need to be understood.

2.6 Software–Defined Radio (SDR)

There have been many developments with regards to Software-Defined Radio (SDR), implemented on reconfigurable processors, and maritime users are well-placed to take advantage of SDR. As an example, Australia has recently re-equipped its GMDSS DSC network with SDR transmitters and receivers. However we need to be careful of the term 'waveform', which we referred to above as the characteristics of the line or transmission codes to be used.

In SDR terms, however, the term 'waveform' [4] is also used to refer to an application that is supported by the SDR platform and configures the platform in accordance to a dedicated radio communication standard. Therefore, the waveform enables the platform to be part of the related radio communication system. Waveform developers are able to build multiple waveforms for their platform.

Some AIS manufacturers have already begun implementing SDR for their AIS equipment.

3. THE FUTURE IS NOW

The maritime community manages well with the tools available. If a shipowner wants, a ship can be fitted with multiple satellite antennas, obtaining the business advantages of the internet and give the crew complete 'info-tainment' services via the internet. Fast broadband to ships is currently available, but it doesn't necessarily come cheap and it may not always be stable. Is this enough?

As we have seen from the development of e-navigation, and from our own experiences with

Science content – Modulation schemes and data rate (current VDES proposal)

	AIS & AIS 2	VDE(S)	VDE(S)	VDE(S)
Channel bandwidth	25 kHz	25 kHz	50 kHz	100 kHz
ITU-R Recommendation	M.1371	M.1842 Annex 1	M.1842 Annex 3	M.1842 Annex 4
Modulation	GMSK/FM	∏/8 D8PSK	16 x 16-QAM	32 x 16-QAM
Data rate	9.6 kbit/s	43.2 kbit/s	153.6 kbit/s	307.2 kbit/s

GMSK/FM = Gaussian Minimum Shift Keying/Frequency Modulation
∏/8 D8PSK = pi/8 shifted, 8-ary Differential Phase Shift Keying
QAM = quadrature amplitude modulation

data and communications, there seems to always be a need to transfer more data, more quickly.

The transmission of digital data over analogue spectrum at MF, HF and VHF – is not only possible, it is an existing capability. The development of a system that transfers more data over a portion of VHF spectrum – the VDES – is well underway as providing an effective and efficient means to transfer more data at faster speeds. We won't be actually seeing the land context of 'broadband' data transfer, but we should be able to meet the developing requirements identified by e-navigation.

While working within the finite resource of the maritime mobile band – with a current focus on VHF spectrum – we can start learning to do what that fictional animated character Buzz Lightyear does – we can learn to 'fly with style' by taking what we have – spectrum and science – and make it work harder and smarter. ■

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61 PRODUCT SPECIFICATIONS DEMYSTIFIED

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For e-Navigation to take of the development of product specifications by the IALA Committees and Members is essential. In order to assist in the development of product specifications a guideline was developed. This paper gives a general introduction about the Registry, the development of product specifications and the guideline Producing an IALA S100 Product Specification 1106.

Para la e-Navegación es esencial que los Miembros y Comités de la IALA se encarguen del desarrollo de las especificaciones de producto. Con el fin de ayudar a este desarrollo se elaboró una directriz. Esta ponencia presenta de forma general el Registro, el desarrollo de las especificaciones de producto y la Directriz 1106 Elaboración de una Especificación de Producto S100 de la IALA.

Pour l'e-Navigation, prendre en compte les spécifications de produit développées par les Commissions et les membres de l'AISM est essentiel. Un guide a été mis au point pour aider au développement de spécifications de produits. Ce rapport donne une introduction générale au Registre, au développement des spécifications de produit et au Guide de l'AISM 1106 sur les spécifications de produits S100.

Product specifications demystified

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&

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

Product specifications demystified

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Introduction

e-Navigations is defined by IMO as *"The harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment."*

This definition means that information from systems onboard and ashore need to be able to seamlessly exchange information with each other systems. The complexity of this challenge is the fact that shore systems and infrastructure will vary from port to port, and onboard systems will vary from ship to ship. So to facilitate e-Navigation to the fullest, the exchange of information will need to be set-up in a way that it is system and platform independent. One of the principals that would enable the seamless exchange of information is the e-Navigation data model, the Common Maritime Data Structure (CMDS).

Figure 1 shows the overarching e-Navigation Architecture as seen from the user perspective including the operational and technical services. The ship side represents the users on-board a ship, whilst the shore side typically represents users from communities like Vessel Traffic Services (VTS), Allied Services and even users from communities within the logistics domain. To enable both sides to communicate and to exchange information, e-Navigation uses the general term "service".

The services that will be identified and defined in the years to come would consist of both operational- and technical services. From a user's perspective, the important services will be the operational services, the "what". From a technical point of view the technical services, the "how" is what is introduced in this document. The "how" part is the services that would need to be harmonised and standardized.

In order to exchange information it is necessary that it is defined what kind of data is transferred, how it is transmitted and in what form. The service provider needs to describe the details about the data and how to get it. In other words the provider needs to have a common way to model the data used by the technical service(s).

The International Hydrographic Organisation (IHO) have already created a framework (S-100) for developing data models, so the tool for defining future data services already exists to some extent. The S-100 term for a fully developed data model is called a *"Product Specification"*. A product specification is a description of all the features, attributes and relationships of a given application and their mapping to a data service. It is a complete description of all the elements required to define a particular data product.

Certain technical services could be viewed as an exchange of data described by data products. A technical service could consist of more than one single data product.

In order to exchange information in a harmonized way and make it easy accessible and usable, a common understanding about the product is essential. It is also important that the product specifications is available for all the service providers, and thus the specifications needs to be stored at a location which it is accessible for all stakeholders who want to utilize them. This is what a product specification register is used for.

A registry is simply a dictionary where definitions/specification are kept in organised locations known as

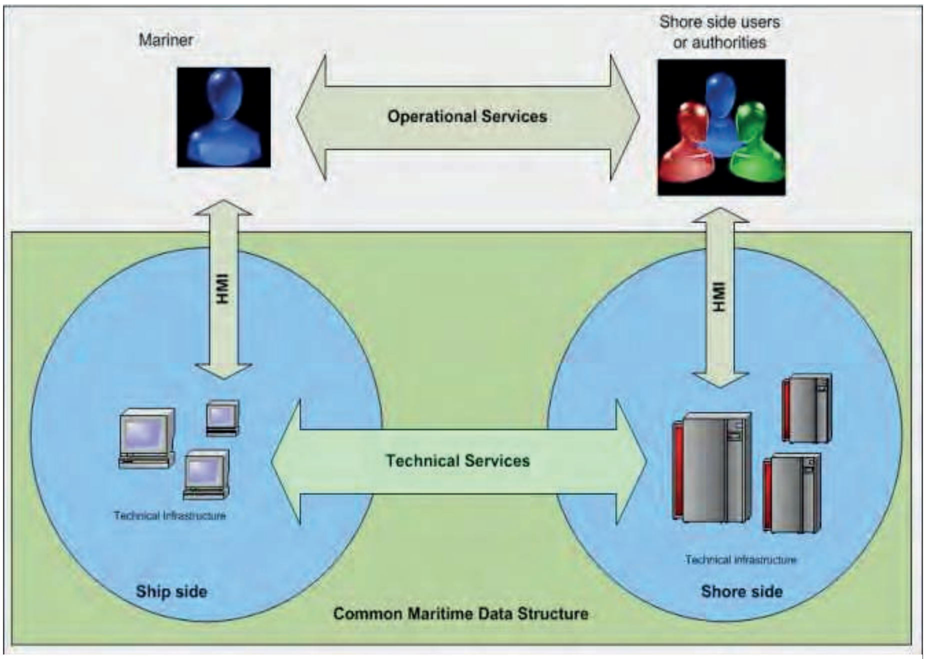

Figure 1: operational and technical services.

registers. The registry eases the task of developing new functionality, by providing a centralised source for storing and finding definitions/specifications.

Instead of developing a specific e-Navigation registry, IMO NAV at its 57th session agreed to make use of the offer from IHO to use the IHO GI Registry as a baseline for the collection, exchange, and distribution of data. Supporting a greater variety of information and therefore supporting increased harmonization and interoperability.

Various organisations will in the future be the owner of parts of the registry reflecting the organisation domain. IALA is in the process of establishing its own domain, and the next step for IALA committees and contributors is to populate the IALA Domain within the registry. Were the development of product specifications comes first and then the required items are registered into the registry.

For the moment, there is limited knowledge on the development of product specifications within IALA. Therefore a guideline was drafted to support the development of product specifications. This guideline Producing an IALA S100 Product Specification 1106 explains how to produce an IALA S-100 product specification, and the document is available to all committees and members.

In the next chapters of this document, the guideline and development of product specifications is briefly explained.

The guideline Producing an IALA S100 Product Specification 1106

The above mentioned guideline was developed to assist committees and members of IALA in the development of product specifications, and has the following objectives:

- provide a common understanding of what is needed to implement products in the registry;
- explain the process from user needs to product specification;
- give an understanding of what is needed to prepare a product specification;
- be a reference to those developing product specifications on what is to be delivered to IALA as a Domain Manager;
- explain the IALA and IHO Registry process in a step by step manner, supported by examples and formats.

The guideline consists of 3 major parts:

- General information
- Procedural part
- Technical details and a Product Specification Template

The development of a product specification requires various skills; therefore the guideline is intended for different audiences.

The *general part* of the guideline is written for the Service providers, both on shore- and ship side. The general objectives are to develop an understanding amongst the stakeholders of what is needed to be done in order to get e-Navigation going. It is important to establish an understanding of what is to be developed and the appropriate procedures involved in the process. The service provider will need this information for the development of a product specification, to consider the services that will be provided, and to get an idea of the amount of work and related costs etc.

In order to develop a product specification which is S-100 compliant it is essential that the developers understands what is to developed and provided. The *technical details* and *product specification template* part is therefore targeting the product specification developers, the software- engineers and developers.

Both need knowledge about the procedures for submission.

From User Need to Product Specification

The products in the e-Navigation context all start from the user needs. These user needs, which are high level and functionally specified, have to be transformed to product requirements in order to realize the needed functionality. The development of product requirements drives the data model, which in turn generates into a product specification and the items to be registered in the registry. This would be the task of the product specification developer. In ***figure 2*** an impression of the route from user need to product specification is shown.

In order to develop a product specification it has to be clear what the product should be. For the provision of e-Navigation the product could be a part of a Maritime Service Portfolio (MSP). The authority responsible for the relevant service creates a description of the desired product based upon the applicable user needs. Then it is up to the product specification developer to check the registry and dictionaries if the needed features already exist. In cases where the feature does not exist, a new feature has to be added to the Feature Concept Dictionary (FCD).

Next a data-model has to be produced, either by means of a conceptual schema language or by means of an encoding specific language. Finally the previous and other information is captured in a product specification. The product specification will then be registered, after an approval process, in the product specification register of the GI Registry.

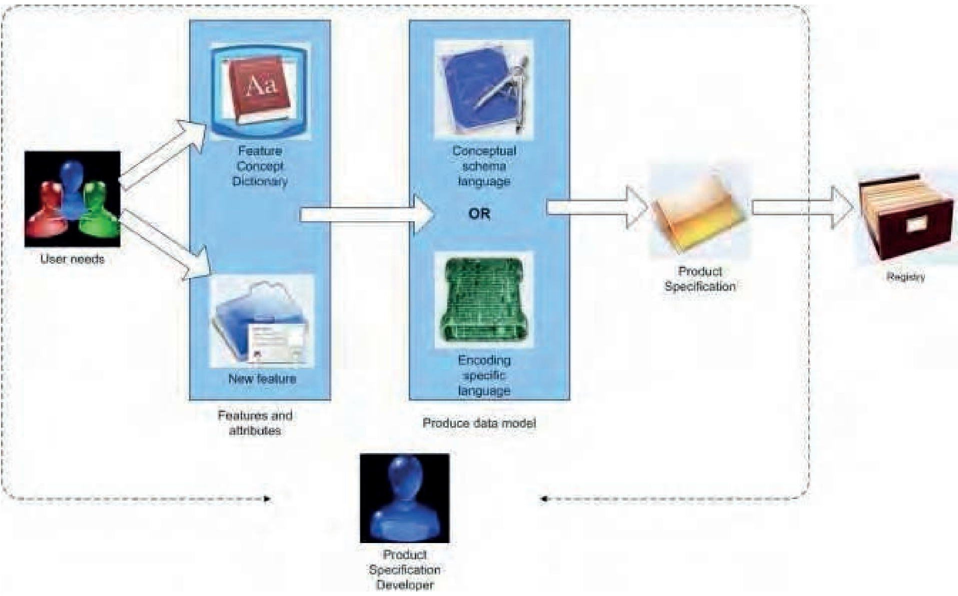

Figure 2: Transformation of a User Need into a Product Specification

For the development of a product specification a certain level of expertise is necessary. This level of expertise is not only necessary on the developer side, also the service provider needs to have some understanding of the process. The right mixture of expertise consists of S-100 experts and understanding of the product requirements and context of the product within the e-Navigation scope.

Developing a product specification

As mentioned a product specification allows for the harmonization and standardization of a data product according to the S-100 framework, and further to be implemented within the context of Maritime Service Portfolio (MSP) and e-Navigation. The MSP for a given region consist of a collection of standardized Operational Services, which are supported by Technical Services. The technical services make use of 'data products' to exchange data. Examples of such IALA related data products are AtoN, IVEF or AIS Application Specific messages. Product specifications may be created and used on different occasions, by different parties and for different reasons.

A product specification can be summarized as a precise technical description, defining a data product within the S-100 framework and standards. It describes the features, attributes and relationships of a given application and their mapping to a means of data exchange, such as exchange sets (AtoN) and dynamic data streams (IVEF).

For this purpose the product specification includes general information for data identification as well as information for data content and structure, reference system, data quality aspects, data capture, maintenance, delivery and metadata.

The applied methodology for product specifications is derived from the IHO profile of the International Organization for Standardization (ISO) standard 19131, and ensures a clear and consistent structure for data product specifications being consistent with the other standards that have been developed as part of the IHO S-100 framework.

For the creation of a data product specification, the 'IALA Product Specification Template' must be used. This template is a part of the guideline XX and will assist IALA members in the development of product specifications

Product specification template

The Product specification template defines a standardized method to define and describe the product specifications. In the guideline, the main components as applicable in the template are described. The template contains all the relevant information that is necessary when developing a product specification.

Conclusion

With the decision to use the IHO GI Registry as a baseline for defining the collection, exchange, and distribution of data, the foundation for the realization of e-Navigation was laid. It is now up to the IALA committees and members to use the guideline and template to start developing product specifications and take e-Navigation to next level.

120 NAVIGATION AIDS INFORMATION DISTRIBUTION SYSTEM IN THE E-NAV

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Aids to Navigation (AtoN) is an important component in navigation-aids information and plays a significant role in ensuring safe sailing. The definition of e-Navigation attaches importance to ensuring navigation safety and marine environment protection. In order to publicize real-time navigation-aids information comprehensively and accurately, navigation-aids information system is designed and developed by computer network technology, modern communication technology and key technologies such as GPS, AIS, ECDIS and Web. The system implements comprehensive display function of 360° channel panorama based on Image-Based Modeling and Rendering (IBMR) AtoN, channel display information based on Remote Sensing (RS) image, and physical and virtual AtoN information based on Automatic Identification System (AIS), etc.. This thesis aims to elaborate the combined system which realizes the collection, integration, exchange and release of various kinds of navigation-aids information in the sea.

Key words: aids to navigation; navigation-aids information; real-time distribution; function realization

Las Ayudas a la Navegación (AtoN) son un componente importante en la información de ayudas a la navegación y desarrollan un papel significativo garantizando una navegación segura. La definición de e-Navegación otorga importancia a garantizar la navegación segura y la protección del medio ambiente marino. Con el fin de difundir la información de ayudas a la navegación en tiempo real de modo comprensible y preciso, se ha diseñado y desarrollado el sistema de información de ayudas a la navegación mediante tecnología de redes informáticas, tecnología de comunicación moderna y tecnologías clave como GPS, AIS, ECDIS y Web. El sistema implementa una función de pantalla global con una vista de los canales de 360° basada en AtoN con Renderizado y Modelado Basado en Imágenes (IBMR) AtoN, información de los canales en pantalla basándose en imagen de teledetección (RS) e información de AtoN virtuales y físicas basada en el Sistema de Identificación Automática (AIS), etc. Esta tesis pretende elaborar un sistema combinado que realice la recopilación, integración, intercambio y publicación de los diferentes tipos de información de ayudas a la navegación en el mar.

Palabras clave: ayudas a la navegación; información de ayudas a la navegación; distribución en tiempo real; realización de función

Les aides à la navigation donnent des informations importantes pour la navigation et jouent un grand rôle pour la sécurité de la navigation. Par définition, l'e-Navigation considère important d'assurer la sécurité de la navigation et la protection de l'environnement. Pour fournir des informations détaillées et précises en temps réel, un système a été conçu par la technologie des réseaux informatiques, des communications modernes et autres technologies clés telles que le GPS, l'AIS, l'ECDIS et internet. Le système applique une fonction d'affichage à 360°du chenal basée sur une image captée à distance (RS), des informations d'aides à la navigation physiques et virtuelles à partir de l'AIS, etc... Ce travail consiste à élaborer un système qui réalise la collecte, l'intégration, l'échange et la diffusion de différentes sortes d'informations sur les aides à la navigation en mer.

Navigation-aids Information Distribution System in the e-NAV

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INTRODUCTION

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) held the 16th Conference in Shanghai on May 2006 with the theme of "aids to navigation in digital world", which first officially put forward the concept of e-Navigation[1]. IALA is actively promoting strategic development of e-Navigation. Based on the influence of International Maritime Organization(IMO) and IALA, countries are actively planning and prompting the development of aids to navigation service system on the basis of e-Navigation architecture.

Shipping industry has an important role in foreign trade and economic development in China. As one of categorty (a) council members of IMO and council member of IALA, China has been attached great importance to the development of e-Navigation system, and hopes to develop its e-Navigation system and to combine it into the e-Navigation development in the world. So far, China's coastal port waters, inland ports and waters have almost been covered by various kinds of AtoN and navigation-supporting system, such as VTS, AIS etc.. Based on the construction of AtoN and navigation auxiliary facilities, maritime units, colleges and scientific research departments developed a series of navigation-aids service system such as local information exchange system, information publishing platform and so on. The Navigation-aids Information Distribution System arises in this environment.

1 SYSTEM DEVELOPMENT BACKGROUND

IALA puts forward new electronic navigation service system that combines the function of remote monitoring of AtoN, information processing, information broadcast, reception and display, to realize the informatization and networking of navigation-aids service. The main ideal is, with the help of Automatic Identification System (AIS) base station and internet resources, to integrate various maritime safety information system and establish new AtoN Navigation-aids information service system with the characteristic of integration and broadly sharing, thus to enhance navigation safety[2]. IMO subcommittee on safety of Navigation(Nav55) points out that the user of the ship preliminary requirements mainly includes more powerful standardized interface[3], more effective display of NAVTEX and MSI, alarm management, improved reliability and better reliability demonstration, report facilities of more standardization and automation, improved target detection, more effective warning scope, management pressure reduction, important information update of higher degree of automation ,etc. IALA also puts forward the specific research contents of e-Navigation in the electronic aids to navigation service system to provide more realistic guidance and reference for our research in electronic navigation-aids services.

Countries actively seeks, researches and develops the specific project of electronic navigation-aids service system with the aim to providing safer, more reliable and effective aids to navigation service for mariners and aids to navigation users. In recent years, the construction of navigation-aids information service system in China bases on the demand of ship users. However, with the increase of navigation-aids informatization, the problems of information sharing and acquisition of marine navigation information are gradually emerging among waters. So far, a mature and stable navigation-aids information service system has not been built in China [4]. The international status and economic impact of China and the impact of economy of China have very large improvement. China's foreign trade is completed by shipping with value of 80% and weight more than 90% which greatly increase the density of maritime navigation. In order to improve the navigation safety of ships and efficiently ensure the safety of maritime traffic, real-time and reliability of navigation-supporting information by its users is put forward new requirements. China is a maritime power with nearly 300 square kilometers area and 32000 km long coastline, and the urgency of the construction of the integrated navigation-aids business platform is more and more obvious.

To this end, Xiamen Aids to Navigation department of Shanghai Maritime Safety Administration and Ship Navigation-aids Technique Research Institute of Jimei University, through follow-up study for the international advanced navigation service system related and Combine with the actual needs of China's navigation-aids business, developed the navigation-aids information distribution system. The system collects and processes various navigation information, pwhich is sent to users by the Internet and AIS to provide real-time and security AtoN navigation-aids information and service to Marine and offshore related users.

2 THE OVERALL DESIGN OF THE SYSTEM

2.1 The Route of design system

This design of the system guided by demand, make top-level design as guidance, design as base, Research and development as centre, maritime traffic safety with high efficiency and security as objective. The specific design of system is shown as follow ***Figure 1***.

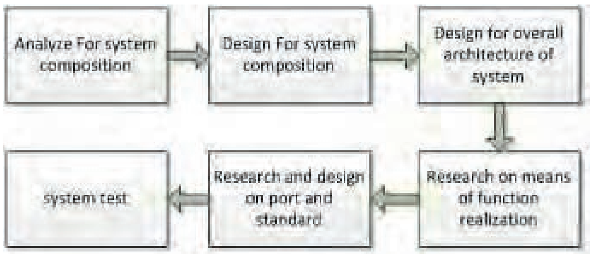

Figure 1: Routine of design

2.2 The overall architecture design

"Aids-Navi Info Publishing system" refering to the e-Navigation system framework proposed by IMO and taking users as center, releases the latest real-time shipping port information of navigation environment, supervision and hydrological tide and related the ship navigation safety to the domestic and foreign. The system uses the Microsoft Visual Studio.NET development tools, Oracle database, Web GIS network, IBMR panorama publishing platform, ship handling simulator of ship tracks and AIS remote access platform to make conventional bandwidth users can land the site quickly, and get rich, accurate port navigation information [6].

2.3 System composition

The system mainly includes: the telemetry buoy remote control subsystem, Web ECDIS navigation information publishing platform and AIS navigational information issue subsystem. The specific component is shown in ***figure 3***. In the **system**, the telemetry buoy remote control system include navigation mark controlling system with GSM/GPRS and navigation mark monitoring system based on AIS. Web-ECDIS navigational information releasing platform is a platform that shows information of AIS shipping and navigation marks and other navigation information on network electronic chart. AIS navigation-supporting information releasing subsystem broadcast AIS aids to navigation information and navigation information through AIS base station [7].

3. THE KEY TECHNOLOGY OF THE SYSTEM

According to the standard format for data transmission among VTS systems issued by the IALA [8], navigation-supporting information releasing system real-timely release the AIDS to

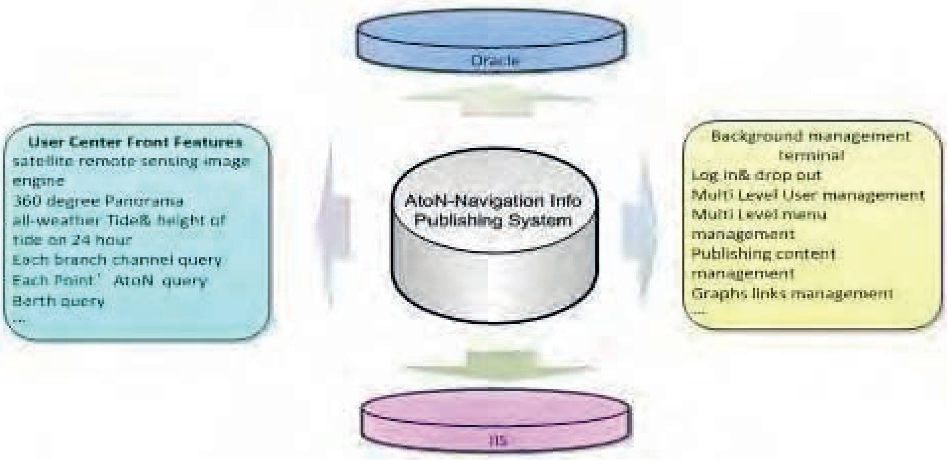

Figure 2: System architecture

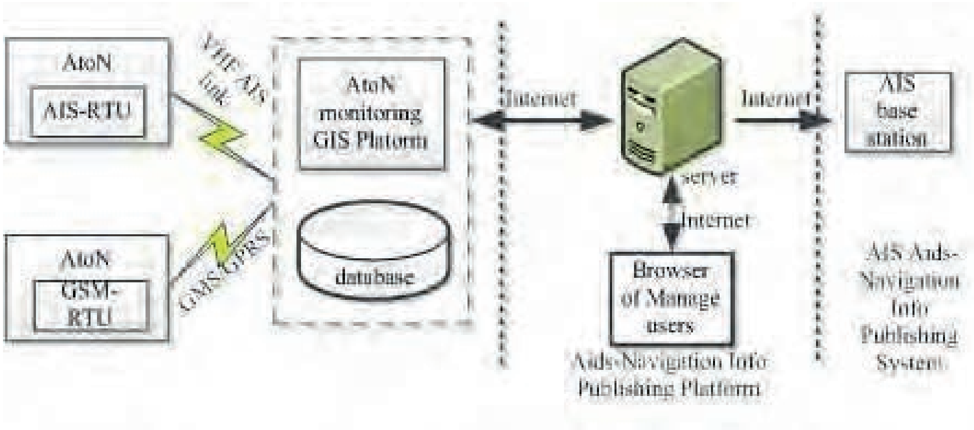

Figure 3: System composition

navigation dynamic/static information, navigation/warning, VTS, information of navigation elements, information of hydrological and meteorological, AIS, GNSS and other navigational information. The system gathers navigation-supporting information, processes the information, integrates and classifies the information, then publish the relevant information. Key technology of the system as follows:

3.1 Information collection technology

3.1.1 Remote control technology

The remote control technology main realize collecting related information of navigation mark. Accomplishment of telemetry and telecontrol technology requires the navigation mark remote monitoring RTU terminal, technology of wireless sensor Ad hoc in remote control system, navigation mark remote monitoring technology based on integrated communications of BeiDou2 /3G/GSM [9], video inspection technology of navigation mark. Design integration LED lantern, according to the working environment and function of navigation mark, solving high failure rate of connection structure, easy to water, battery wire easily damaged, short range problems existing in the traditional navigation mark lamp.

3.1.2 Navigation mark telemetering and remote control Intelligent Disposal technology

This technology bases on S-57 international standard electronic chart and satellite remote

Figure 4: Terminal of RTU

Figure 5: The integrative Aids to navigation with AIS

sensing image. It treats international standard electronic chart and satellite remote sensing image processed as base map. Display remote telemetry navigation mark data through combining with GPS positioning technology and computer technology, remote control technology.

3.1.3 Mobile navigation inspection technology based on IPAD/IPHONE platform

The overall architecture of mobile navigation patrol system as shown in ***Figure*** *7*. Make exchange with background data service platform through IPAD/IPHONE. Specific functions include: navigation information query, navigation positioning, ship inspection, inspection record query, query information input, photographing in inspection live, inspection data reporting with business database synchronization. Research and development of this system makes beacon inspection getting rid of the traditional inspection methods of manual and paper documents, achieving paperless operation and effective sharing and transferring of relative inspection data of navigation marks.

3.2 Releasing navigation–supporting information technology

Using variety of navigation-supporting information technology to achieve more ways to send navigation-supporting information, users can use corresponding ways of releasing information, according to their own needs.

3.2.1 Navigation–supporting information service technology based on AIS

sensing image. It treats international standard electronic chart and satellite remote sensing image

processed as base map. Display remote telemetry navigation mark data through combining with GPS positioning technology and computer technology, remote control technology.

In view of practical requirements of AIS, this project research and develop AIS base station front-end communication machine, integrative server, AIS information display terminal in Chinese and RTU of AIS navigation mark and so on, achieving the broadcasting, receiving and displaying for the AIS navigation-supporting information, and monitoring to navigation mark technology based on AIS, and so on. AIS front-end communication machine receiving, parsing the output data from AIS base station, and sending it to the consolidated server database, its means of communication is TCP/IP. At the same time, package message coming from server, then send it to AIS base station to transmit. Communication mode is a serial port or TCP/IP, Protocol adopt maritime navigation and radio communication equipment with system digital interface standard (IEC61162) developed by the IEC (International Electrotechnical Commission).

AIS server provide communication and data transmission services between database and AIS front-end communication machine or the WebGIS platform. AIS database realize the management of AIS data storage. System broadcasts navigation-supporting information by AIS message 6, 8, 12,

Figure 6: Systems interface based on S-57 ECDIS and Satellite remote sensing

14, 21 (including simulation beacons, virtual beacons).

3.2.2 Beacon navigation information technology Based on IBMR panorama (virtual 3D)

IBMR panorama (virtual three-dimensional) display technology can have the unfamiliar or who had never been to a harbor ship handling more intuitively understand this area. The core parts of the display technology is achieved by a mixed double programming, through the Flash writing ActionScript and through the WEB page writing JavaScript.The JavaScript of WEB page can be invoked to jscall (SRC, deg) functions defined in ActionScript of Flash and pass the external parameters derived from the database to it, that is, through external parameters, such as, some spots in the src field is stored in the database location and azimuth angle deg is to manipulate Flash, ordering it to load the whole scenic spot image data.

3.2.3 Route video services technology–based navigation aid information release technology

Stacking beacons, waterways and other object information in the sea panorama, supplemented with electronic charts for comparison, to determine the location and form three-dimensional images navigation. This technique mainly has three main steps: image preprocessing, image registration, image fusion and boundary smoothing. Route panoramic images from photography to capture the real scene, so panoramic photography is essential. We use professional cameras shooting 720 degree view of a group of photos obtained by the seamless processing into a panoramic image stitching, and then uses Flash technology made into a mouse can be used freely up and down, left and right, front and rear drag the viewing of media formats.

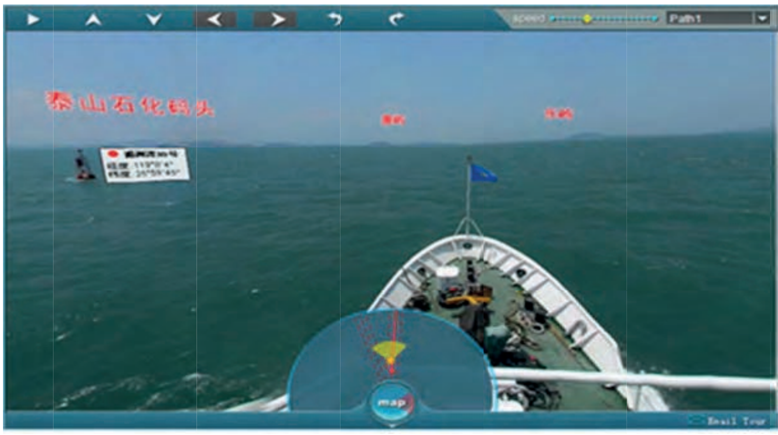

Figure 8: Panorama of route

3.2.4 Broadcast and display of AIS binary messages

Aids information releasing platform takes the practical research on binary messages dedicated according to IMO "AIS binary messages application guide" (SN.1/Circ.289) [11]. This system accomplishes that broadcast beacon packets navigational information binary message through the AIS binary messages.

4 SYSTEM APPLICATIONS

4.1 Main functions

Navigation-aids Information Distribution System can achieve functions such as collection,

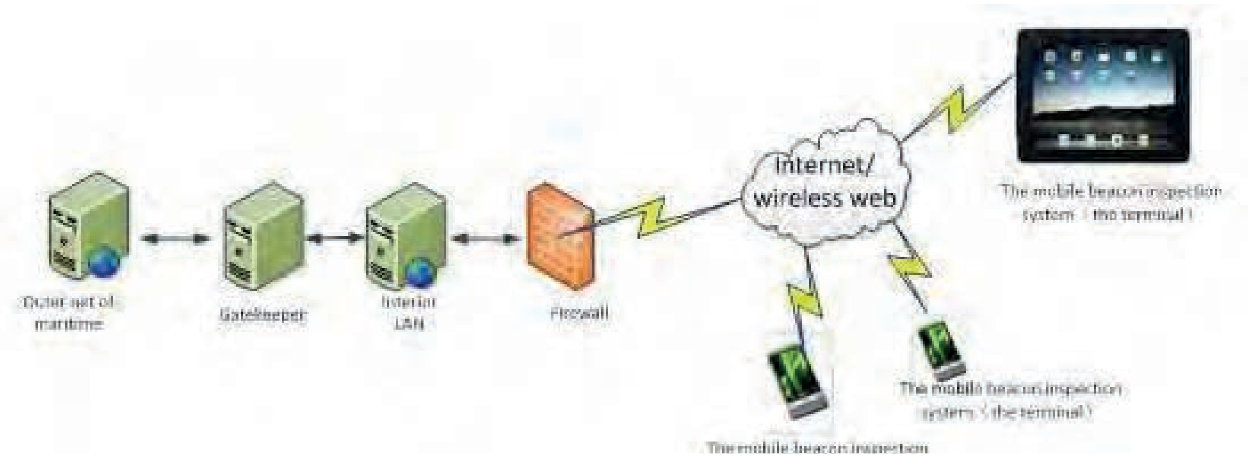

Figure 7 : Network architecture of mobile Beacon inspection technology

management and release of the beacon data about aids to navigation. The data include real-time and dynamic information both about physical and virtual aids to navigation, real-time online AIS information based on map engine, information about anchorages, waterways, berth , place names, soundings , 360 degree views and positioning display and query service about many other elements. There are also some function services such as administrative affairs, maritime bulletin, laws and regulations, maritime services, hydro meteorological, aids to navigation, navigation and berthing method, AIS data analysis , user feedback. The system implements the main channel for external services in both English and Chinese which is shown in ***Figure 9***. Enter the platform, you can see all services. As is shown in ***Figure 10***, functions of the platform are mainly about three parts, layer control, desktop tools and menu display.

Layer control often uses electronic chart as the base map which can be overlayed by striograph, berths, fairway, anchorages, place names, soundings, names of aids to navigation, full views, night layers, all of which are public and you can see them once the INTERNET is collected. After entering from the upper left corner of the login screen, you can also check RTU, AIS, the name of the vessel and other information. Open the platform With IE browser, after entering the electronic chart service interface, select the menu "Layer Control" in the right of display area, you can enter the selection window.

Users can selectively display additional layer information on electronic chart only by selecting the column on the left of the attribute information column. If there is no need, just click the attribute information column again.

Tools mainly include restoring, aids to navigation query, ships query, Hawkeye, ranging and EBL, navigation. Restoring means restore the interface to original state. Hawkeye map enables fast positioning. Navigation often indicates the direction by using that up is north, down is south, left is east and right is west. Aids to navigation query and ships query are designed to query aids to navigation and ships quickly. Information of the system is mainly queried through menu selection. By menu selection, you can query information about aids to navigation, ship navigation panorama, regulations and standards, maritime bulletin, transport services, hydrometeorology, fairway, anchorage, ports, methods of navigation, berthing and unberthing methods, AIS data analysis, requirements and approval on aids to navigation, feedback of users, etc.

Figure 9: Enter interface of Aids-Navigation Info Publishing Platform

Figure 10: Display interface of Aids-Navigation Info Publishing Platform

4.2 Examples of functional applications

4.2.1 Monitoring on aids to navigation

RTU remote monitoring terminal can monitor working voltage, current, light quality, brightness of LED lamp and other working information about beacon light. With the use of wireless sensor networking technology working information about beacon light, tides, speed and direction of flow, hydrological, meteorological and other aids to navigation information can be acquired. Through the GSM/GPRS and other wireless communication systems the information is transmitted to shore-based central server and then is sent to underlying database about aids to navigation. The RTU system reads the database or the former central server to obtain information about aids to navigation and to display real-time conditions about abnormal beacon. Meanwhile, Aids to navigation management department deals with exceptions as soon as possible, and release the information which may affect the safety of navigation through the AIS and INTERNET which is shown in ***Figure 11***.

In order to monitor beacons better, the system can achieve the functions that right click can gives us a view of beacon basic and dynamic information and other relevant information, and in the lower right corner the dynamic reminder function of beacon management and monitoring department can be achieved which is shown in ***Figure 12***.

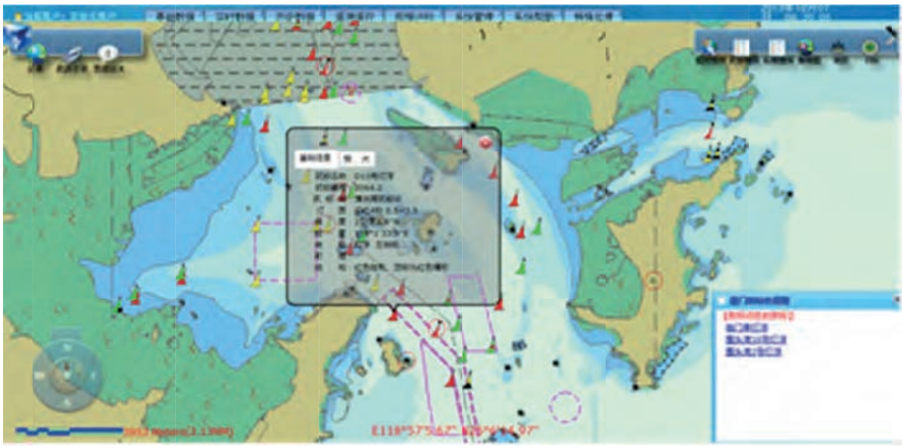

Figure 12: Aids to navigation remote monitoring

4.2.2 Applications of ship's AIS sailing trajectory distribution

Through the system, number of ships through a port and their tracks can be achieved through statistical analysis on AIS information and combined with pilot's experience, guide for entering and leaving the port can be created and released through the releasing system. Users can click navigation and berthing method on navigational information publishing platform to appears navigation and berthing method interface. As is shown in ***Figure 13***, users

Figure 11: Real-time abnormal state of Aids to Navigation

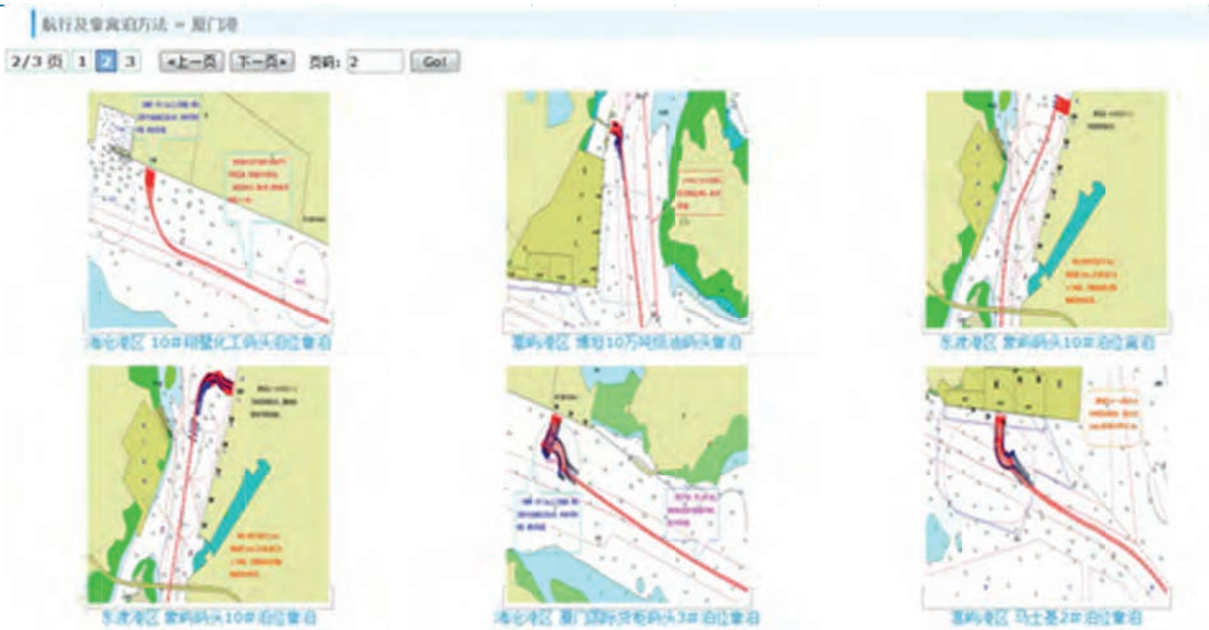

Figure 13: AIS track berth alongside in Xiamen area

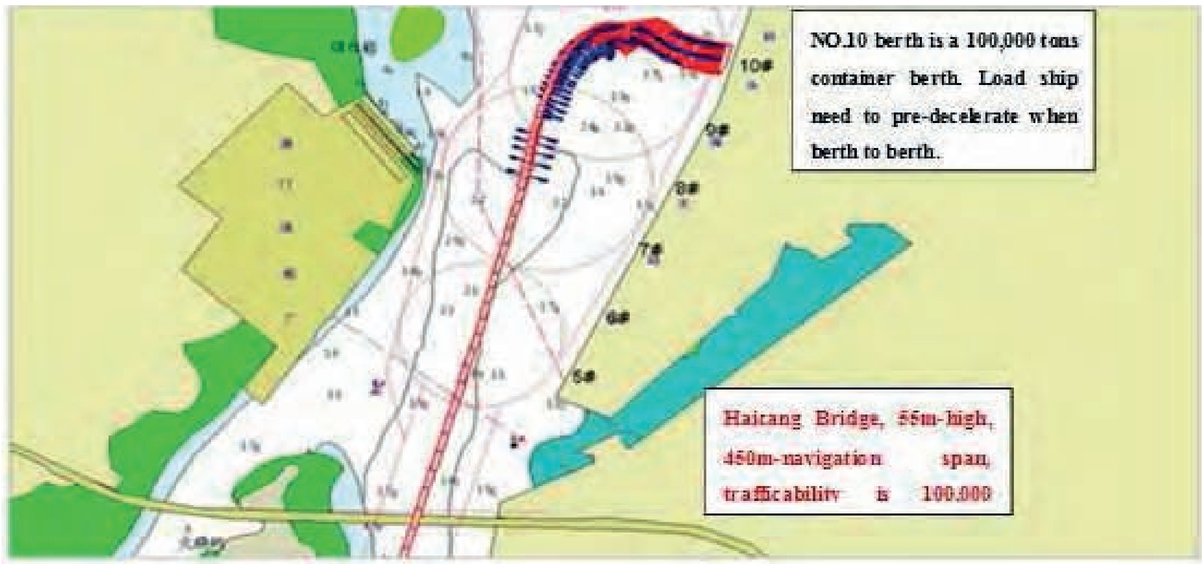

Figure 14: Xiangyu wharf NO.10 berth in Dongdu port area

can choose the information in need according to their actual situation.

Take dock port 10 # on Xiangyu port in Dongdu area for example. Click the relevant image in ***Figure 14*** labeled "East Minato Pier 10 berth berthing Xiangyu" you can enter the interface as ***Figure 14***. It shows us AIS track information, reference docking path which is provided by docked ship, berth information, and route information during berthing.

4.2.3 Beacon panorama display applications

Take buoy No. 31 in Xiamen Port for example. When the ship is traveling to Xiamen port near buoy No. 31, search this beacon on the platform and click its panorama, you can display 360-degree environmental conditions near buoy No. 31 by the four keys up and down , left and right. Right chart shows ship's position on electronic chart. On the chart you can see the specific navigation environment information. In the bottom of the chart there are the buildings near buoy 31. As is shown in the figure, it is the Songyu container berths in front of about 270 °, 0.5 nautical miles, north of it is Xiamen Port Zhaoyin area. Users who are not familiar with the waters can see that through the display specifically, comprehensively and intuitively. 360 degree panorama allows users to directly learn the information of the navigable waters and avoid maritime traffic accidents because of unfamiliar port.

CONCLUSION

Navigation-aids Information Distribution System, as an important marine practice for e-Navigation, plays an important role for safety of maritime transport, and is an important way to be used for computerized and scientific management of aids to navigation. The display interface of the system is various, explicit, and easily expanding (such as a virtual beacon can be easily added), and information query and maintenance is easy and quick. Since the system is put into use, it has won much recognition and applause for their remarkable economic and social benefits. In early 2013, this platform has been extended to the East Sea and the North Sea in China and will be introduced, as expected, to South Sea by the end of 2013. Then the platform will be popular in the whole China. Platform popularization has got some achievements in hardware facilities, software systems, network infrastructure, basic database, management system, laws and regulations, etc., which have laid a solid foundation for building navigation information service platform in China, such as the ongoing NAVICLOUD engineering.

NAVICLOUD is a practice for e-Navigation proposed by Xiamen Aids to Navigation department of Shanghai Maritime Safety Administration and Ship Navigation-aids Technique Research Institute of Jimei University based on existing information technology about aids to navigation. It represents advanced service concept and latest achievements of navigation-aids support in China. With the cooperation of Denmark, Finland Maritime Safety Administration, NAVICLOUD is connected with E-navigation. After the project is completed, it will be of great significance in water transport, ocean development, fishing, charts mapping and national defense construction. In order to deepen the links between China and the world, China will establish "Aids to navigation Information Network" which release the process of marine information infrastructure and dynamic information of aids to navigation. Users can directly access the site for information.

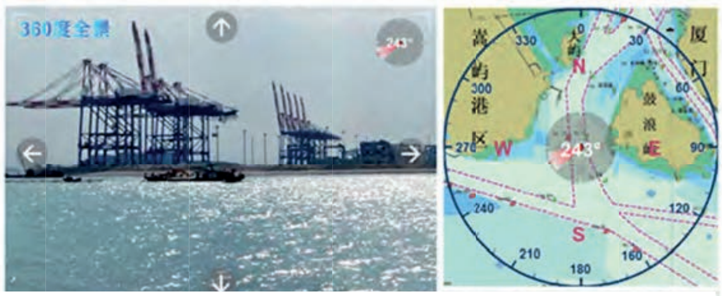

Figure 8: Panorama Point near the NO. 31 Beacon of Xiamen port

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76 DEVELOPMENT OF S-100 BASED NEW PRODUCT SPECIFICATION FOR ATON AND METHOD FOR INTEGRATION WITH LEGACY SYSTEMS

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Currently in the maritime field, there is a great deal of interest in e-navigation as a basis for the integration and utilization of various maritime and maritime-related data. Implementations in the e-navigation environment seem to be centering around the International Hydrographic Organization (IHO)'s S-100, which is being utilized as a base data model and means of data utilization. The Aid to Navigation (AtoN) field also is showing growing interest in S-100-based data and services. Indeed, in light of the current directions of e-navigation, development of S-100-based product specifications for description and distribution of data has become a necessity. On top of the S-100-based product specifications developed, the facilitation of S-100-based data integration and utilization promises fully interoperable S-100-based information services. However, replacing existing legacy systems with S-100 compatible ones is prohibitively cost- and time-expensive. In the present study, we developed an S-100-based new product specification for AtoN data, on which basis, we were able to devise a way to integrate new S-100-based services and legacy systems without modifying them.

Actualmente hay un gran interés en el ámbito marítimo por la e-Navegación como base para la integración y utilización de diferentes datos marítimos y relacionados con lo marítimo. Parece que las implementaciones en el entorno de la e-Navegación se centran en torno a la S-100 de la Organización Hidrográfica Internacional (IHO), que se está utilizando como modelo de datos base y medio de utilización de datos. El ámbito de Ayudas a la Navegación (AtoN) también está mostrando un creciente interés en los servicios y datos basados en S-100. De hecho, a la luz de las direcciones actuales de la e-Navegación, el desarrollo de especificaciones de producto basadas en S-100 para la descripción y distribución de datos se ha convertido en una necesidad. En la parte superior de las especificaciones de producto desarrolladas basadas en S-100, la facilitación de la integración y utilización de datos basados en S-100 promete servicios de información basados en S-100 totalmente interoperables. Sin embargo, sustituir sistemas heredados existentes por sistemas compatibles con S-100 es prohibitivo en términos de coste y tiempo. En el estudio actual, desarrollamos una nueva especificación de producto basada en S-100 para datos AtoN, sobre cuya base fuimos capaces de diseñar una forma de integrar nuevos sistemas heredados y servicios basados en S-100 sin modificarlos.

Actuellement, dans le domaine maritime, on accorde beaucoup d'intérêt à l'e-Navigation comme base d'intégration et d'utilisation de données maritimes ou en relation avec le maritime. Les installations dans l'environnement e-Navigation semblent centrées sur la S-100 de l'Organisation Hydrographique Internationale (OHI) qui est utilisée comme modèle de base de données et moyen d'utilisation des données. Le domaine des aides à la navigation s'intéresse aussi de plus en plus aux données et services basés sur la S-100. En effet, dans les conditions actuelles de l'e-Navigation, un développement de spécifications basées sur la S-100 pour la description et la distribution des données est devenue nécessaire. Outre les spécifications développées suivant S-100, la facilité d'intégration et d'utilisation des données promettent des services d'information totalement compatibles. Cependant, remplacer les systèmes existants conventionnels par d'autres compatibles avec S-100 est d'un coût prohibitif et prend du temps. Dans cette étude, nous avons développé des spécifications du nouveau produit basées sur S-100 pour les données d'aide à la navigation. Sur cette base nous avons pu trouver un moyen d'intégrer les nouveaux services basés sur S-100 et les systèmes conventionnels sans les modifier.

Development of S-100 based new product specification for AtoN and method for integration with legacy systems

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1. Introduction

In e-navigation, various marine and marine-related data may be used to provide for harmonized information services. For harmonization and effective utilization in e-navigation information services, data resources should be represented in the Common Maritime Data Structure (CMDS) format. The International Maritime Organization (IMO) has been trying to develop a common data model for shipboard-to-offshore sharing of marine data [4–7].

Recently, the International Hydrographic Organization (IHO)'s S-100, an information service framework for harmonization and utilization of various hydrographic data, was adopted as the baseline of e-navigation's CMDS [7]. IHO S-100, a new standard universal hydrographic data model, includes several data models and procedures by which geographic information can be described and dealt with in the hydrographic domain. S-100 is compliant with the International Standardization Organization (ISO)'s 19100 geographic information standards [1–2].

After adopting S-100, many organizations naturally become interested in understanding how S-100-based product specifications can be developed for data in their own domains [3, 12]. In the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) domain for example, draft versions of product specifications for Aids to Navigation (AtoN), Inter-VTS Exchange Format (IVEF), and Automatic Identification System (AIS) were introduced at a recent IALA e-Nav committee technical meeting. There have also been meetings concerning the development of S-100-based product specifications [8–9].

Meanwhile, in the e-navigation environment, legacy systems can be data providers. However, modifying legacy systems to S-100-based systems difficult; instead, it is necessary to integrate them with data-providing e-navigation information services. In this paper, we present a new S-100-based product specification for support integration of AtoN data with legacy systems. Additionally, we suggest a way to render legacy systems interoperable with S-100-based services by focusing on the results of a study on successfully achieved interoperability between an existing Korea AtoN-integrated management system and the new S-100-based services, based on conversion of the legacy data format to an S-100-compatible form.

The structure of this paper is as follows. In section 2, we present IHO S-100 and legacy systems for AtoN management. In section 3, S-100-based product specification for AtoN data is presented and in section 4, a method of legacy-system integration is introduced. Finally, in section 5, we draw conclusions and anticipate future work.

2. Related Work

2.1 IHO S–100 and S–10x Product Specification

S-100 is the new IHO standard on universal hydrographic data that is set to replace the S-57 transfer standard for digital hydrographic data [1]. As it is based on the ISO 19100 series standards, which are international standards on geographic information, S-100 supports interoperability between systems dealing with marine and marine-related geographic information. In order to support sharing and use of data in the IHO domain, for instance Electronic Navigation Chart (ENC) data and bathymetry data, the IHO currently is developing S-100-based product specifications [2].

Recently, the IMO adopted S-100 as the CMDS baseline for e-navigation. Many organizations including the IALA, are keenly interested in S-100 and are developing S-100-based data product specifications for their own domains. In a recent IALA e-Nav committee technical meeting, for example, drafts of S-100-based product specifications for AtoN, IVEF, AIS data were introduced. Each product specification, moreover, proposed an S-100-compliant application schema.

Certainly, S-100 helps interested communities develop their own maritime geospatial products and services, specifically by providing the theoretical concept models and procedures that are the very basis of S-100-based product specifications. The most fundamental element of any S-100-based product specification is an application schema. An application schema is based on a General Feature Model (GFM), which is a conceptual model of the types of features to be used in S-100 products. On the basis of the GFM, the data content of a geographic application, structured in terms of objects, is defined.

2.2 Korea's regional AtoN integrated management System

Aids to Navigation (AtoNs) are tools to assist the safe navigation of vessels. As such, AtoNs need to be continuously monitored and managed. In Korea, AtoNs, installed both at sea and on land,

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are monitored and managed by regional maritime affairs and port administration offices. To those ends, AtoN-integrated management systems are used. As most AtoNs are equipped with communication devices such as AtoN AIS, information on the status of AtoNs can be gathered in regional AtoN-integrated management systems. A status information record includes the following data elements: AtoN identification, AtoN name, AtoN type, observation time, main power voltage, AIS current, and AtoN location (longitude and latitude).

3.1 Classification of AtoN Data

AtoN data, as handled by the AtoN-integrated management system in Korea, is classified into three types. The first is data that describe the characteristics of AtoNs or AtoN-related objects. This information consists of attributes representing the appearance (e.g. color, shape, height), situation (geographic location or topology), and unique specifications (i.e. purpose) of a target object. The second is management data, which include such attributes as 'AtoN identifier', 'AtoN Name', 'administration authority', and 'installation date'.

MMSI	BUOYTYPE	OBSERVTIME	LATITUDE	LONGITUDE	MAINPOWER VOLTAGE	BATTERY VOLTAGE	AIS CURRENT	LANTERN CURRENT	CHARGE CURRENT	DISCHARGE CURRENT
994401540	Buoy (lit)	18:00.0	34° 45' 37.08"	127° 49' 06.06"	12.5	12.8	0.49	0.07	0	0.28
994401540	Buoy (lit)	28:00.0	34° 45' 37.14"	127° 49' 06.24"	12.6	12.8	0.48	0.07	0	0.14
994401540	Buoy (lit)	38:00.0	34° 45' 37.08"	127° 49' 06.12"	12.7	12.9	0.48	0.07	0.13	0
994401540	Buoy (lit)	58:00.0	34° 45' 37.14"	127° 49' 06.12"	13.1	13.3	0.47	0.07	1.07	0
994401540	Buoy (lit)	08:00.0	34° 45' 37.2"	127° 49' 06.12"	13.3	13.5	0.46	0.07	1.38	0
994401540	Buoy (lit)	18:00.0	34° 45' 37.2"	127° 49' 06.18"	13.4	13.6	0.46	0.07	1.3	0
994401540	Buoy (lit)	28:00.0	34° 45' 37.2"	127° 49' 06.18"	13.5	13.7	0.46	0.07	1.51	0
994401540	Buoy (lit)	38:00.0	34° 45' 37.2"	127° 49' 06.18"	13.6	13.8	0.46	0.07	1.71	0
994401540	Buoy (lit)	58:00.0	34° 45' 37.2"	127° 49' 06.24"	13.7	13.9	0.46	0.07	1.8	0
994401540	Buoy (lit)	52:00.0	34° 45' 37.14"	127° 49' 06.06"	12.6	12.8	0.48	0.08	0	0.19
994401540	Buoy (lit)	02:00.0	34° 45' 37.14"	127° 49' 06.06"	12.6	12.9	0.48	0.08	0	0.06

(a) AtoN status information

MMSI	ZONE	OBSERVTIME	LATITUDE	LONGITUDE	WIND DIRECTION	WIND SPEED	AIR TEMPERATURE	RELATIVE HUMIDITY	AIR PRESSURE
994402917	1	18:48.0	34° 52' 55.74"	127° 45' 35.4"	156	2.6	17.1	89	1014
994402917	1	21:45.0	34° 52' 55.74"	127° 45' 35.34"	157	2.6	16.5	90	1014
994402917	1	24:48.0	34° 52' 55.74"	127° 45' 35.34"	162	1.5	16	89	1014
994402917	1	30:47.0	34° 52' 55.74"	127° 45' 35.34"	160	1.5	17	89	1014
994402917	1	33:45.0	34° 52' 55.74"	127° 45' 35.34"	161	2.1	17.3	89	1014
994402917	1	39:45.0	34° 52' 55.74"	127° 45' 35.34"	163	1.5	16.5	89	1015
994402917	1	42:46.0	34° 52' 55.74"	127° 45' 35.4"	165	1.5	16.7	89	1015
994402917	1	45:46.0	34° 52' 55.68"	127° 45' 35.28"	162	1	16.8	89	1015
994402917	1	48:48.0	34° 52' 55.68"	127° 45' 35.34"	168	0.5	17.2	88	1015
994402917	1	51:46.0	34° 52' 55.68"	127° 45' 35.34"	160	1	17.1	88	1015

(b) sensed weather information

Figure 1 Example of AtoN data

Some AtoNs also are equipped with sensors for weather observation and dissemination of weather information that includes data on current wind speed, current wind direction, air pressure, horizontal visibility, and other measure. Weather information, like AtoN status information, is periodically transferred to a regional AtoN-integrated management system, where it is categorized by observation time and AtoN identifier.

3. AtoN Product Specification

In this study, we focused on formulating a method for support of legacy systems enabling AtoN management and data provision in e-navigation. To those ends, we developed an S-100-based product specification for AtoN management data.

Finally, the third type is observation data, which include specific factors and values indicative of the status of and AtoN at a specific time. Sensed data provided by sensors attached to AtoNs also include observation data.

3.2 Data Elements of AtoN Data

Data elements representing the contents of AtoN data are defined on the basis of the S-100. We assume that AtoN data terminology is registered in a Feature Concept Dictionary (FCD) register for the IALA domain. Using common terms in the IALA domain, we define the data elements that compose the AtoN data contents.

3.2.1 Feature Type

General AtoN data, like ENC data, are feature based. Most consist of descriptions of AtoN objects, AtoN equipment, and AtoN-related objects or structures. We define the concept classes for AtoNs and AtoN-related objects or structures as feature types. A feature type can have geographic attributes as well.

AtoNs such as lighthouses, beacons, buoys, sector lights, and leading lines are defined, based on the IALA Navguide [8], as feature types. AtoN equipment, for instance, lights, radars, radio signaling devices, also are defined as features, as are AtoN AIS and cardinal marks, lateral marks, special marks, isolated danger marks, and safe water marks.

3.2.2 Information Types

Information type is identifiable data with some attributes. But this data type does not include any geographic attributes. It can be referenced by feature type or other information-type data element. In our AtoN data model, the concept class for management of data on AtoN objects is defined as information type. The data element for status information on AtoN at a given time is also defined as information type. For sensing information provided by sensors attached to AtoNs, we define an information type data element.

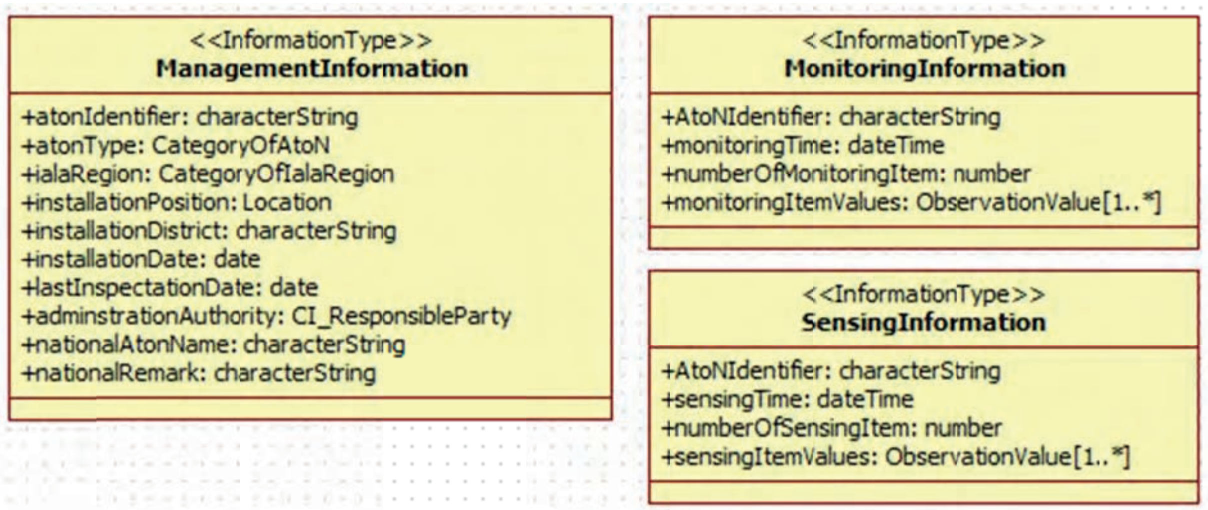

Figure 2 Example of information-type data element

3.2.3 Enumerated Value Types

Attributes for feature-type or information-type data elements should be set as attribute values. Some attributes have values from a pre-defined list. Enumerated value types are pre-defined value lists. For some attributes, we define lists consisting of pre-defined values. For example, color is defined as an enumerated value type, and includes different color items such as white, blue, green, black, and others. When we set an attribute value for color, only values in the list are used. For AtoN data, the many enumerated value types in addition to "color" are buoy shape, IALA region, topmark shape, color pattern, cardinal point, and category of lateral mark.

3.2.4 Complex Attributes

Complex attributes are attribute sets. For instance, a complex attribute 'sector' consists of the start angle and end angle representative of a certain angle area. Complex attributes are defined for reuse in some feature types or information types. An AtoN 'sector light' has attributes for representing lighting sectors or obscured sectors. Unit of measure is also used to represent observed value in status information type and sensed value in sensing information types.

3.3 Application Schema

An application schema represents the content and structure of data. Data contents, in turn, are represented by data elements, and data structure is represented by the relationships among the data elements. After defining the data elements of AtoN data, we design an application schema. AtoN data elements are feature type or information type. For description of some specific attribute values, enumerated value-type data elements are defined. Some complex attributes are defined to represent combinations of characteristics. The relationships among all of these data elements are represented in the AtoN data application schema. For example, lighthouse data are represented by feature- type

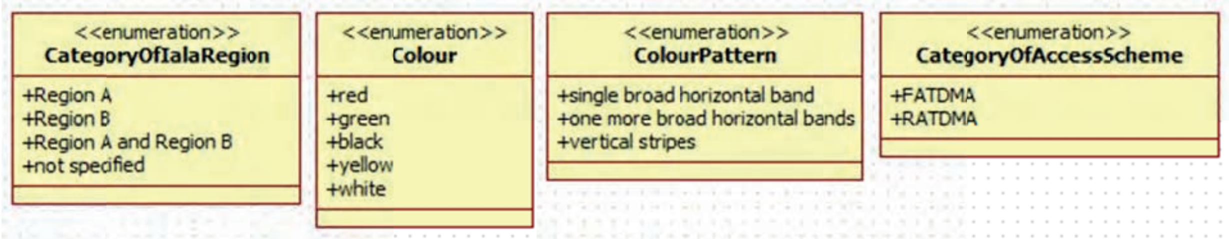

Figure 3 Example of enumerated value type

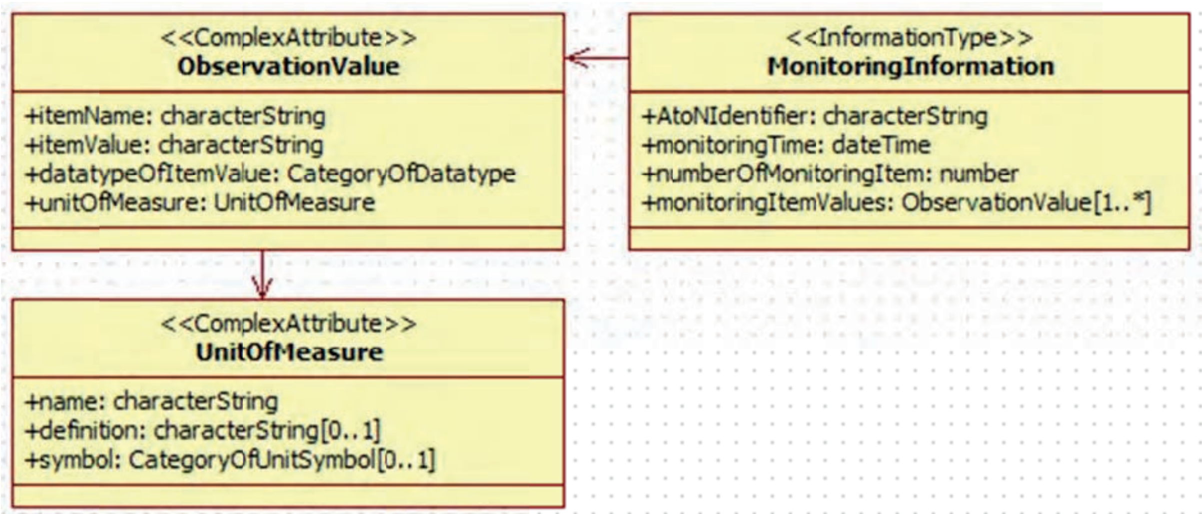

Figure 4 Example of complex attributes

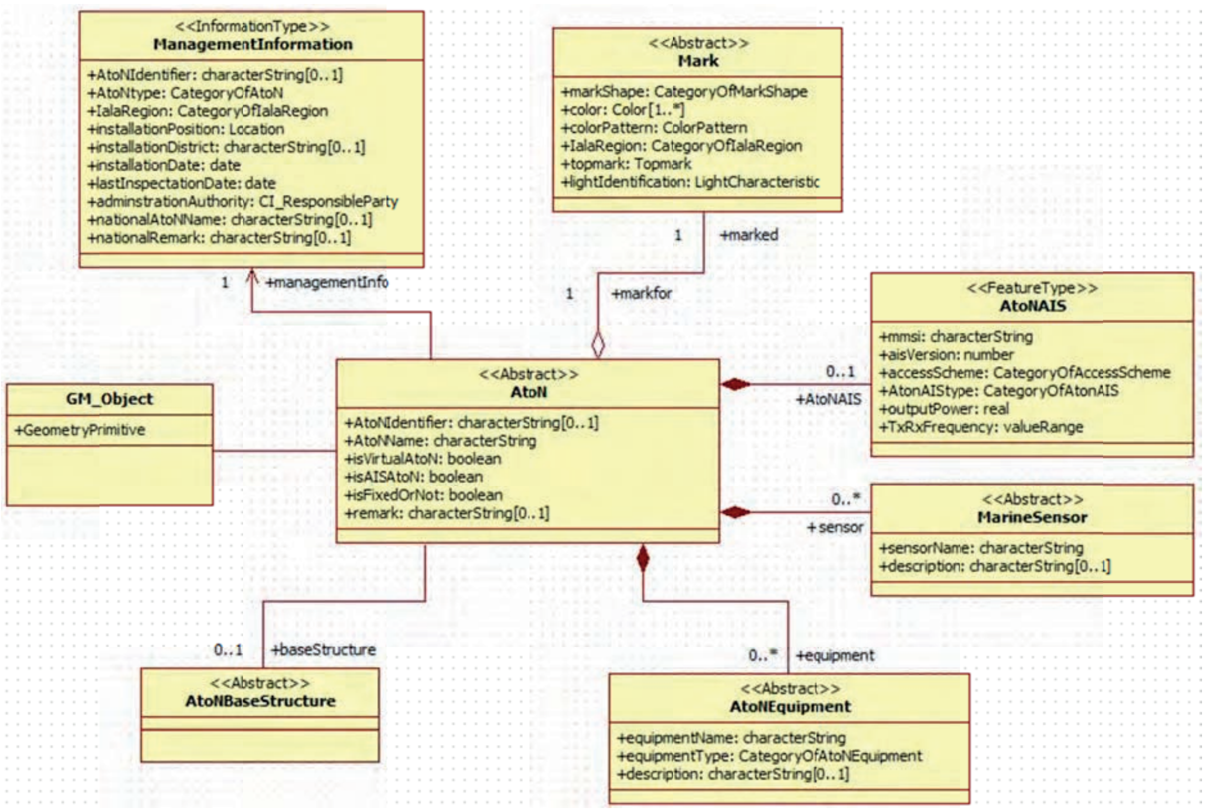

Figure 3 Snapshot of AtoN application schema (overview)

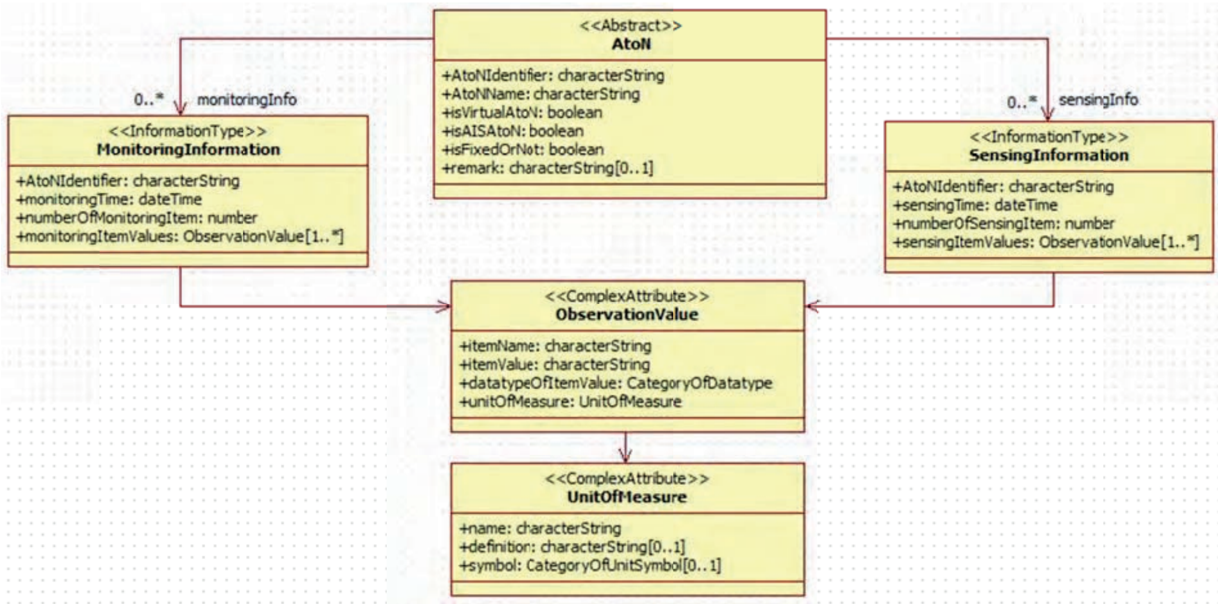

Figure 6 Snapshot of AtoN application schema (part for observation data)

elements such as 'lighthouse', 'light', and 'mark'. Management data on the lighthouse object are represented using the information-type data element 'management Information'.

4. Method for integration with Legacy System

4.1 S-100 compliant AtoN Data Product

As IHO S-100 is based on the CMDS, S-100-based product specifications support the sharing, exchange and usage of data in the e-navigation service environment. Complementarily, our AtoN product specification facilitates harmonization and utilization of AtoN data products in that environment.

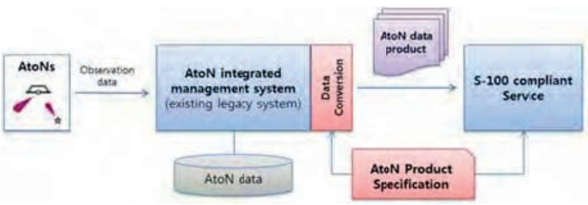

Figure 7 Diagram of AtoN data conversion process

AtoN legacy-system data, in order to be compatible with other systems, needs to be converted to a common data format. As S-100-based product specifications provide common data structures, AtoN data of legacy systems, if they are converted to AtoN data products on the basis of an AtoN product specification, will be used easily in other systems.

4.2 AtoN data-conversion

Legacy systems can play the data-provision role in the e-navigation environment. We convert AtoN legacy-system data to S-100-compliant data products on the basis of the AtoN product specification. Figure 7 illustrates the conversion process.

In order to convert AtoN legacy-system data to S-100-compliant AtoN data products, we map AtoN data elements to those of the AtoN application schema. According to their types, AtoN data are converted to two different dataset files, respectively. One includes general specifications on AtoN objects and the corresponding management data. This kind of dataset file includes only static data. The second dataset file type includes observation data on the related AtoN objects. Observation data, including monitoring information and sensing information, are temporal data. These temporal data are represented in a dataset file according to the general descriptions of the AtoN objects observed. Dataset files for AtoN data are constructed as XML documents.

4.3 Case Study: Integration AtoN legacy system with ENC system

In this section, we introduce a model for integration of legacy systems with other systems. By this model, AtoN data can be overlayed onto systems such as ENC. AtoN legacy-system data are transferred, in the form of S-100-compliant AtoN data products, to the ENC system. The ENC system loads the AtoN data products and displays the ENC data. In the AtoN product specification, the ENC system decodes AtoN XML documents and displays using the AtoN catalogue. Figure 8 shows the results of the harmonization of the legacy system with the ENC system.

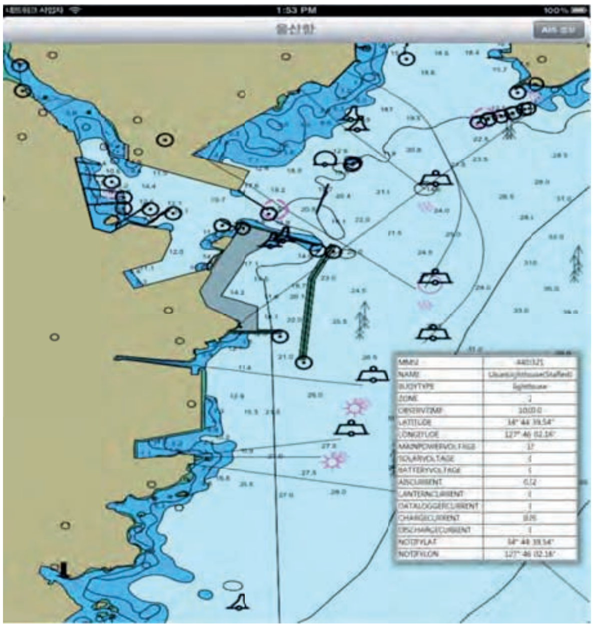

Figure 4 Snapshot of AtoN data overlayed onto ENC

5. Conclusions

After the adoption of IHO S-100 as the CMDS baseline for e-navigation, many organizations including IALA have shown interest in S-100. The IALA has been discussing the development of S-100-based product specifications for IALA-domain data. In the e-navigation environment, various data types are and will be used. Legacy systems in many domains, in fact, can be e-navigation data providers. In order to harmonize and utilize various data in the e-navigation environment, many organizations have tried to apply S-100 to their own systems. Unfortunately, it is difficult to modify all legacy systems to S-100-based systems. Therefore, it is necessary, instead, to integrate legacy systems with S-100-based systems.

In Korea, AtoNs, devices or structures enabling safe navigation of vessels, are managed by regional AtoN-integrated management systems. In the e-navigation environment, these legacy systems can be good data providers. In order to integrate them with S-100-based information services, it is necessary to provide legacy-system data to e-navigation services. In this paper, we present an S-100-based product specification for AtoN data. We also suggest a method for integration of legacy systems with the S-100-based system, chiefly by way of conversion of the legacy-data format to an S-100-compatible form. As the AtoN product specification was developed on the basis of the characteristics of legacy-system AtoN data, AtoN data products are fully S-100-compliant data and thus can easily be utilized in the e-navigation environment.

As further work, we will study semantic level integration of various data in the e-navigation environment. In this environment, there can be identical or similar objects in different domain data. In order to harmonize the various data in the different domains, therefore, we have to decide how to deal with them. Semantic-level integration of different domains is one option.

Acknowledgments

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