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FOREWORD

This volume is one of five volumes of conference proceedings, including the 4th IALA Heritage seminar proceedings, and contains abstracts, biographies and full papers, where these have been prepared and provided. We hope they enhance your conference experience and act as a useful reference source for future discussion and research in the Marine Aids to Navigation sector.

The volumes are compiled as follows:

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"S2.4 Case Study – Inspection of floating AtoN by drone (153)"

is session event 2.4 and the unique paper number is 153. Any sessions with numbers 1 to 16 formed the main auditorium programme, whilst sessions starting 101, 102 etc. formed the Speaker's Corner programme held concurrently. Papers, where submitted are included, otherwise the paper abstract only is included. These can be found by session number through the main table of contents or by their unique conference paper number via the index at the back of the document.

Tenga en cuenta que a lo largo de las deliberaciones, el título del documento está precedido por el número de evento de la sesión de la Conferencia y seguido por el número único del documento entre paréntesis, por ejemplo:

"Estudio de caso S2.4 – Inspección de AtoN flotante por dron (153)"

es el evento de sesión 2.4 y el número de papel único es 153. Las sesiones con los números 1 a 16 formaron el programa principal del auditorio, mientras que las sesiones que comenzaron 101, 103, etc. formó el programa Speaker's Corner celebrado simultáneamente. Los artículos, cuando se presentan, se incluyen, de lo contrario solo se incluye el resumen del artículo. Estos se pueden encontrar por número de sesión a través de la tabla de contenido principal o por su número de conferencia único a través del índice en la parte posterior del document

SESSIONS 1 AND 101 - ATON MANAGEMENT

S1.1 Modernizing Marine Navigation Service Delivery (145)

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ABSTRACT

The Canadian Coast Guard's marine navigation services, comprised of icebreaking, aids to navigation, waterways management, and marine communications and traffic services, are fundamental to navigation in Canada but currently lacking in their ability to respond to modern demands. Future increases in shipping traffic and the dangers posed by extreme weather events make this shortfall even more apparent. Modernized systems and the digitalization of services will allow for seamless data collection and efficient information sharing with mariners and partners. Canada will redesign and digitalize its marine navigation services to support the economic growth of shipping industries through the implementation of the s-100 framework and other key e-navigation initiatives. The transition to digital delivery of marine navigation services and the implementation of e-navigation is essential to the flow of the supply chain and shipment of goods in and out of Canadian ports, ensuring Canada remains globally competitive and a port of choice. Canada will be able to optimize trade through digitalization. Modernizing marine navigation services will also allow the Canadian Coast Guard to improve information sharing of its maritime data products and harmonize levels of services that meet national and international standards and requirements for the safe use and design of waterways and commercial shipping channels.

KEYWORDS: Modernization, Digitalization, Marine Navigation, Digital Services

1 INTRODUCTION

The Canadian Coast Guard's marine navigation services, comprised of icebreaking, aids to navigation, waterways management, and marine communications and traffic services, are fundamental to navigation in Canada but need to be modernized and digitalized to respond to modern demands. Future increases in shipping traffic and the dangers posed by extreme weather events make this requirement even more apparent. Modernized systems and the digitalization of services will allow for seamless data collection and efficient information sharing with mariners and partners.

Canada will redesign and digitalize services to support the economic growth of shipping industries through the implementation of s-100 and e-navigation. The transition to digital delivery of marine navigation services and the implementation of e-navigation is essential to the flow of the supply chain and shipment of goods in and out of Canadian ports, ensuring Canada remains globally competitive and a port of choice. Canada will be able to optimize trade through digitalization.

2 CURRENT STATUS OF COAST GUARD'S MARINE NAVIGATION SERVICES IN CANADA

The Coast Guard, as the enabler of safe and efficient marine traffic in Canada, is heavily relied upon by both shippers and ports during their voyages. In addition to maintaining Canada's aids to navigation system, which mariners rely to navigate safely, the Coast Guard's Marine Communications and Traffic Services also regulates traffic movements and supply marine safety information to vessels and provides icebreaking and ice management services to mariners. These services are crucial to supply mariners with key safety services and to enable safe and efficient shipping in Canada.

Marine navigation is an interdepartmental effort in Canada. Coast Guard works closely with other Federal departments such as Transport Canada, Canadian Hydrographic Services, Environment and Climate Change Canada, to deliver services to mariners in Canadian waters.

Coast Guard's marine navigation services ensure reliable and open flow of goods to markets on a 24-7-365 basis. We support Canada's economy by enabling the safe and efficient flow of $251 billion in marine trade, moving more than 342 million tonnes of critical goods, and supporting tens of thousands of jobs across the country annually. In 2020, marine transportation carried nearly $103 billion (20%) of Canada's exports to world markets and brought in $122 billion (23%) of Canada's total imports by value. Combined, 21.1% of all Canadian trade is transported by water. Marine traffic in Canada is projected to grow by 50% by 2030 and trade volume is projected to double.

International trade is critical to the future success of the Canadian economy, and Canada's marine-based supply chain and waterways corridors are fundamental enablers of trade and play a significant role in connecting Canadian products to emerging global markets.

3 CURRENT CHALLENGES

The Canadian Coast Guard relies on older systems and requires manual reporting, based heavily on voice communications and multiple reports to be filled in by mariners and reporting call-in points. The shift to digital services is essential for Canada to remain a port of choice, as industry and other countries are well underway to adapt to the modern delivery of services and real-time information sharing.

Industry is using modern and digital platforms. Coast Guard is hoping to improve how services are delivered and fulfil its commitment towards the efficient movement of goods and services in Canadian waters. Digital navigation services are particularly essential in areas of high traffic, including major ports and waterways near the United States border.

4 DIGITALIZATION OF MARINE NAVIGATION SERVICES

The digitalization of Coast Guard's marine navigation services will allow Coast Guard to provide real-time information and streamline communications with mariners, maximizing each vessel voyage along the Canadian marine shipping route, avoiding collisions and groundings, and minimizing impacts to the environment. This push to a digital marine navigation service promotes the flow of the supply chain and shipment of goods in and out of Canadian ports.

Reliable, secure, and continuous communications infrastructure and accurate vessel traffic movement data will ensure unfettered fishing and shipping activity and support transition to new marine technologies such as autonomous shipping, which cannot be enabled without modern communication systems, infrastructure and digitalized service delivery for machine-to-machine interactions. Digital maritime services will rely on efficient and robust ship-ship, ship-shore or shore-ship electronic data transfer.

The digitalization of marine navigation information will align Canada with the modern systems already in place in Canadian ports and in other countries. The Coast Guard needs to continue advancements to have modern systems to mariners to minimize disruptions to the shipping industry and react quickly in the wake of supply chain disruptions.

This work will be implemented in a phased approach with an initial focus on the foundational elements for Coast Guard, which include:

- Smart vessel traffic services;
- Virtual aids to navigation; and,
- The implementation of e-navigation

Once those elements have been implemented nationally, Coast Guard will build on those successes and look for further opportunities, including opportunities for partnerships and addressing regional requirements across Canada.

4.1 Optimizing Shipping Traffic Through Digitalization

The shift to digital services and the implementing e-navigation in Canada will unlock numerous digital, interoperable layers of information.

In a redesigned approach to service delivery, Coast Guard will actively watch traffic, using digital capabilities and real-time information to anticipate and recommend route changes that will result in optimized, Canadian maritime traffic and resilient supply chain routes. This will also allow the Coast Guard to adapt shipping route recommendations when facing significant weather events.

More specifically, the digitalization of marine navigation services will enable bi-directional sharing of information between Coast Guard, ships, ports, and federal partners, allowing Coast Guard to focus on the monitoring, surveillance, and assistance of vessel traffic and traffic optimization. By automating links between voyage route plans and the Coast Guard's vessel traffic information management system, which will shift our service delivery from manual, labour-intensive and unidirectional operations to more efficient, bidirectional workflow that can react and adjust to changing situations. The goal is to ensure continuous, situational awareness by increasing the time spent on traffic monitoring, route recommendations, and risk analysis for enhanced marine safety, while reducing time spent on labour-intensive data entry. Optimizing routes and traffic management will directly contribute to smoother port operations, unimpeded supply chains and facilitate route planning for mariners.

4.2 Alignment with International Standards

Canada must keep pace with international standards that are shifting to digital platforms and must implement e-navigation and digital marine services to meet International Maritime Organization and International Hydrographic Organization obligations starting in 2026. Compliance to international standards is key to ensure that Canadian waters are open and ready to receive international ships who are expecting digital services.

As a result, Coast Guard will continue to advance the implementation of e-Navigation in Canada and will focus on the following priorities as drivers of the modernization efforts:

- Implementing electronic aids to navigation
- Digitalizing maritime services
- Realizing cybersecurity requirements
- Emergence of autonomous vessels
- Modernizing vessel traffic management

5 CONCLUSION

To ensure that the Canadian Coast Guard remains an enabler for international trade and commerce, and to avoid supply chain disruptions, Coast Guard is moving away from the existing dated, complex systems and transition to modern services, tools, and workforce to provide digital real-time, integrated services for the safe, and efficient maritime traffic. Coast Guard will continue to work, through a phased approach, to improve information sharing of its maritime data products and harmonize levels of services that meet national and international standards and requirements for the safe use and design of waterways and commercial shipping channels.

Coast Guard's key next steps will focus on:

- The development of an implementation strategy and critical path leading to 2026.
- Advancing the delivery of interoperable digital services to mariners.

Canada has an opportunity to re-design its marine navigation service delivery to build a strong economy post-pandemic, while ensuring the health and sustainability of its oceans and waterways.

AUTHOR BIOGRAPHY

Antonella Ferro is the Director, Marine Navigation Programs within the Fleet and Maritime Services Directorate at the Canadian Coast Guard. Her team manages the operational and program policy work for the 4 marine navigation programs and e-Navigation.

Antonella joined Coast Guard in 2000 as a Marine Communications and Traffic Services Officer and has more than 20 years public service experience. Within CCG, Antonella has held roles with increasing responsibility including acting at the executive level and in various management roles within Maritime Security; Oceans Protection Plan (OPP) Implementation Team; and, Marine Navigation Branch. Antonella has extensive policy, operational, and program implementation experience.

Antonella holds a Masters of Public Administration from Lake Superior State University and a Bachelor of Arts Sociology/Criminology form the University of Windsor; and, she completed the National Security Programme at the Canadian Forces College in Toronto, Ontario.

S1.2 Establishment of the Private Sector Support Group for Lighthouse Servicing System (094)

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ABSTRACT

In November 2021, Japan amended the Act on the Aids to Navigation, a law aimed at promoting the safety and efficiency of vessel traffic by stipulating the maintenance and operation of Aids to Navigation, to establish the Private Sector Support Group for Lighthouse Servicing System. This system is intended to further improve the Aids to Navigation management by providing a clear legal background to enable the private entity that consider the local lighthouse as the symbol of the community and voluntarily carry out lighthouse servicing activities such as cleaning and mowing the ground of lighthouses at their own expense. In February 2022, the Japan Coast Guard designated the first 23 groups under the new system. The JCG will further improve the management of Aids to Navigation by providing necessary information and advising private sector support groups for lighthouse servicing to promote their activities.

KEYWORDS: the Act on the Aids to Navigation, the Private Sector Support Group for Lighthouse Servicing System, local community, advantage of the system

1 INTRODUCTION

In Japan, we have received numerous requests from private bodies and local governments for making use of lighthouses in various ways, considering them as local symbols and tourist attractions. However, under the regulations for public properties, it is specified as a main principle that the national properties (Aids to Navigation including lighthouses) shall be managed by the Government (Aids to Navigation shall be managed by Japan Coast Guard (JCG)). In addition, as there is no legal system to approve such activities, we could not correspond to such requests sufficiently.

As announced in this presentation, it is expected that the Private Sector Support Group for Lighthouse Servicing System and its activities will contribute to management of Aids to Navigation as well as facilitating the use of lighthouses by legalizing the group and activities.

1.1 Current State of Japan

The overall population of Japan as of September of 2022 was totalled with 124.971 million people, which has been consistently decreasing since 2011. It is forecasted that development of a declining birth rate and growing proportion of elderly people, and a declining productive population accompanied by the depopulation will result in more serious social and financial problems including shrinkage of the scale of economy, labor shortage, a drop in international competitiveness and an increase in medical care treatment expenses etc.

Such problems are prominent in local cities which are located apart from large cities where there are the lighthouses on the cape (which refers to coastal lighthouses whose light reachable distance is 12 miles or more and whose size are relatively large). Therefore, the Government and local governments, and other organizations, both public and private, have been focusing on local vitalization, such as improving local residents' motivation to be active and activating economic activities, social activities, cultural activities and industry activities, as the countermeasures against such problems.

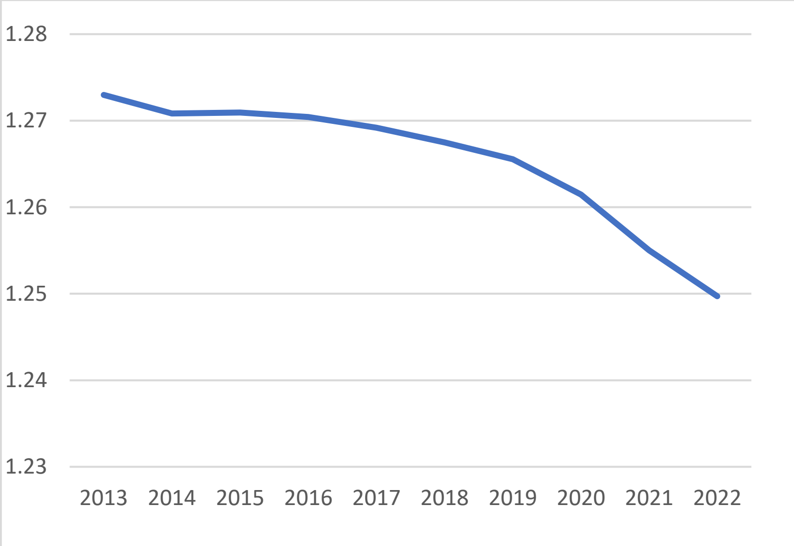

Figure1: Changes in the Total Population of Japan

1.2 Aids to Navigation in Japan

In Japan, in principle, lighthouses, light buoys and Aids to Navigation of VTS centers have been managed by JCG. As of April 1 of 2023, there are 5,134 units of AtoN managed by JCG. Having been carrying out various kinds of duties all day and all night. For management of AtoN, JCG has been called for effective and efficient responses thereto within a limited budget.

Table1 Number of units for each kind of AtoN

Kinds of AtoN	Number of AtoN
Coastal lighthouse※1	391
Other lighthouses※2	2,719
Lighted beacon	455
Lighted buoy	1,164
VTS Center	7
AIS signal stations	20
Others	378
Total	5,134

※1 The lighthouse whose light reachable distance is 12miles or more.

※2 The lighthouse whose light reachable distance is less than 12miles.

1.2.1 Management of AtoN

The officers of 71 Coast Guard Offices throughout Japan and 7 VTS centers located in the sea areas congested with ships have been engaged in management of AtoN as one of numerous duties.

Additionally, such management of AtoN includes quick recovery of the equipment in the case when the light is extinguished due to failure of such equipment and when the facilities suffer from disasters as well as regular inspection for such equipment of facilities, which requires a lot of workload and budget. Above all, most of the lighthouses situated at the edge of the cape are at the inconveniently located places in terms of transportation, cannot be reached without using ships or walking through steep mountain rods and require mowing on the paths to the sites of the lighthouses, which imposes a heavy burden on the officials.

1.2.2 Lighthouses Supported by Local Community

With regard to the confirmation whether lights for AtoN are lighted or not, for larger lighthouses and light buoys or AtoN for larger ports, it is possible to be checked by using equipment to monitor such lights or using monitoring cameras from Coast Guard Offices and the like.

However, for the local lighthouses for smaller ports, as the scale of their facilities are small and their communication environment has not been well established, it is not possible for them to install such monitoring equipment and thus to check their lighting. Furthermore, under such circumstances, it is not possible to grasp the state of such facilities by using monitoring equipment.

By this reason, JCG have been asking for volunteering work to check the lights and facilities to the people involved in AtoN on a daily basis including fishery operators, ferry companies or the residents living near the lighthouses.

Besides, there are some volunteer groups engaging in cleaning and mowing for the lighthouses, considering them as the symbols of their local areas. Thus, the lighthouses in Japan have been supported by local people.

Figure 2: Volunteering Work to Clean Lighthouses

1.3 Lighthouse potentiality

The lighthouses located on the edge of capes have various kinds of historical and cultural values in addition to acting as AtoN to become the landmarks for navigating vessels and creating beautiful landscape of the areas in harmony with their surrounding scenery. Such lighthouses have an appeal as the sightseeing spots that attract a large number of tourists as well as valued symbols for the local people.

1.3.1 Lighthouses in Collaboration with Local Areas

The lighthouses located in the place of scenic beauty such as the edge of the cape has been open by the officers of JCG in response to the request from their local people for the events such as local festivals in order that local people as well as tourists can enjoy the scenery from the lighthouses. Among these, the lighthouses where in particular many tourists visit have been open to the public throughout the year, through raising donations by the groups aiming at diffusion of knowledge on AtoN.

Thus, JCG has been engaged in cooperation with the local communities through opening to the public of the lighthouses as long as such opening does not interfere with its duties.

Additionally, in order to familiarize people with lighthouses, we adopt the design that fits into the circumstances of the local areas to construction of the lighthouse.

Other than afore-mentioned matters, there are some examples where the local governments utilize the lighthouses for the local communities by developing the associated buildings and the sites that have become unused due to unmanned operation of the lighthouses into the restaurants and parks for the local communities.

1.3.2 Lighthouse with Historical/Cultural Values

There are a large number of lighthouses with historical/cultural values including the ones that were constructed during Meiji Era after 1868 when Japan rapidly modernized and the ones designated as important cultural properties.

For example, we can understand how Western technologies have been adopted in Japan from the lighthouses that were constructed by introducing French and English technologies in the beginning of Meiji Era, which is of high value from the viewpoint of the history of technology. Further, at that time, for the people in the local areas which had no choice but to depend on the transport of goods and people, it was extremely important for them to ensure safe navigation for vessels. So the lighthouses are closely related to the local history as indispensable facilities for development of the areas.

Figure 3: Lighthouse of Historical/Cultural Value

2 PRIVATE SECTOR SUPPORT GROUP FOR LIGHTHOUSE SERVICING SYSTEM

As mentioned above, although there are a number of lighthouses with various possibilities, they have not been fully made use of due to some restrictions. Therefore, after considering if we can contribute to the local area more or if we can ask people to do more activities for the lighthouses by supporting those who have been involving the activities for the lighthouses and the local areas, JCG have created “Private Sector Support Group for Lighthouse Servicing System” by amending the Act on the Aids to Navigation in November 2021.

Since JCG designates the group that conducts beneficial activities for such management including cleaning the lighthouses and confirmation of light of the lighthouses, studies on historical materials and dissemination of knowledge relating to lighthouses, this system contributes to local vitalization as well as enhancement for management of AtoN, by supporting such activities.

As of April of 2023, JCG has designated 44 support groups for 54 lighthouses throughout Japan, each of which provide various kinds of activities.

2.1 Advantages of the System

Designation as the group leads to vitalization and stabilization of the activities, which further enhances the activities of the Group.

I will explain the advantages of the System by dividing into three points.

2.1.1 Support can be obtained from JCG

The first advantage is that the group can get the support required for its activities from JCG. Once a group is designated as a private sector support group for lighthouse servicing, it shall be legalized as the Group that conducts beneficial activities for management of AtoN and its activities shall be ensured. Thus, the Group can be provided with the activities required for such activities including the drawing of the lighthouses and historical materials related to the lighthouses and can ask for necessary advice to JCG.

2.1.2 Free Access to Lighthouses

The second advantage is that the group can use lighthouses freely. So far, while JCG occasionally opens the lighthouses to the public in response to the request from the local communities, the primary role of the lighthouses should be securing safety of vessel traffic and promotion of vessel operation efficiency. Moreover, there have been some restrictions on their use. Specifically, as the lighthouses are unmanned facilities managed by JCG, in the case of being open to the public, it is necessary for the officers of JCG to take the trouble to visit them in order to lock and unlock their doors. In addition, in the case where a visitor is injured within the lighthouse, in principle, as JCG takes the responsibility for such injury, JCG officers always need to respond to such injury independently such as taking safety measures. However, as JCG officers have been carrying out various kinds of duties all day and night, in the case where they are not available, in some cases, it was difficult to respond to the requests from the local communities. However, once a group is designated as a private sector support group for lighthouse servicing, the group can use lighthouse freely according to the group’s convenience under its responsibility without the JCG’s response.

Figure 4: Status of Lighthouse Open to the Public by a Private Sector Support Group for Lighthouse Servicing

2.1.3 Moneymaking Activities

The third advantage is that moneymaking activities can be achieved by making use of lighthouses.

Expenses for purchasing tools and the ones for disposing of garbage are required for cleaning and mowing for lighthouses. In addition, in the case when the lighthouse is open to the public and the events are held, the expenses for safety measures are also required, such as installation of fall prevention fence. Because of that, even if the local communities desire to make use of the lighthouses for the local areas, the situations have made it difficult to be active for making use of the lighthouses due to financial reasons.

However, once a group is designated as a private sector support group for lighthouse servicing, entrance fees of the lighthouses and event fees can be collected and souvenirs can be sold within the sites of the lighthouses. Thus, the expenses required for the activities can be covered by the profits gained by the collected fees and sales, by which the financial burden can be mitigated or eliminated.

2.2 Examples of Activities by a Private Sector Support Group for Lighthouse Servicing

While it has been only one year and half since operation of Private Sector Support Group for Lighthouse Servicing System started, I'd like to introduce some examples as there are various activities that make use of the System. For example, they are environmental beautification activities in Lighthouses and their vicinities, simple inspection for lighthouses as well as research and studies on lighthouses.

3 CONCLUSION

While it has been only a short while since Private Sector Support Group for Lighthouse Servicing System started its operation, there are various kinds of activities that had not been seen before establishment of the System, beginning to show the results.

On the other hand, while there are some lighthouses that can contribute to the local communities, some problems can be found that there is no group that desires to work on vitalization of the local areas by making use of the lighthouses and that cannot make use of them even if the local people desires to do so due to aging of population. Because of these, JCG will continue to making efforts to develop the System by finding the resolution therefor by listening to the local people in order to solve such problems.

Additionally, JCG will make efforts to convert the effects of saving of management expenses for Aids to Navigation into numerical values, not just into the sensuous results.

Finally, in the near future, I hereby promise that we will strive to make all of you to become willing to visit Japanese lighthouses as the successful examples for making use of the lighthouses, and would like to conclude my statement.

AUTHOR BIOGRAPHY

LCDR ARITA Mayumi is a Special Assistant to the Director of the International Affairs and Engineering Development Office, Administration and Planning Division, Maritime Traffic Department, Japan Coast Guard (JCG). She is currently in charge of international matters of the Maritime Traffic Department, mainly IALA activities.

She graduated the Japan Coast Guard School in 1998 and started her career as a radio operator of a coastal radio station of JCG. Since then, she has involved with several kind of JCG works, above all, VTS is her area of specialization. She has the experience of working as a VTS operator and a supervisor in Tokyo-Wan VTS and Osaka-Wan VTS and as an officer for the coordination of duty and training for VTS operator. In addition, she engaged in establishing the VTS Operator Course of the Japan Coast Guard School when it founded in 2018 and gave classes as an instructor to students for a few years.

From 2011 to 2012, she worked at the IALA Headquarters as a seconded officer from JCG. She has C0103-1 and C0103-3 certificates and finished C0103-4, the On-the-Job Training Instructor Course.

S1.3 Focus on streamlining and cost reductions in the long run - from 7 to 1 buoy tender in 30 years (151)

Jan Thorn, Danish Maritime Authority, Director, Safety of Navigation National Waters, Denmark

ABSTRACT

Over the last approx. 30 years, the Danish Maritime Authority (DMA) has reduced the number of buoy tenders used to handle maintenance of AtoN from seven (7) to one (1) ship. DMA has consistent and continuously utilized the technological advances optimally. This applies to both the fixed and floating AtoNs, which now have a significantly longer lifespan as well as requiring a significantly less energy supply. With this presentation, the DMA will present what we have done and which financial and environmental-improving measures have been developed and used to achieve this. DMA will show how due diligence and the tracking of deviations/observed failures used in a systematic way affects and streamlines the entire supply chain from deliverance over preparation for installation and maintenance, lifetime of the equipment and disposal of the AtoNs at the end of their service.

KEYWORDS: Buoy tender, lifespan, energy supply, environmental improvement, streamlining

1 INTRODUCTION

1845 the very first dedicated buoy tender "LØVENØRN" was put into operation, by 1985 there were seven (7) vessels tendering the buoys, signals and lighthouses in the Danish National Waters. In 2019 the remaining fleet was reduced to 1 buoy tender tending 4,651 floating AtoN and 14 stationary beacons at sea.There is no single event, that have caused the efficiency improvement, but a long list of smaller improvements that collectively have made the reduction in the number of buoy tenders a reality.

This paper will explain how improvements was done by presenting some of the individual actions that have made it possible.

2 LIGHT BOUYS

Around 1990, the light buoys only had a deploying time of 1 year. At that time we used brown- stone batteries (The blue colored ones from Hellesen's that most "mature" people remember from their childhood). The lanterns used approx. 30 watts at the time. This required a large buoy tender fleet available for maintenance.

Figure 1 shows the significant The difference in appearance and size of buoys then and now.

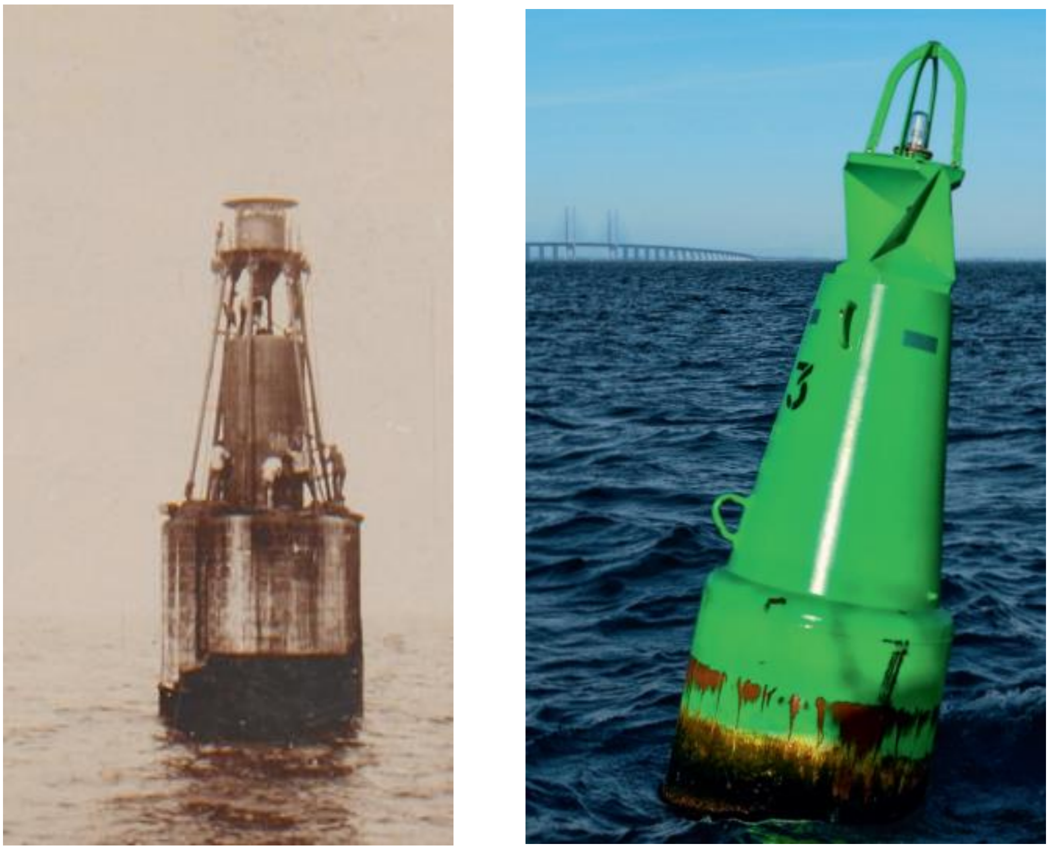

Figure 1 The difference in appearance and size of buoys then and now

In 1995 we changed to a new type of Alkaline batteries (similar to flashlight batteries) with larger capacity and implementing LED lanterns.

The light buoys were refitted with so-called “ice tops” with a built-in radar reflector. This made the light buoys more robust in relation to the physical influences and with new batteries and LED lights, the light buoys now had a lifespan of 3.5 years before it needed to be replaced and the interval between inspections of the buoys was approx. 12 months.

In 2010 we acquired a new type of LED lanterns which required even less energy than initial smaller LEDs. The first LEDs used approx. 10 watts and the new buoy lantern was down to a consumption of approx. 4 watts. This meant that the deploying time could be further increased to approx. 5 years and inspection approx. every 15 months. In 2020, we invested in a newer type of LED lanterns where the consumption is between 0.8-1.6 watts and together with new improved paint systems, the laying time of a light buoy is now 7 years.

Now we are testing new battery systems with Lithium as well as solar cells in order to replace the alkaline batteries (Flashlight battery).

Another issue regarding extended deploying is the quality of mooring equipment and paint systems. 25 years ago it was common practice to buy used chains of different sizes and unknown quality, and used shackles refurbished by welding and grinding. Today only 3 different chain sizes are used and only of a specific quality, improving safety when handled by our buoy tender significantly reducing the amount of drifting buoys caused by broken mooring.

Different types of paint systems have been used during the last 30 years. Water based paint was used for a number of years, but proved less durable when deploying surpassed 5 years. The paint simply faded out of IALA specifications.

All surface treatment of the buoys was outsourced 7 years ago. The contractor uses Epoxy paint of similar type as used on offshore wind turbines. This paint system has proven very durable, possibly expanding the deployment time further.

All these initiatives are expected to lead to expanding the deploying time on the steel light buoys up to 10 years. The sum of all these initiatives have greatly contributed to the reduction of our buoy tender fleet.

3 UNLIT BOUYS

Around 1990 we had four (4) smaller buoy tenders working solely with the unlit buoys. They were designed for maintenance, inspection and change of the small unlit steel buoys used at the time and which had a laying period of approx. 1-2 years.

In 2000, we invested in a new generation of unlit buoys, which were made of plastic. Their deploying period is approx. 10 years, and the need for inspection is every two years. This has meant a huge reduction in both vessels and manpower for handling these buoys both at sea and ashore at the maintenance centres.

Today, the unlit light buoys are mainly handled by locally hired part time personnel with smaller boats, and by our remaining buoy tender POUL LØWENØRN.

4 RADIO BEACONS

In the 1920s radio navigation beacon service was established in Denmark.

Bearing via sound signals from the radio beacons was used at sea in Denmark up until around 1997, when the radio beacons were decommissioned. The satellite based GPS had taken over and more or less made the radio beacons redundant.

However, the new GPS system had two weaknesses; The accuracy could fluctuate up to 130 meters, and there was a lack of control of the transmitted GPS signals (integrity control). Therefore, attempts were made to transmit a differentiated GPS signal (DGPS) from the mid-1990s to 1999. With DGPS, an accuracy better than 10 meters could be achieved, and the system comes with an integrity warning if the signal disappears, or is more than 10 meters off course.

In 1999, Hammer Odde, Blåvandshuk and Skagen DGPS stations were declared operational, and in 2000 Torshavn DGPS at Faroe Island became operational. All four stations reuse the old radio beacons for broadcasting the DGPS signals.

Alongside radio beacons, GPS and DGPS, a radar-based navigation aid has been developed. The USA and the UK joined forces after World War II to develop a radar-based beacon, a RAdar beaCON = RACON. These have been improved over time, and are still used as e.g. marking of positions (beacon and light buoys) and marking of bridges, etc. demanding less and less time for maintenance and inspection.

5 LIGHTHOUSE CONCEPT IN THE GREAT BELT

Figure 2: Buoy tender POUL LØWENØRN with Great Belt Lighthouse on board

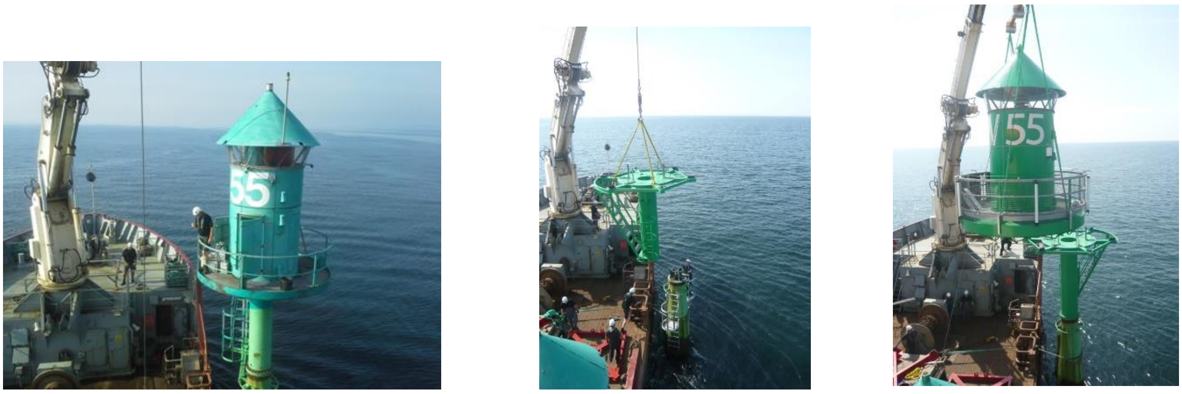

Figure 3: Sequence of changing a Great Belt lighthouse

The Great Belt Lighthouses have previously been responsible for consuming a large number of sailing hours for our buoy tenders. When established around 1970 the lighthouses were fuelled with acetylene gas and we spent many sailing hours changing gas cylinders. The gas cylinders used weighed 70 kg. and there were 10 cylinders at each lighthouse to be changed at least twice a year depending on the light characteristics.

The lighthouses were modernised with wind turbines as well as solar cells. However many sailing hours were spent on maintaining wind turbines and maintaining the lighthouses' steel structures.

In 2007, we initiated a new thorough modernisation project where 13 Great Belt lighthouses were totally renovated and the beacons converted into modular systems for successive maintenance ashore. The lanterns converted to LED lanterns and the energy supply converted to pure solar cell operation. The buoy tenders can carry one Lighthouse, with room on board to placing the worn Lighthouse on board, while switching the two Lighthouses on the same voyage (See figure 2 & 3).

This project has greatly reduced the time needed for a buoy tender on maintenance of the beacons and it was a major contributing factor of phasing out one of now only two remaining the buoy tenders.

6 OPERATIONS IN GREENLAND AND THE FAROE ISLANDS

Up until 2006, there has been a buoy tender operating in Greenland every summer year. The last of these was JENS SØRENSEN sold in 2019, now an arctic cruise vessel. Previously many of the vessels were equipped to sail in the icy and dangerous waters, former buoy tenders such as Argus, Narsaq and Janus typically had the task in Greenland as well as operations at the Faroe Islands.

The work consisted of maintaining beacons and lighthouses. In connection with the modernisation of the lighthouses and the beacons, the needs for a buoy tender in Greenland, as the work could be done by chartering local vessels and companies and supported by the Operations Center in Grenå/Denmark.

There are 63 lighthouses, all converted from gas operation to battery operation using solar cells supplemented with 22 RACONs also powered by solar panels, which have eliminated the need to refill gas cylinders twice a year per lighthouse. The gas was sent to Greenland in cylinders weighing 70 kg. The largest lighthouses used eight (8) bottles each.

530 land based day markers were originally vulnerable wooden structures, which often overturned during storms and needed attention. Present day land based day markers replaced with stainless steel that does not require any maintenance.

These initiatives have led to a large financial saving on the operation of lighthouses and beacons in Greenland along with the withdrawal of buoy tenders support.

7 VESSEL EFFICIENCY

THE NUMBER OF CREW DECREASES

The vessels have decreased in numbers as well as the crew needed to man them.
The largest buoy tender ("ARGUS") needed a crew of 17, the 1 remaining buoy tender is manned by a crew of 8.
Many of the work tasks on board have been streamlined and exposed to work environment initiatives. An example of this is that the crew have optimised the use of high pressure flushing water to clean the floating AtoN before they are taken on board, saving manual labour and cleaning on board.

FROM MID 70`S

A number of circumstances have streamlined the efficiency of the vessel used as buoy tender:

- Extensive development within electronic navigation aids as well as aids to navigation (AtoN)
- Light buoys could replace the resource heavy lightships
- The energy supply for the offshore lighthouses was converted from gas and diesel engines to solar cells
- The use of local vessels in Greenland
- The need for buoy tenders as icebreakers have decreased
- The vessels decreased in numbers as well as the crew needed to man them
- A purpose built workboat stored on board and delivered January 2022 allows inspection in shallow waters, recovering of drifting AtoN, depth control, diving platform, crew boat etc. adding to the range of jobs the one remaining buoy tender can manage

TODAY IT TAKES APROX.15-20 MIN TO CHANGE A FLOATING ATON

This is due to a number of improvements:

- Dynamic position system eliminates need of anchor support
- An efficient deck crane with remote control eliminated time-consuming boom arrangements
- A chain drum winch releases the crew from having to stack the chains manually
- A shark jaw on the side of the ship secures the chain of the AtoN while the buoy is on deck for inspection
- A water gun cleans buoys and chains eliminating manual cleaning
- Coding of lanterns and voltage check can be done remotely without dismantling any parts of the AtoN
- The same person operates the crane, the shark jaw and the chain drum winch using remote control.
- The vessel is equipped with a watch free engine room
- The remaining buoy tender "POUL LØWENØRN" is a multipurpose buoy tender also equipped to function as seabed surveyor, diver platform and has capacity on deck for 2 small offshore lighthouses used in Great Belt area in order to make a shift

2023: POUL LØWENØRN built I 2002, 53,44 meters (extended 4.8 meters in 2019) is manned by 20 seafarers in two shifts and the tasks handled are inspection and maintenance of:

- 13 Great Belt beacons plus 2 in another water
- 26 RACONs
- 378 Light Buoys
- 897 unlit buoys
- 84 days of seabed survey with 4 extra crew (sea surveyor from the Danish Navy)
- Within a 5 year scheme inspection of all privately and community owned AtoN (3,378)
- Handling a number of unexpected events
- The vessel is so efficient, that we expect to further reduce the number of time used to handle the AtoN in 2023 with 20%.

8 ENVIRONMENTAL GAIN (FIGURE 3)

REDUCTION IN COMSUPTION AND IAR EMISSIONS	OIL CONSUMPTION	CO2 EMISSION	SOX EMISSION	NOX EMISSION
1999	**993M^3**	**5,922 TON**	**213 TON**	**79 TON**
2022	**443M^3**	**1,186 TON**	**0.922 TON**	**15.118 TON**

Figure 3: Environmental gain

The numbers speak for themselves. During the last 20 years, since measurements of CO2, SOX and NOX was documented, there have been a significantly decline in the oil consumption leading to a decline in the emissions from the Buoy tender.

9 CONCLUSION

The success of reducing the number of buoy tenders used to handle maintenance of AtoN from 7 to 1 buoy tender over the last approx. 30 years, is due to a number of initiatives on all levels of the operation of the bouy tender POUL LØWENØRN and the design and operation of the AtoN.

The consistent and continuously utilisation of the technological advances together with listening to the crews suggestions, and supporting trails and tests have been very fruitful.

The recognising of deviations and failures in a constructive and organised manner have ensured, that the continuous development of the different involved entities have keept pace with the crew and their handling on board. The goal to ensure due diligence and the tracking of deviations/observed failures used in a systematic way to affect and streamline the entire supply chain from deliverance over preparation for installation and maintenance, lifetime of the equipment and disposal of the AtoNs at the end of their service have proven to be an efficient road to tread.

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S1.4 Service-Mix Revisited - the trade-off between latest digital technology and classic aids (059)

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ABSTRACT

The notion of an optimal service mix has been around for decades. This is the optimal selection of Aids-to-Navigation (AtoN), Vessel Traffic Services (VTS), Position-Navigation-Timing (PNT) provision, information services, and communication means in a given sea or waterway area provided from ashore for the safe, efficient and environmentally friendly navigation of individual vessels as well as of vessel traffic at large. With the advent of new methods and technologies on one hand and the arrival of new types of vessels such as autonomous and remotely operated vessels on the other hand, the question arises, what fresh options may be created for an optimal service mix in the foreseeable future. Examples for new methods and technologies in particular in the ICT domain are International Mobile Telecommunication (IMT) aka '5G,' (Massive) Machine-Type-Communications (MTC) aka Internet-of-Things (IoT), the 'S-100-World' and unprecedented PNT provision quality without a single mode of failure. Considering this, from a competent administration's point of view the question arises what trade-off there might be with classic aids. This paper brings relevant questions and resulting options to the fore in order to initiate further discussion.

KEYWORDS: optimal service mix of shore-provide services to shipping; Aids-to-Navigation provision; shipboard navigational aids; technological progress; Autonomous Vessel System (AVS); Remotely Operated Vessel (ROV); mixed vessel traffic; Inland Waterway Transport (IWT); e-navigation architectures; Nautical Datalink Communications; High Bandwidth Visual Light Communications; Maritime Architecture Framework; IALA Maritime Service Portfolio; Requirement traceability.

1 INTRODUCTION

The notion or even quest of an optimal service mix has been around for decades (compare e.g. [1]). This is the optimal selection of Aids-to-Navigation (AtoN), Vessel Traffic Services (VTS), Position-Navigation-Timing (PNT) provision, information services, and communication means in a given sea or waterway area provided from ashore for the safe, efficient and environmentally friendly navigation of individual vessels as well as of vessel traffic at large. With the advent of new methods and technologies on one hand and the arrival of new types of vessels such as autonomous and remotely operated vessels on the other hand, the question arises, what fresh options may be created for an optimal service mix in the foreseeable future. Examples for new methods and technologies in particular in the ICT domain are International Mobile Telecommunication (IMT) aka '5G,' (Massive) Machine-Type-Communications (MTC) aka Internet-of-Things (IoT), the 'S-100-World' and unprecedented PNT provision quality without a single mode of failure. Considering this, from a competent administration's point of view the question arises what trade-off there might be with classic aids.

This paper brings relevant questions and resulting options to the fore in order to initiate further discussion. To that end, the next two chapters address the question, why the quest for an optimal service mix is urgent again as seen from the shipboard side (second chapter) and the shore side (third chapter), the fourth chapter introduces criteria to assist in arriving at a future new optimal service mix – as a conclusion.

The term 'service mix' is used to designate all (generic) services together that are delivered from ashore to shipping. The service mix can be subdivided into topical domains or fields, and in this paper the domains of AtoN, VTS, and PNT provision are addressed specifically. The term is related to the term Maritime Service Portfolio (MSP), which was developed during the creation of the e-navigation strategy at IMO, but is wider in scope: A service mix may comprise any and all IMO defined Maritime Services (MS), but may contain additional services. While it is fully understood that services are provided eventually by operational and/or technical systems which in turn employ certain technologies, the term 'service mix' will be used instead of 'system mix' because the service mix delivery is what is required eventually at shipping, while it is irrelevant for the service recipients – humans and/or machines - what system mix has generated the individual services.

2 WHY THE QUEST FOR AN OPTIMAL SERVICE MIX IS URGENT AGAIN

The present author overlooks the developments in shipping's navigational domain for almost three decades now. The quest for an optimal service mix was there from the beginning of his career. Apparently, *this quest has not been resolved – despite much progress made in the meantime – and likely also because of the very same progress made over the period.* This chapter looks at certain factors of progress made and their implications. These factors are the progress of systemic understanding due to e-navigation, the progress of systemic understanding of shipboard systems used for navigation, the advent of the concept of the Autonomous Vessel System (AVS) and its implications regarding co-operative relationships, and – last but not least – progress in technology, proper.

2.1 Progress of systemic understanding due to e-navigation

With the advent of IMO's e-navigation strategy [2] and the term 'harmonisation' at its core, it was necessary to develop a systemic understanding for the harmonised development of the different entities involved, both shipboard and ashore. Thus, the 'overarching architecture for e-navigation' was developed and absorbed as a guiding principle [3]. Not only has this systemic understanding been accepted and used in the maritime domain, it also made its way into the related domains of Inland Waterway Transport (IWT) and River Information Services (RIS), too, with minor amendments only, thus demonstrating its relevance there as well (compare figure overleaf). It should be noted, that IALA's overarching remit comprises both the inland waterway and the maritime domains ([4], Art. 2); hence, it may be appropriate to demonstrate that uptake of IALA's work here as a recent example. At IALA, there have been created correlates to this overarching architecture in the process that will be introduced in a chapter below.

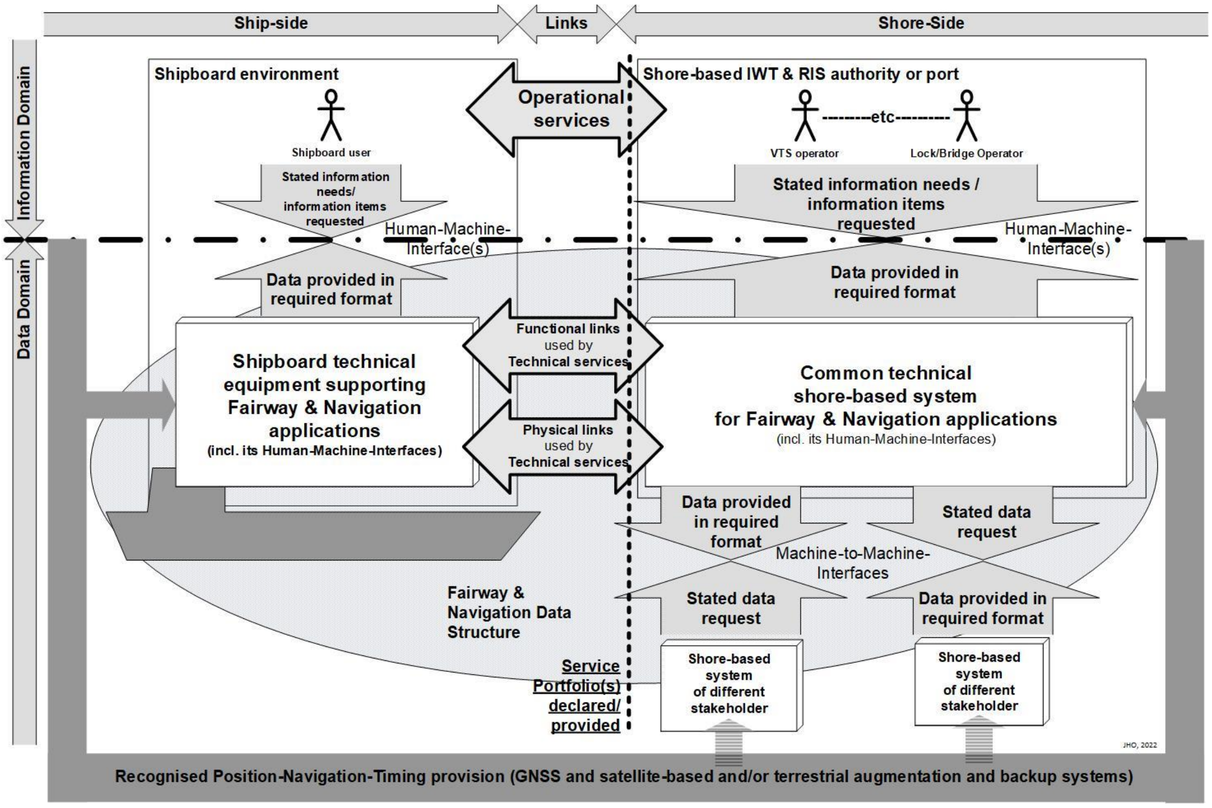

Figure 1: The overarching architecture, developed in the process of e-navigation, here adapted to the Inland Waterway Transport / River Information Services domain (Source: originally own creation, as amended; here from [5], Fig. 18)

2.2 Progress of systemic understanding of shipboard systems used for navigation, i.e. navigational aids

Traditionally, the shipboard functionality supporting the helm regarding navigation proper was labelled ‘navigational aids’, while the aid provided from shore infrastructure in that regard was labelled ‘Aid-to-Navigation’. *Trade-offs regarding the relative weight of navigational aids and Aids-to-Navigation for the navigation have always been an issue.*

There has been made considerable progress of systemic understanding of navigational aids as such and of their shipboard context, thus apparently increasing their relative weight. The following developments serve as examples for progress made over the past few decades up until recently.

‘To ensure effective decision-making and safe navigation [by the bridge team], the proper integration and presentation of information received (…) is essential’ ([6], 93; emphasis and brackets added). In full recognition of this, IMO has extensively addressed the harmonisation of a ship’s bridge layout in general,[1] but also down to the harmonisation of symbols on navigational displays. As a consequence, any generic architecture for shipboard navigation equipment needed to be embedded in the IMO stipulations for ‘Bridge Equipment and Systems, their arrangements and integrations (BES)’ [8], that – in turn – was arranged in accordance with the ‘Modular Concept’ previously defined by IMO to assist in that harmonisation task [9]: *Module A* – Configuration of work station: allocation and grouping of tasks; also references Bridge Alert Management; *Module B* – Arrangement and Design – Human-Machine-Interface: Bridge design, Layout and physical arrangement of workstations, design of bridge equipment; *Module C* – Fault tolerance: System failures and fall back arrangements; *Module D* – Interfacing: Data transfer; *Module E* – System configuration and integration; *Module F* – System and equipment documentation: System configuration, familiarisation.

1 Compare, for instance, [7] addressing ergonomic criteria for bridge equipment and layout.

This list alone brings to the fore a number of aspects that *continue to gain more and more weight with the increased usage of co-operative systems due to digitalisation*. In order to address these existing and further expanding issues more precisely, i.e. down to the level of functions and functional component, a more detailed architecture for shipboard navigation equipment was needed: During the preparation of the first edition of IMO's e-navigation strategy implementation plan, a generic architecture for the shipboard navigation system was created and submitted to IMO [10]; compare following figure.

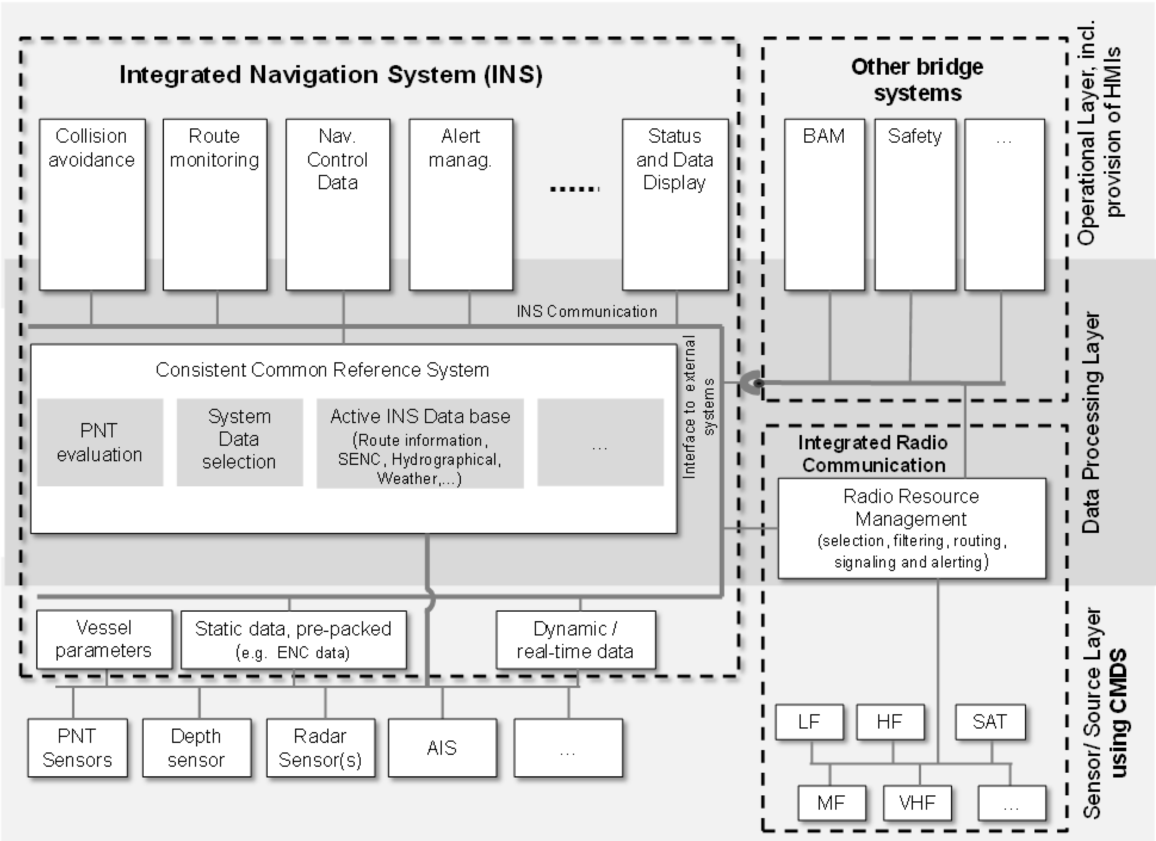

Figure 2: Generic shipboard navigation system architecture in the context of e-navigation[2]
(Source: [10], used with permission by IMO.)

Subsequently, a generic architecture for shipboard navigation equipment was *not* specifically adopted by IMO as such, however, because it was felt by then that its major components have been in place and described in relevant IMO instruments, thus being implicitly stipulated as a whole. While this is certainly true, the generic architecture for shipboard navigation equipment is introduced here since 'a picture sometimes tells more than thousand words' (compare Table overleaf).

More detailed key requirement documents for the navigational systems indicated above have been introduced up until recently as follows (but with no aspiration of completeness):

- 'Guidelines for the Standardization of User Interface Design for Navigation Equipment' [11], which was brought into force by [12].

[2] The reference to the Common Maritime Data Structure (CMDS) was introduced due to the e-navigation vision of a fully harmonised data structure in the context of the overarching architecture. Figure 1 (overarching architecture adapted to IWT domain) has 'Fairway & Navigation Data Structure instead of CDMS reflecting the IWT specifics while there is a major overlap between the two.

Table 1 Most fundamental structure of a shipboard navigation system architecture
(Source: own creation; here from [5], Table 10, amended)

Operational Layer (including Human-Machine-Interface (HMI) at 'helmsman's position') This layer provides the HMI to the bridge team to support their navigational tasks as indicated.
Data Processing Layer (including Machine-to-Machine (M2M)-interfaces to other shipboard systems of the same vessel) This core layer is specialised in processing, storing, and retrieving data relevant for the navigation of the ship, including the selection, filtering, and routing of the available physical radio communication links as well as the handling of all relevant alerts from navigational systems but also from other bridge equipment as received from Bridge Alert Management (BAM).
Sensor / Source Layer (including M2M-interfaces to the physical links) Here reside all shipboard sensors as well as the pre-processing entities for their data ('smart sensors') as well as the radio communication front ends to the physical radio links. This layer provides – generally speaking – the technical interfacing to the physical and operational environment of the ship.

- The 'Guidelines for the *presentation of navigational-related symbols, terms and abbreviations'* have been revised recently to bring them up to date to the latest developments [13].
- *'Functions that must be accessible by single or simple operation action'*, sometimes dubbed 'S-Mode' during the e-navigation strategy development, that aim at improving mode awareness are addressed in ([14], Appendix 4).
- The 'Guidelines for *Shipborne Position, Navigation and Timing (PNT) data processing'* [15] are explicitly referenced in the above guidelines for the user interface due to their importance of PNT for the operational tasks of the bridge team. This will be further discussed in the technology chapter below.
- The 'Interim guidelines for the *harmonized display of navigation information received via communication equipment'* [16] have as one focal point the integration of Maritime Safety Information (MSI) into navigation displays.
- The Integrated Radio Communication System (IRCS) was originally defined by IMO in 1995 [17], but within IMO's e-navigation strategy a task is scheduled on 'seamless integration of *all currently available communications infrastructure* and how they can be used (e.g. range, bandwidth, etc.) and what systems are being developed, along with the revised GMDSS (e. g. maritime connectivity platform) and could be used for e-navigation' ([3], Annex, Task 15, emphasis added), that likely will eventually lead to a revision of the relevant IMO documentation*. It should be noted, that this may be a tough task considering the technological progress of that domain specifically, as will be introduced below. This is emphasised because it is to the core of the topic at hand here.*
- The requirement base for *Bridge Alert Management (BAM)* was adopted by IMO in 2010 [18], and the technical standards for type approval were released by the International Electrotechnical Commission (IEC) in 2018 [19].
- 'Guideline on *Software Quality Assurance and Human-Centred Design* for e-navigation' have been introduced [20].
- Very important for keeping the relevant shipboard systems current regarding their software are the 'procedures for *updating shipborne navigation and communication equipment'* [21].

A comprehensive overview of shipboard navigation and communication equipment stipulations by IMO and of the associated international testing standards can be found in [3], Annex 4.

2.3 'Autonomous Ship System' and its 'wider context' instead of 'just' shipboard system

Parallel to the progress indicated above, *highly automated vessels, Remotely Operated Vessels (ROV)* or even *Autonomous Vessels (AV)* have arrived, and their broad deployment seems inevitable in the long run.[3] In an effort to internationally harmonise the vocabulary and thereby the understanding of these new categories of vessels, the International Organization for Standardization (ISO) has created the concept of an 'Autonomous Ship System' [22]: This systemic approach recognises that an AV/ROV cannot operate without specific support from both ashore and certain other vessels even if AVs are supposed to operate autonomously for a given period of time, as their name implies.[4] In keeping with the approach to render discussions here applicable to both ocean shipping and IWT, the term *Autonomous Vessel System (AVS)* will be used throughout (instead of Autonomous Ship System of ISO). The following figure illustrates the AVS using the epistemology established by the overarching architecture, introduced above, but also the ISO defined terminology.

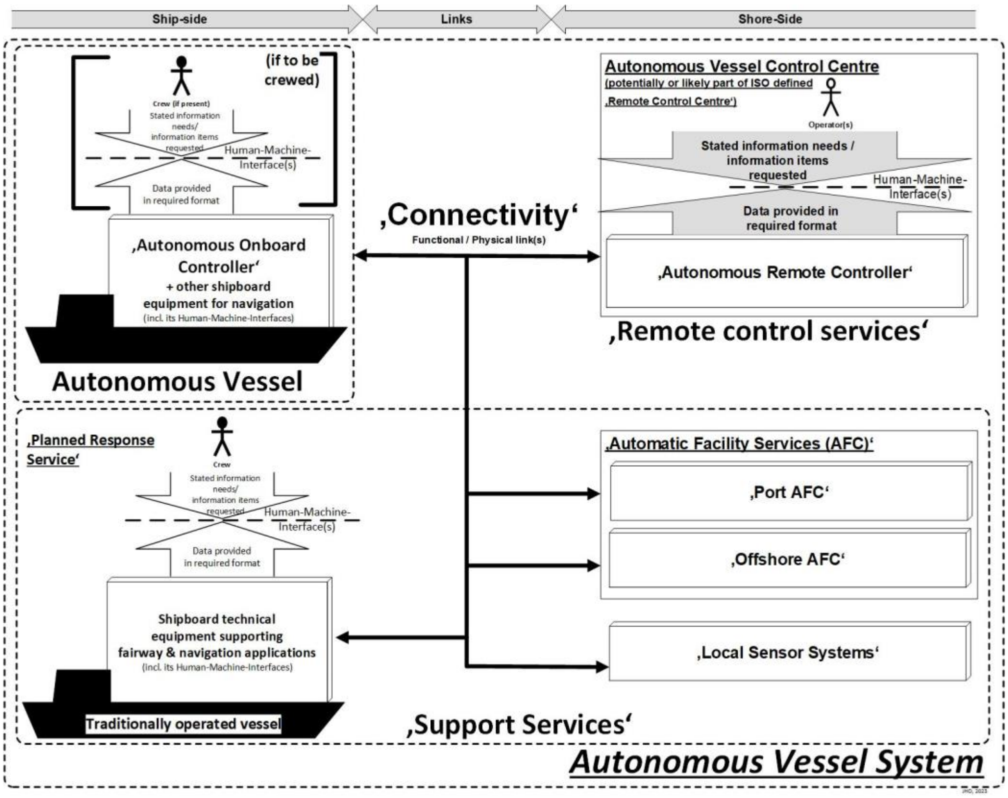

Figure 3: The Autonomous Vessel System (AVS) (Source: own creation; informed by [22], Fig. A.1, as given by quotes)

It should be noted, that the autonomous shipboard decision making functionality, the *'Autonomous Onboard Controller'* ([22], 3.2.4) in Figure 3 would reside in the Operational Layer of Table [1]: This layer provides the

[3] The most fundamental generic terms AV and ROV are used here, reflecting the applicability of the concepts discussed here not only to the maritime domain, but also consistently to the IWT domain: Many sea-going vessels also operate frequently in inland waterways, for example when approaching ports via estuaries or during canal passages, and vice versa. Further, the IALA defined system of AtoNs and the substantial relevant IALA recommendations and guidelines for its membership have been applied to both domains. Similarly, ISO and, as an example of an IALA peer organisation, the World Association of Waterborne Transport Infrastructure (PIANC) have the same comprehensive perspective. A universally applicable terminology will facilitate an emerging internationally harmonised understanding of the advent of AVs and ROVs in both the maritime and the inland waterway domains.

[4] Autonomy is confined to a period and/or to a defined operational scope, that is called *Operational Envelope* ([22], 3.1.3, note 2, in conjunction with Annex B).

HMI to the bridge team to support their navigational task for traditionally operated vessels. When applied to an AV, a dedicated HMI would no longer be required *during regular operation* but the 'Autonomous Onboard Controller' would take over.

Highly automated but traditionally operated vessels, AVS and ROV regularly don't operate in their exclusive waterway domain. From the perspective of a shore authority, there virtually always is a '*mixed target fleet'*, which has been around ever since, but which has been enriched by the advent of AVS, and ROV. Also, the *domain of shore centres* has been enriched by the advent of their associated centres. The following figure illustrates this situation. Explanations of this generic setup of relevant entities follow.

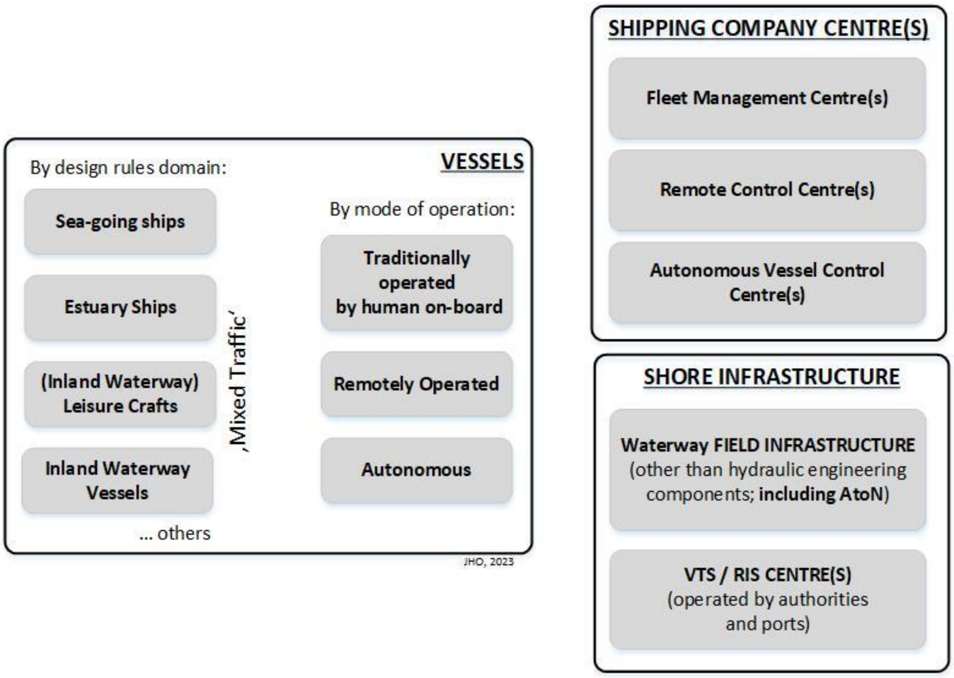

Figure 4: Overview of generic 'mixed target fleet' and different generic infrastructures and centres provided by shipping companies and shore authorities (Source: own creation)

- **Generic vessels by design rules domain** mainly are sea-going ships, estuary ships, leisure crafts, and inland waterway vessels. 'Design rule domain' means to say, that there are specific legal/regulatory bodies defining what a vessel of this rule domain should consist of and carry subject to a carriage requirement. Here, the present and/or future legal/regulatory situation regarding digital electronic equipment is of particular relevance, and that may differ in different rule domains, too.

- **Generic vessels by mode of operation:**
  - A traditionally operated vessel is a vessel the navigating functions of which are performed by a crewmember on-board by using appropriate *Human-Machine-Interfaces (HMI)* designed for that task. The degree of automation supportive of that task is encapsulated within the 'traditional operation' and is therefore irrelevant here as long as the on-board human master is in charge of the vessel's navigation.
  - A ROV is a vessel the navigating functions of which are performed remotely as the regular case from a *Remote Control Centre (RCC)* by a human at that centre. Whether a ROV is actually crewed or uncrewed is irrelevant in regards to its navigating functions as long as they are performed remotely as the intended regular case.
  - An AV is a vessel the decision-making and execution of navigation proper ('sailing') of which are performed autonomously in the strict sense of the word and as the regular case by an

appropriate machinery of the vessel itself without on-board or remote human interaction.[5] Whether the AV actually is crewed or uncrewed is irrelevant in regards to its navigating functions as long as the shipboard machinery performs them as the intended regular case. It likely will be required that AVs are subject to a constant *Autonomous Vessel Monitoring & Contingency Response functionality* performed at an *Autonomous Vessel Control Centre* while navigating autonomously. As part of the contingency response, an AV may fall back to become an ROV (or even a vessel traditionally operated by an on-board crew).

- Generic shipping company centres:
  - An *Autonomous Vessel Control Centre (AVCC)* is a shore-based centre that monitors and controls an AV as part of the AVS, as indicated in Figure 3 above, and is operated by or on behalf of the shipping company that also operates the AV. Since an AV, by its very definition, does not need a operation by crew or human remote control in regular cases, there will likely be a requirement that the AV is constantly monitored and contingency response is active in non-regular modes of operation or even malfunction of the AV. Hence, Autonomous Vessel Monitoring & Contingency Response is the main functionality to be performed by the AVCC. Since an AV may fall back to an ROV as part of the contingency response, the AVCC may also fall back to an RCC.
  - *A Remote Control Centre (RCC)* is a shore-based centre that performs the remote operation of an ROV and is operated by or on behalf of the shipping company that also operates the ROV. RCC appears to be an established term and is used here for that reason, although remote control, strictly speaking, may be limited in scope compared to remote operation.
  - The functions of the RCC and of the AVCC *can be merged in practical applications*.[6] The functionalities should be treated distinctly, however, reflecting the differences of remote control by a human and the autonomous decision making of a machine entity.

2.4 Emergence of a complex network of co-operative relationships

From the above it can be concluded, that the main impact of the advent of the AVS in the context considered here is that *the shipboard system of a vessel considered so far needs to be replaced conceptionally by the AVS.*

This in turn introduces a number of new operational relationships with other stakeholders:[7] The AVS *cannot be construed as an encapsulated entity from the perspective of the surrounding vessel traffic and vessel traffic management* as suggested by ISO, however,[8] because it comprises several entities being capable of *independently influencing the vessel traffic in a given area,* to a different degree each, though: But even if neglecting the 'planned response service' vessel, there obviously emerges a *network of co-operative communications relationships with unprecedented high complexity.* This is illustrated in the figure overleaf.

This network of communication relationships depicted generically in that figure comprises *operational relationships supported by functional links which in turn are supported by physical links,* the two latter of which are directly subject to technological developments as will be discussed in the following section.

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[5] ISO defines autonomy as 'processes or equipment in a ship system which, under certain conditions, are designed and verified to be controlled by automation, *without human assistance*' ([22], 3.1.3, emphasis added).

[6] This is indicated by ISO, by positioning the functionality of the 'Autonomous Remote Controller' into the RCC ([22], 3.2.5 and Figure A.1).

[7] This is recognised by ISO by their figure on the 'wider context' of the AVS ([22], Figure A.2).

[8] This is suggested by ISO ([22], Figure A.2) by drawing the AVS in a 'black box' fashion within its 'wider context'.

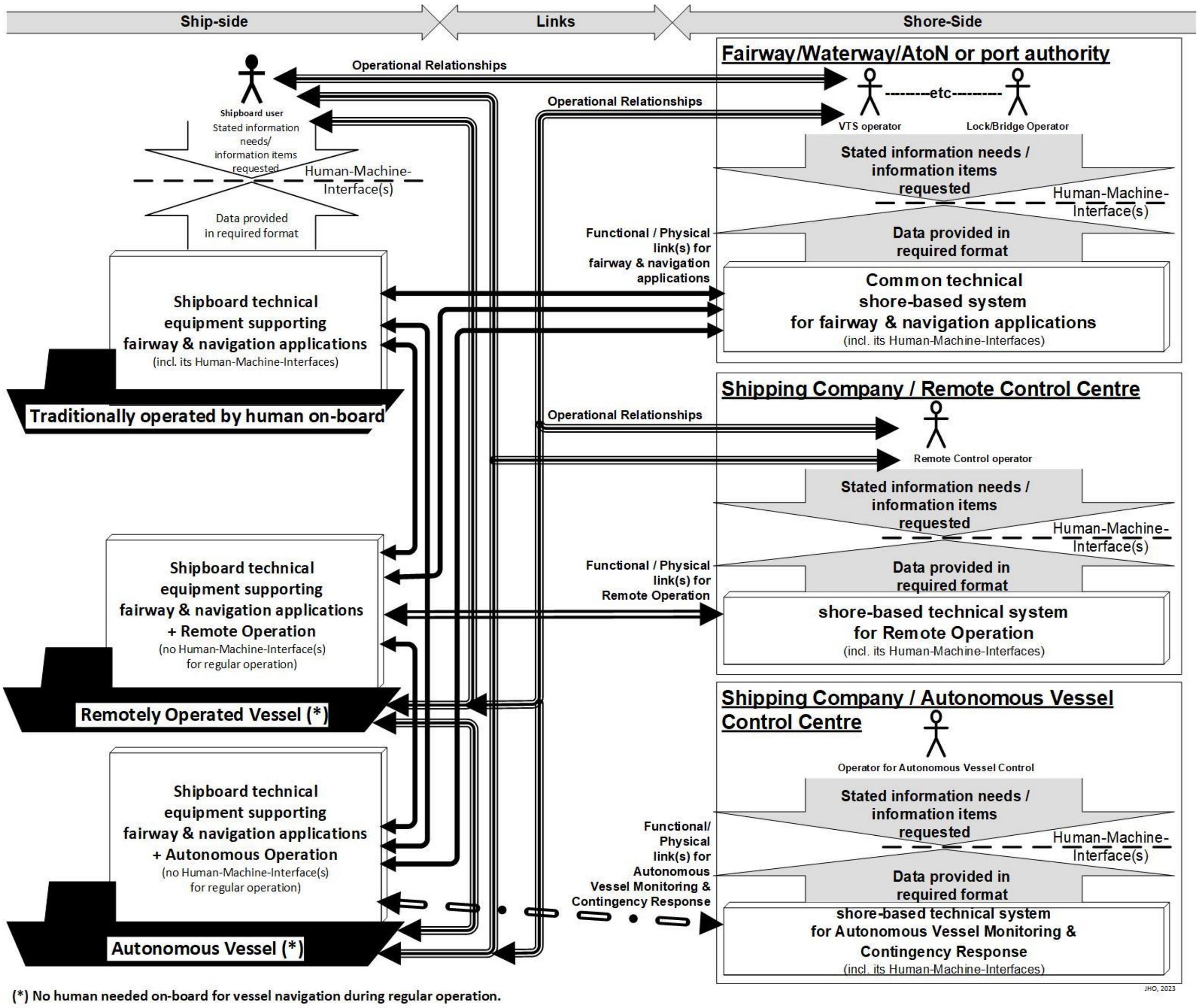

Figure 5: Generic operational relationships and resulting generic communications relationships
(Source: own creation)

2.5 Challenges due to the progress of individual technology families

Regarding the progress at technologies proper, in an overview manner specific *functional technology families* can be considered, all essentially co-operative in nature:

- Position, Navigation, Timing (PNT) by radio navigation technologies;
- Communication link technologies;
- Sensor technologies (including position sensor technologies other than radio navigation);
- Data modelling methods & technologies;
- Data evaluation methods & technologies.

These functional technology families are ordered in a functional 'bottom-up' fashion, i.e. considering the most fundamental functional technology family first, and functional technology families building and therefore relying on them later.

While it is not possible to introduce here all or even a comprehensive picture,[9] the need to re-visit the quest for service mix may be *illustrated* by the most fundamental functional technology families of the above, only.

2.5.1 Progress at Position, Navigation, Timing (PNT) by radio navigation technologies

Because PNT data is particularly important for all kinds of electronic navigation the most important progress lies with the development of a generic functional setup of the shipboard PNT equipment, by introducing the *shipboard PNT data processing entity* as a shipboard navigational aid.[10] IMO's *'Guidelines for Shipborne Position, Navigation and Timing (PNT) data processing'* [15] refer. They describe it as follows and as illustrated by Figure 6: "The shipborne provision of resilient PNT data and associated integrity (…) and status (…) data is realized through the combined use of onboard hardware (…) and software (…) components. The shipborne PNT Data Processing (PNT-DP) is the core repository for principles and functions used for the provision of reliable and resilient PNT data. The PNT-DP (…) is defined as a set of functions facilitating: (1) multiple sources of data provided by PNT-relevant sensors and services (e.g. GNSS receiver, DGNSS corrections) and further onboard sensors and systems (e.g. radar, gyro, speed and distance measuring equipment (SDME), echo-sounder providing real-time data) to exploit existing redundancy in the PNT-relevant input data; and (2) multi-system and multi-sensor-based techniques for enhanced provision of PNT data" ([15], paragrahs 2 +3).

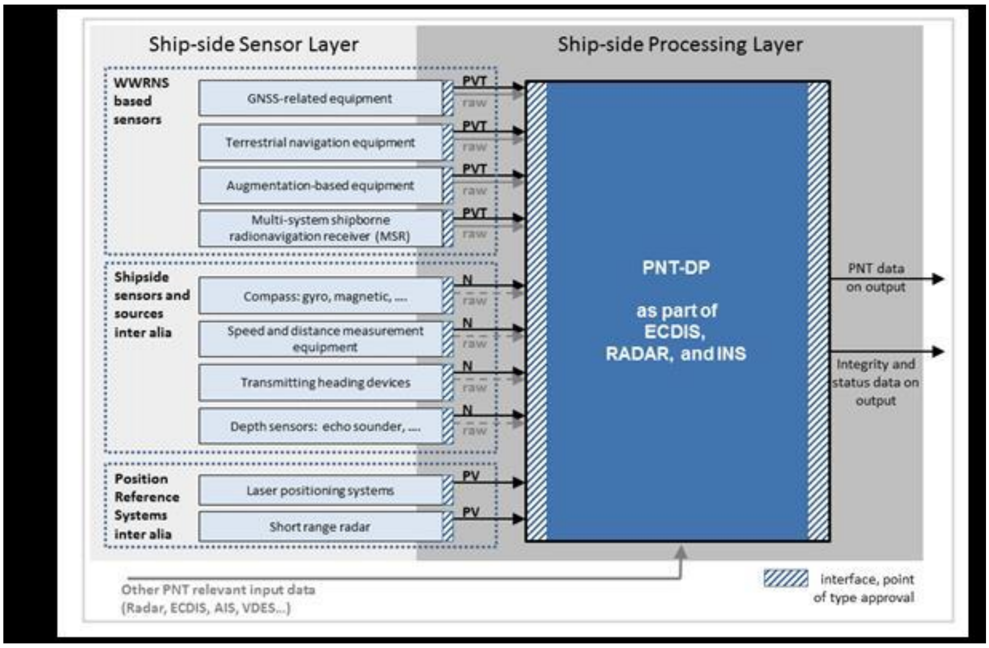

Figure 6: Shipborne PNT Data Processing (PNT-DP) integrated as software into INS, ECDIS, or Radar (Source: [15], Figure 2. Used with permission by IMO)

In the context of the generic shipboard navigation system architecture as introduced in Table 1, the two layers 'Ship-side Sensor Layer' and 'Ship-side Processing Layer' in Figure 6 are the same as the two lower layers in

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[9] Such an attempt was done recently as part of the EU co-funded project Masterplan Digitalisation Waterways (DIWA) from an IWT perspective. The publication of the findings is underway presently at www.masterplandiwa.eu.

[10] There has been made progress regarding individual kinds of shipboard radio navigation receivers, too, as follows: Considering the different individual radio navigation systems in use and recognised at the maritime domain, IMO developed performance standards for a shipboard radio navigation receiver that uses several satellite and terrestrial radio navigation sources as input, hence – *multi-system shipboard radio navigation receiver* ([23] and [24] refer). Considering the variety of recognised Global Navigation Satellite Systems (GNSS), IMO concluded to develop performance standards for a *Generic GNSS Shipboard Receiver* [25]. As opposed to the Shipboard PNT processing entity and the Multi-system shipboard radio navigation receiver, these IMO performance standards don't integrate different radio navigation sources, but simplify the GNSS related setup of shipboard PNT solutions.

Table 1 respectively. It is important to note, that the above IMO guidelines would be applicable to traditionally operated vessels and AV alike: The functionality of all layers would still be required, likely with higher demands on the PNT data quality even, in order to satisfy the demands of the Autonomous Onboard Controller.

2.5.2 Communication link technologies – summary of technological progress and issues at hand

Major progress has been made in the understanding of *communication profiles of an operational relationship* (as introduced in Figure 5): To know the communication profile of an operational relationship is *essential for selecting the most appropriate communication technology or technologies of any service mix* – the topic at hand. The following attributes are offered to constitute the communication profile (not exhaustive):

- *Direction of communication:* One-way or bi-directional.
- *Addressee of communication:* Broadcast (to everybody or a group) vs. individually addressed.
- *Confidentiality vs. timing of a transmission in relation to the time characteristics of an operational relationship:* These two attributes have become particularly important. Timing of a transmission in relation to the time characteristics of an operational relationship is essential for any real-time remote operation and/or control process, such as are required by ROV and AVS. This attribute means that the actual occurrence of the transmission would either be allowed a certain degree of latency while still being 'in time' for the time characteristics of the supported operational process itself; or be required to happen instantaneously without any sensible latency. *Ultra-low latency* would thus mean being synchronous with fast real-time processes.[11]

The following figure maps different radio communications technologies in a matrix mainly composed by the two latter attributes. The addressee(s) of the communication is incorporated, where this makes a difference.

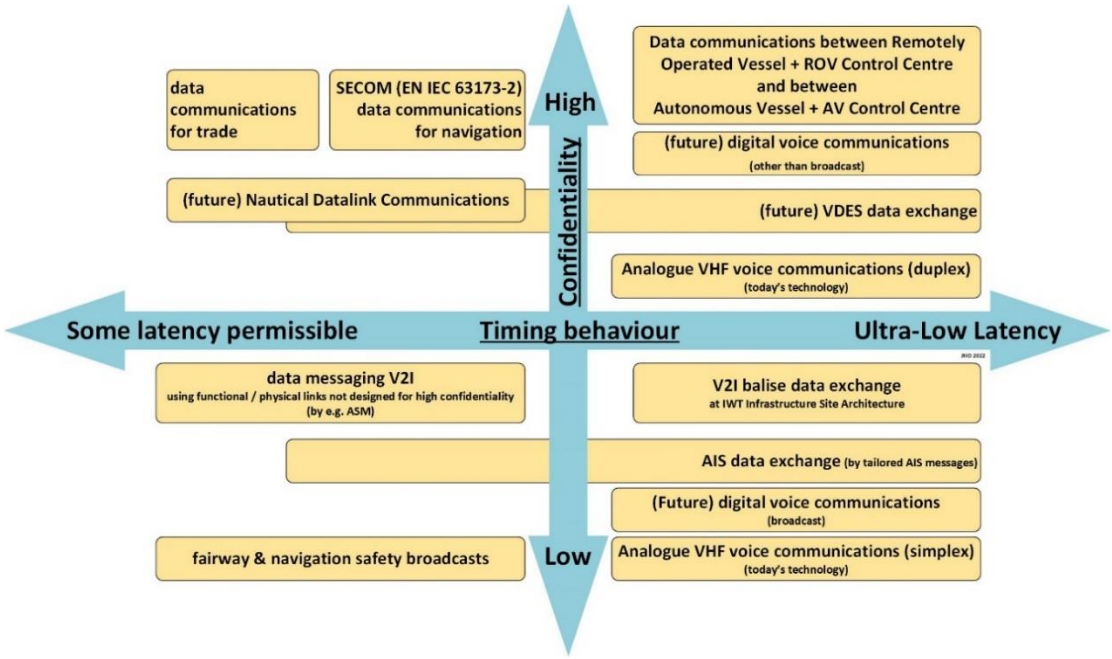

Figure 7: Confidentiality vs. Timing Behaviour in communication profiles
(Source: own assessment, informed by [26] and [27]).

Regarding the radio communication technologies proper, there has been made progress in several ways: There have been developed certain radio communication technologies, such as *VDES* and *NAVDAT*, that were tailored to the maritime domain from the outset and which could thus be called 'maritime specialties'; the AIS

11 The term 'ultra-low latency' apparently was first introduced when forming the vision for IMT-2020 (aka '5G') [26].

– another maritime specialty – has been steadily further developed culminating in a recent call for the *need of a 'consolidated view' of AIS* [28]. Also, although already raised as a topic at the times of the inception of the AIS roughly thirty years ago, the maritime domain recently has addressed the need to *introduce digital voice communication technology,* eventually: IALA was specifically instrumental by bringing the *maritime adaptation of two general purpose technology families* to the attention of IMO, namely *International Mobile Telecommunication (IMT)* and *Conventional Digital Land Mobile Radio (CDLMR)* ([29] and [30] refer respectively). Also, the *communication satellite domain* has progressed considerably, touching into the maritime domain in the contexts of the Global Maritime Distress and Safety System (GMDSS) and of the satellite components of both AIS and VDES, so far apparently only. In addition, the application of *Internet of Things radio communication technologies,* also called *(Massive) Machine-Type-Communications (MTC),* to the maritime domain have begun, namely by the IMT technology family again and by the technology family of the *Low Power Wide Area Networks (LPWAN).* This situation is sketched in the following figure.

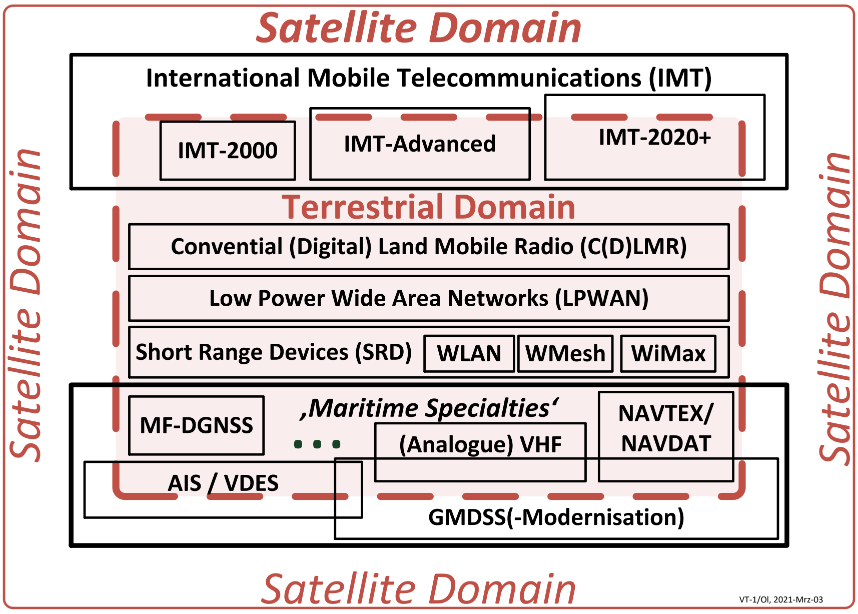

Figure 8: Overview radio communication technologies in the maritime domain based on the International Telecommunication Union (ITU)'s generic terminology (Source: own creation, [31])

Whether it could be called 'progress' that these developments have now rendered debates between different radio communication technology families competing for becoming *the* (potentially even mandated) means in the wet domains for the *same* operational purposes may be subject to personal taste; alas, 'Pandora's Box' has been opened. In the wet domains, these debate take place for example

- regarding the *(future) digital voice radio communications* (IMT family vs. CDLMR family),
- regarding *Machine-Type-Communications/Internet of Things applications* (IMT family vs. LPWAN family vs. Short Range Device (SRD) family), and also
- regarding the *transparent physical links for carrier-agnostic, containerised data messages* (such as Nautical Datalink Communications (NDLC; see below), Application Specific Messages (ASM), S-421 messages (IEC EN 63173-1), SECOM (IEC EN 63173-2) to name a few, only) (VDES vs. IMT family vs. SRD family vs. and LPWAN, to name a few, only, again).

It is no room here to go into any further detail of those debates (but compare [5]). Also, a certain range of communication profiles, that would prompt the continuous co-existence of certain otherwise incompatible technology families, may be justifiable. However, considering the time horizons involved in any transition from a present situation to a desired future situation in even only one of the above fields, including the need to cater for legacy systems and services*, a process to finalise the above debates productively as soon as possible* *should also start as soon as possible.* In any case, these debates are points in case for the topic at hand – the (future) optimal service mix; here indeed focussing on the underlying system mix, namely regarding radio communication technologies, proper.[12]

2.6 Intermediate conclusion

The above discussion substantiated the progress made in the domain of navigational aids in the past few decades, even – on one hand – to the extent of challenging any future role of shore-provided services *within IALA's remit*, namely in the AtoN and VTS domains. On the other hand an increasing number of co-operative technologies employed would increasingly require a counter-part for proper operation – be it either other vessels of the 'mixed target fleet' or shore-provided services. But here, *these shore-based service providers would not necessarily be the AtoN/VTS authorities as assembled at IALA:* As a general tendency, it can be observed, that services building on co-operative technologies introduced above are or may increasingly often not (likely) be provided by an AtoN/VTS authority. Increased co-operation between shore-based service providers may be a consequence, likely to further increase in the future. The advent of AV/ROV is adding to this considerably.

3 PROGRESS AT SHORE-PROVIDED SERVICES WITHIN IALA'S REMIT

The basic question at hand is why the quest for an optimal service mix is urgent again. In the previous chapter it has been demonstrated that the navigational aids domain has made considerable progress in several regards leading to the above intermediate conclusions. It is of course self-evident that the progress of technology has been adopted by the shore-side as well: Of course, the general ICT progress has been adopted as was a lot of technological progress in the design and operation of both AtoNs and VTS in detail: AtoN lanterns still emit their visual signals as before, but they use LED technologies nowadays; VTS employ radar still to gather vessel traffic images, but that radar now uses solid state technologies; this list may be continued. Their common point is *that technological progress was and is implemented, keeping AtoN/VTS administrations busy in doing so, while 'only' maintaining a steady state in service mix provision. And **that steady state may be outpaced** by the above developments in the navigational aids domains in the long run.*

Hence, this chapter looks specifically at those factors of progress made at shore-provided service domain within IALA's remit *that **added** or have the potential to **add fresh implications** for the question at hand.* Luckily, some factors can be identified, and again, this is not intended to be a concluding list. Similarly to the previous chapter, these factors are the progress of improved architectural understanding due to e-navigation and certain relevant technology developments.

3.1 Improved architectural understanding at shore side, too

As a consequence of the adoption of the overarching architecture by IMO, the need emerged to have an internationally harmonised eco-system for technical shore systems in place *capable of seamlessly incorporating new functionalities* stemming from e.g. e-navigation as well as operating and further developing classic services, while specifically taking into account the demands of long-term technical operation. Therefore, life-cycle management considerations feature prominently. Hence, IALA started with the development of a 'common shore-based system architecture' – both in a broad generic sense and in a sense of a more specific architectural solution, then labelled Common Shore-bases System Architecture (CSSA). IALA's work in this regards is geared towards those of its members, most often national authorities, that deploy and operate shore systems or technical services of various kinds – ranging from visual aids-to-navigation via PNT and radio communication services to VTS, to name a few – and need to continue to do so even with the advent of new technologies and the legacy issues associated with phasing-out classic one, if at all possible. The necessary architectural framework to achieve that is a three-layered service-oriented

12 A potential way out regarding the radio communication domain is described in [32].

architecture geared towards the data/information flow implied by the overarching architecture and therefore functionally similar to the three-layered shipboard navigation system architecture. The top level structure of the CSSA is illustrated in the following figure, where the arrows indicate data/information flow between its different functional components.

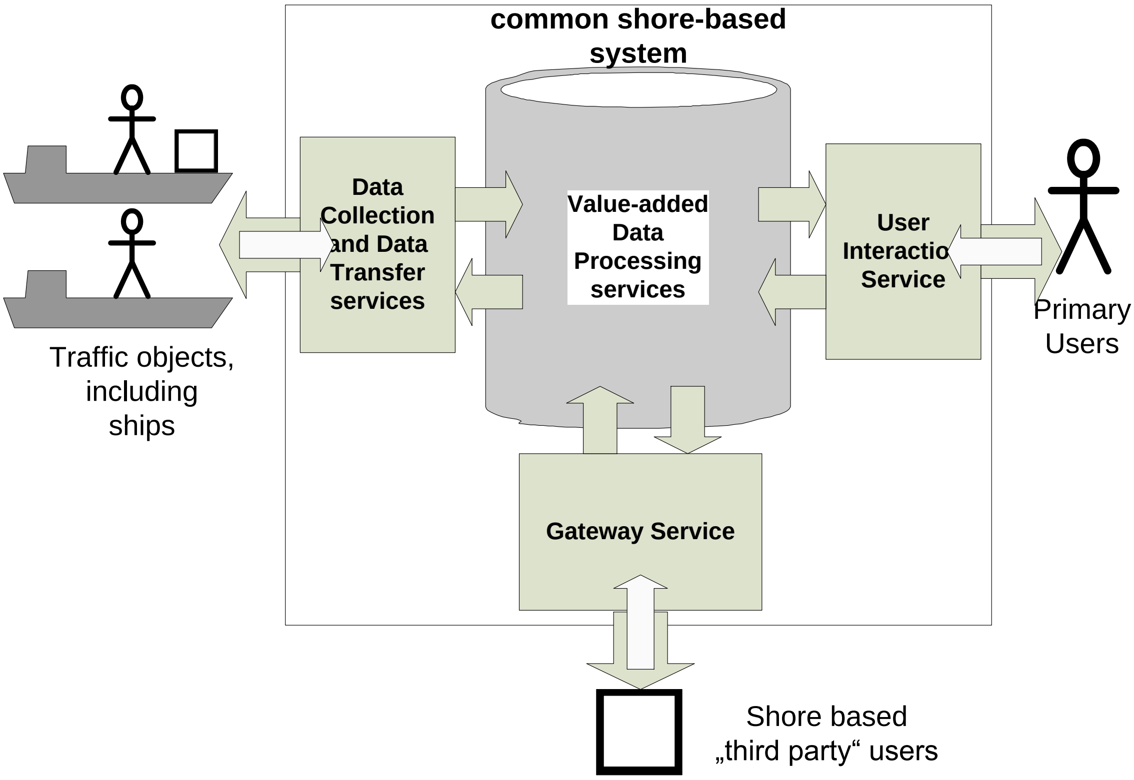

Figure 9: Structural overview on Common Shore-based System Architecture (CSSA)
(Source: originally own creation, as amended; here from [36], Figure 2)

The group of *Data Collection and Data Transfer services* interface with the waterway, the traffic objects including vessels, and with the physical environment. Their data is pre-processed, evaluated and stored in the *Value-Added Data Processing services* with the purpose their very name implies. They are the data/information core of the CSSA. Via the *Gateway Service* data can be exchanged with systems of other shore-based stakeholders and with any kind of external information and/or telecommunications or internet providers. The *User Interaction Services* finally provides the HMI to those operators in centres operated by authorities that also operate the shore system, hence their ‘primary users’. Besides the introduction of the CSSA in IALA’s NAVGUIDE for a general audience ([33], 74-76), – over the course of more than a decade by now – IALA has described further details: [34] introduces general and generic and yet precise recommendations for authorities when planning, deploying and operating a shore system. The CSSA is introduced in [35], resulting in a generic technical specification for the CSSA in [36], including the many different generic technical services potentially populating an administration’s instance of CSSA; they are described therein frequently with an outlook into the future still awaiting fulfilment today. Technical services listed there need to be tailored to the authority’s needs at hand, and technical services not foreseen presently can be introduced in due course due to the versatility of the service-oriented architecture employed.[13]

[13] IALA maintains two different notions of a ‘technical service’ in their documentation: Firstly, a technical service as deployed by an authority along the waterway comprising layered hardware such as radio front ends and base stations and processing stages, as well as software to provide the data gained to other services; this notion of a technical service

3.2 Increased need of datalink communications – for AtoN and VTS alike: the Nautical Datalink Communication (architecture)

An even more fundamental architecture underlies the overarching architecture (compare Figure 1) which reflects the entities involved in an operational relationship when it comes to communication: mobile side – infrastructure side – links in-between. This *'three-sides-of-the-coin architecture'* shows the vessel under consideration, being traditionally operated by a human, a human operator in one operational centre, and how the communication in-between is done by a *datalink* as the default means and – *in addition* – by voice ('words of mouth'). This most fundamental architecture thus can be called a *datalink communications architecture.* A datalink communications architecture may be employed without labelling it that way. The defining point of a datalink communications architecture is, that it includes the *full chain of the data flow from its ultimate source* – in the case of a human entered by a (dedicated) HMI – *to its ultimate destination ('sink' in ITC parlour)* – in the case of a human displayed on a (dedicated) HMI again. *The interfaces to the ultimate sources or sinks of the data are thus integral parts of the datalink communications architecture and are thus consciously reflected in datalink applications*. This is illustrated in the following figure.

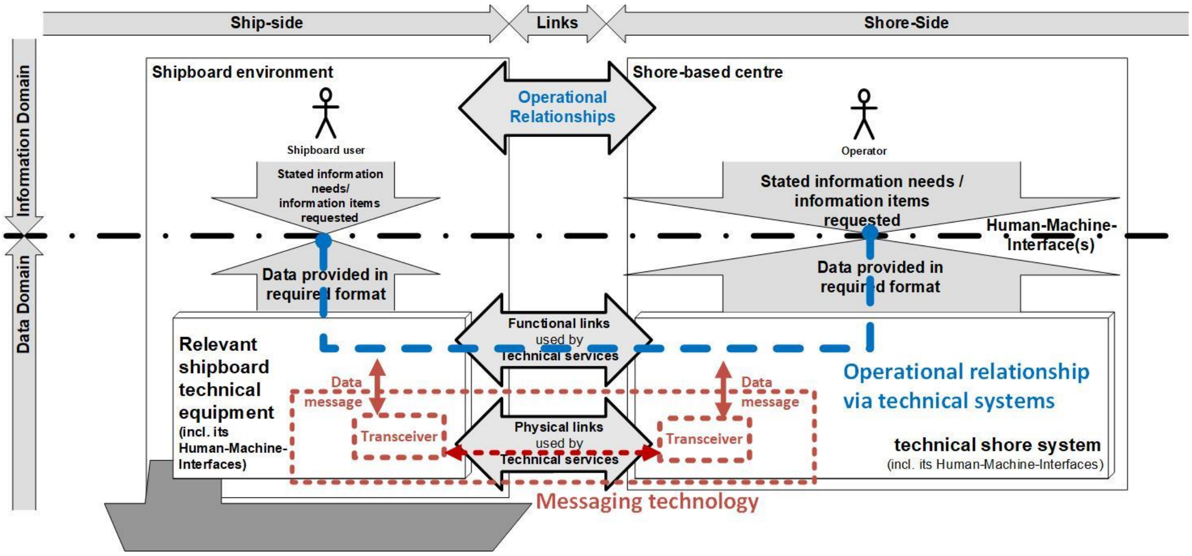

Figure 10: Voice and datalink communications implied by overarching architecture (Source: own creation)

At maritime, datalink communications have been used for decades now, *without labelling it that way:*

- In the context of the GMDSS and there in particular by means of the terrestrial *Digital Selective Calling (DSC)* technology: In case of an emergency, a human member of the shipboard bridge team presses an alert button at a *dedicated HMI,* which initiates an emergency call via the DSC datalink communications to be displayed on another *dedicated HMI* at the receiving station (another ship, shore centre) to a human on the watch, who then may reply via datalink communications and/or voice and take further search & rescue actions, as appropriate.
- In the context of the AIS, a dedicated HMI labelled '*Minimum Keyboard & Display (MKD)'* was included as an integral part of an AIS shipboard station for sea-going ships subject to the SOLAS mandatory carriage requirement from the beginning, thus allowing for the full communication chain to be covered, at least in ship-ship AIS-datalink communications. The wish to integrate the

is employed here. The other notion of a 'technical service in the context of e-navigation' is a pure software-based functionality interacting via internet with platforms like and in particular the Maritime Connectivity Platform (MCP); this notion of a technical service is described in [37]. Both notions co-exist and can thus be reconciled (compare IALA ENAV17-10.4.2, section 3.4).

AIS data into shipboard HMIs which are much more powerful than the MKD, such as *Integrated Navigation Systems (INS),* was there from the beginning, too. However, as opposed to the MKD, this dataflow integration from *a shipboard HMI other than MKD* to the shipboard AIS station was not made mandatory by IMO up to present. This deficiency may also be one of the main reasons for ASM not being used to their full potential, although they have been defined for extensive bi-directional datalink communications.

With the advent of e-navigation, this long established notion of maritime datalink communications *has been generalised and made foundational* to the overarching architecture, *not* excluding voice communications conceptually, however. Thus, a datalink communications architecture is underlying the IMO adopted overarching architecture, as explained in e.g. [35]. In this context, it may be helpful to learn from a different mode of transport with at least as stringent safety requirements as maritime and/or IWT.

Aviation has gone much further by implementing the datalink communications architecture conceptually for operational relationships in *Air Traffic Control (ATC)*: The full chain covered by the datalink communications architecture from the ultimate source of data – e.g. an air traffic controller at an ATC centre – to the ultimate sink of data – e.g. at the cockpit crew - has been used operationally for several decades now in an ATC system called *Controller Pilot Datalink Communications (CPDLC)* ([38], [39]). It comprises *dedicated HMIs* on both sides together with an internationally standardised but essentially *carrier-agnostic* datalink technology for the functional links, which in turn are using as physical link(s) one or more radio communication technologies such as aviation VHF for short range, or HF and/or communication satellites for long range. The CPDLC was designed to remove the need for voice communications in ATC – a safety application with very high standards! – in *routine* use cases for several strong reasons to the maximum extent possible and use voice communication for the critical use cases remaining. Hence, CPDLC should *not* be construed as even attempting to render a *voiceless* ATC, but *rather renders a 'voicelesser'* ATC*.* The operational use of CPDLC for several decades now in regions with high air traffic density has proven that this intention works even in safety applications with very high standards.

CPDLC – and its underlying datalink communications architecture - may thus be an example for the wet domains: ***With the advent of highly automated vessels and AVs, the need emerges to have machines communicate with each other and/or with humans,*** as demonstrated in Figures 3 and 5 above: Thus the initial need to communicate via datalink and thus voiceless amongst the machines and voicelesser whenever humans are involved does not appear by intent of system designers, but as a consequence of the advent of above vessels. The conclusion to be drawn is, that *the* ***wet domains should adopt their variety of datalink communications as systematically as aviation did,*** *too.* The wet domains' variety of the datalink communications henceforth is called ***Nautical Datalink Communications (NDLC)***, and the human-to-human case – abbreviated *H2H-Nautical Datalink Communications (H2H-NDLC)* was already illustrated in above Figure 10. Within the datalink communications architecture, ultimate data source can be a machine and ultimate data sink can also be a machine. This leads to the recognition of *Machine-to-Machine Nautical Datalink Communications (M2M-NDLC)* and *Human-to-Machine Nautical Datalink Communications (M2H-NDLC)*, the latter of which would be a common name for the human or machine on either end. Compare following figure. ***Within IALA's remit, both AtoN and VTS would be well positioned to embark on that transformation: AtoNs, being machines by very definition, by implementing M2M-NDLCs with automated vessels, AVS and/or ROV, and by implementing M2H-NDLCs with shipboard crew; VTS by implementing all three varieties in parallel.***

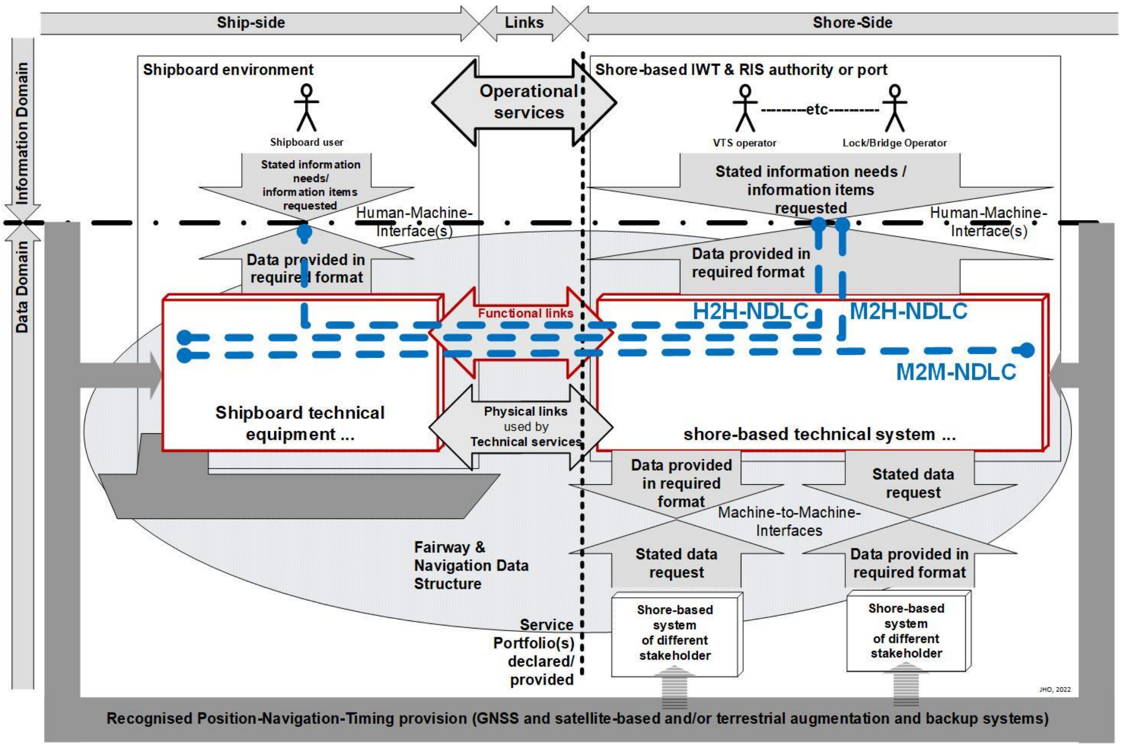

Figure 11: Nautical Datalink Communications (NDLC) highlighted in overarching architecture (Source: own creation)

It is important to note, that the datalink communications architecture is *carrier-agnostic* by definition, thus rendering several different physical links possible for application. Turning now to the contents of that NDLC based communication, it may be safely assumed, that there are today many operational phrases routinely used in day-to-day voice communications in operational relationships in VTS, in particular between a centre and vessels, even if they have never been collected systematically. In the maritime domain, IMO has collected and published the 'Standard Marine Communication Phrases (SMCP)' [40]. There are available translations into other languages than English. The SMCP would certainly serve as a starting point for the first step, namely the *collection* of the content (phrases) of the NDLC based communication both in VTS and AtoN domains. As a second step, the *operational contexts* of the content (phrases) identified need to be established, i.e. which functional entities are involved in what operational relationships.[14] In a third step the *operational concepts* expressed by the operational phrases in them are described in a *structured data model* which conforms to the demands of consecutive encoding. In a final step, based on the structured data model, the relevant operational phrases need to be *encoded in messages for NDLC functional link transmission*.

3.3 Classic AtoNs not just for signals to humans – High Bandwidth Visual Light Communications

Communication by light signals with the human eye as recipient has a very long history in the Aids-to-Navigation domain. Recently, due to an entirely different motivation, ITU has conducted a survey on the emerging technology enabling 'short distance broadband communication via visible light' ([42], para. 5), which

[14] Potentially learning from rail: As a preparation to their adaptation of a general purpose digital radio communication system and as a starting point for determining their user requirements, the International Union of Railways (UIC) as the organisation responsible for setting global standards for rail operations and rail-specific technologies has established the operational contexts of any and all communication ([41], Figure 1 'Application Layer Relationship Diagram' *in just one page*).

precisely expresses the idea.[15] This is labelled '(near) visible light communication (VLC)' or alternatively 'Optical Wireless Communication' ([42], para. 1). Use cases of relevance here are identified as follows ([42], para. 3.4), most of which are self-explanatory:

- 'Location-based services / indoor positioning and navigation' - VLC would be an option to support PNT.
- 'Vehicular communications' and 'Point-to-(multi)point/relay/communications' – this implies both Vessel-to-Vessel as Vessel-to-Infrastructure (AtoN and/or VTS!) options.
- 'LED based tag applications' – when either a vessel carries such a tag it can be detected as 'being there' (by another vessel or by an infrastructure sensor) or vice versa when an infrastructure position can be detected as 'being there' by a vessel, this may offer interesting options for in particular the automation of (inland) waterways. Slightly more specifically but still relevant would be the use case: 'Digital signage and location based content delivery'.
- 'In-Vehicle data services (flight, train, ship, bus, etc.)' – there may be options for local VLC link e.g. in the bridge or wheelhouse.
- 'Connected-cars and Autonomous Vehicles'– in the wet domains this would be highly automated vessels and AV/AVS.
- 'Underwater/Seaside Communications'
- 'Internet of Things (IoT)'.

Hence, wherever data must be exchanged in *short* distances in spot-like situations between a fixed and a moving position, which is often the case in the wet domains when 'under land', VLC may offer an emerging solution, even it is only 'one bit' – namely the detection of presence of an (expected) object. But also, vessel to vessel data exchange at short distances might be an option specifically in approaches and (inland) waterways with their regularly close encounters. Finally, the motivation to shift communications from a radio link to a visual link may be helpful also for the domains in the light of the congestion of the VHF Maritime Mobile Service frequency band. For the application in the outdoor domain, the requirements to be met by any VLC application are given as 'coexistence with ambient light [and] coexistence with other lighting systems' ([42], para. 3.4). Since a number of products and application domain projects employing VLC are given worldwide ([42], para. 5.4), and standardisation is under way already, it may be assumed that the VLC technology as such reaches a maturity level of 'testing prototype in user environment' when considering a potential adaptation to the wet domains. This implies also, that existing VLC modules may be applied to the wet domains readily.

With this technology potential assessment in mind, it may be concluded, *that introducing light for M2M communications by* ***using IALA's well established AtoN asset domain*** *may provide fresh options* not only to the AV / ROV but also to traditionally operated vessels at whatever degree of automation. The *combination of VLC from AtoNs used as a carrier for NDLC might be a strong combination, even.* ***IALA is thus invited to investigate the options of using VLC to the ends introduced here.*** As a starting point a more elaborate discussion of this can be found in [43].

[15] 'Visible light optical wireless access data rates ranging from a few b/s to excess of 10 Gbit/s are possible at standard indoor illumination levels. VLC has the potential capability to ease congestion with low radio frequency (RF) spectrum bands since light spectrum can be used as an additional spectrum resource for broadband communications.' ([42], para. 3.1).

4 SOME CRITERIA FOR AN OPTIMAL SERVICE MIX

So far the question was, *why* the quest for an optimal service mix is urgent again. With that knowledge in mind it is now necessary to determine some criteria for a future optimal service mix. Here are some such criteria offered, while no aspiration is made regarding completeness.

4.1 Optimal regarding 'completeness in minimum' – the 'complete minimum scope'

A complete minimum set of operational and functional requirements ***must*** be determined for those services within IALA's remit that need to be provided from ashore by AtoN and VTS authorities, taking into account also the advent of AVS and ROV as part of the future 'mixed target fleet' as shown above: If not developed and imposed a minimum set of functional requirements for each and every domain, ***every stakeholder can rely on for application planning,*** then the nice looking technology solutions (proprietary or even standardised) will end up in a global 'Flickenteppich' (patchwork) which may apparently be a 'clondyke' situation for some, but eventually a nightmare for most (stakeholders).

The (desirable) side effects of doing this, are:

- A new or renewed balance between navigational aids and AtoN/VTS/PNT shore provision can be found in specific requirement terms.
- A relatively precise responsibility distribution between shore-based stakeholder organisations can be defined. It may be assumed that this may assist IALA to sharpen its focus on its core business (AtoN/VTS/PNT provision) in the process.

Some ***tools*** for arriving at a new 'complete minimum scope' are available at IALA, already: The need of ***requirement traceability*** has been recognised and expressed together with a feasible methodology in [44]. The ***Maritime Architecture Framework*** ([33], 71-74) may greatly assist in capturing the operational and functional requirements as of today, but also when creating a new complete minimum scope. Finally, the notion of the Maritime Services, that is fully compatible with the above, may be helpful, too, in particular in a future attempt to specify the IALA remit in terms of a ***(IALA) Maritime Service Portfolio*** in – by then – no imprecise terms.

4.2 Optimal regarding 'complete minimum standardisation and regulatory coverage'

Following directly out of above 1st criterion, the (fresh) complete minimum scope eventually determined by working on above 1st criterion needs to be translated into a 'level playing field' in the regulatory domain and into standardisation regarding the operational procedure and machine domains to become effective.

4.3 Optimal regarding 'quality of service provision'

IALA's remit *may seem* to be limited, and above it was argued to sharpen IALA's focus again on it. But a third criterion for a new service mix would render even that as a challenge: Whatever will be offered in terms of the new service mix should meet the highest standards for quality, i.e. what is offered should be optimal in quality. This may include graded levels for different quality of service provision, which in turn would complement the emerging automation grades for highly automated vessels and AV/ROV, once consolidated.

4.4 Side considerations

Mechanism must be built in to keep that complete minimum scope under review and thus incorporate future innovations. The steady-state organisational implementation of a properly understood Plan-Do-Check-Act cycle may assist in this regards.

ACKNOWLEDGEMENTS

I am particular thankful for the many intense discussions with colleagues at the DIWA project over the period of the past two years, that provided an ‘incubation chamber’ for some of the ideas presented here and that have been fruitful for the understanding of the maritime domain better, although or maybe even because of the perspective from another mode of transport. Also, I am thankful to IMO for granting permission to reproduce their figure from [15] here. Regarding the materials of the International Maritime Organization (IMO) used in this report, please note the following: “Materials are reproduced with the permission of the International Maritime Organization (IMO), which does not accept responsibility for the correctness of the material as reproduced: in case of doubt, IMO's authentic text shall prevail. Readers should check with their national maritime Administration for any further amendments or latest advice. International Maritime Organization, 4 Albert Embankment, London, SE1 7SR, United Kingdom“.

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S1.5 The importance of visual Aids to Navigation in the era of high technology and automation in Brazil (165)

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ABSTRACT

With the remarkable advent of technology and automation in several areas that affect our daily lives, there is a progressive tendency to abandon simpler methods, systems and concepts, which continue to fulfill their function and have as main advantage the ease of understanding and greater accessibility by most users. The issue that encompasses the theme is that in certain areas, technology should not replace traditional methods, but at the same time, it can be well applied when complementing them. From this idea, the present work aims to evaluate how far the advancement of digitalization and automation is beneficial when analyzing its applicability in aids to navigation (AtoN), especially with regard to its application to visual AtoN, which are indispensable for the safety of navigation. Emphasizing its application in restricted and sheltered waters, in an expository way and reviewing the existing literature of some stakeholders involved with the safety of maritime transport (Maritime Authority, Port Authority, IALA, IMO, Pilotage etc) this text aims to evaluated some advantages and disadvantages of some new AtoN systems. The conclusion found only reinforces how much visual aids to navigation, fixed or floating, continue to be indispensable for navigation safety, and it is up to the Maritime Authority to analyse new projects and adapt emerging technologies to the national reality.

KEYWORDS: Aids to Navigation; virtual aids to navigation; maritime buoyage; autonomous ship; navigation safety; technology.

RESUMEN DEL ARTICULO

Con el notable advenimiento de la tecnología y la automatización en varias áreas que afectan nuestra vida diaria, existe una tendencia progresiva a abandonar métodos, sistemas y conceptos más simples, que siguen cumpliendo su función y tienen como principal ventaja la facilidad de comprensión y mayor accesibilidad por parte de los usuarios por la mayoría de los usuarios. Así, el tema es que en ciertas áreas la tecnología no debe reemplazar a los métodos tradicionales, pero al mismo tiempo puede ser bien aplicada al complementarlos. A partir de esta idea, el presente trabajo pretende evaluar en qué medida es beneficioso el avance de la digitalización y la automatización al analizar su aplicabilidad en las ayudas a la navegación (AtoN), especialmente en lo que se refiere a su aplicación a las AtoN visuales, indispensables para la seguridad de la navegación. Haciendo énfasis en su aplicación en aguas restringidas y abrigadas, de manera expositiva y revisando la literatura existente de algunos actores involucrados con la seguridad del transporte marítimo (Autoridad Marítima, Autoridad Portuaria, IALA, IMO, Practicaje etc) este texto pretende evaluar algunas ventajas y desventajas de algunos nuevos sistemas AtoN. La conclusión encontrada no hace más que reforzar cuánto las ayudas visuales a la navegación, fijas o flotantes, continúan siendo indispensables para la seguridad de la navegación, y corresponde a la Autoridad Marítima analizar nuevos proyectos y adaptar las tecnologías emergentes a la realidad nacional.

PALABRAS CLAVE: Ayudas a la navegación; ayudas virtuales a la navegación; balizamiento marítimo; barco autónomo; seguridad en la navegación; tecnología.

RESUME DE L'ARTICLE

Avec l'avènement remarquable de la technologie et de l'automatisation dans plusieurs domaines qui affectent notre vie quotidienne, il y a une tendance progressive à abandonner des méthodes, des systèmes et des concepts plus simples, qui continuent à remplir leur fonction et ont comme principal avantage la facilité de compréhension et une plus grande accessibilité par la plupart des utilisateurs. La question qui englobe le thème est que dans certains domaines, la technologie ne doit pas remplacer les méthodes traditionnelles, mais en même temps, elle peut être bien appliquée en les complétant. A partir de cette idée, le présent travail vise à évaluer dans quelle mesure l'avancement de la numérisation et de l'automatisation est bénéfique lors de l'analyse de son applicabilité dans les aides à la navigation (AtoN), en particulier en ce qui concerne son application aux AtoN visuels, indispensables à la sécurité de la navigation. . En mettant l'accent sur son application dans les eaux restreintes et abritées, de manière explicative et en passant en revue la littérature existante de certains acteurs impliqués dans la sécurité du transport maritime (autorité maritime, autorité portuaire, AISM, OMI, pilotage, etc.), ce texte vise à évaluer certains avantages et inconvénients de certains nouveaux systèmes AtoN. La conclusion trouvée ne fait que renforcer combien les aides visuelles à la navigation, fixes ou flottantes, restent indispensables à la sécurité de la navigation, et il appartient à l'Autorité Maritime d'analyser les nouveaux projets et d'adapter les technologies émergentes à la réalité nationale.

MOTS CLÉS: Aides à la navigation ; aides virtuelles à la navigation; balisage maritime; navire autonome ; sécurité de la navigation ; technologie.

1 INTRODUCTION

With the notable development of technology and the application of automation in various areas that affect our daily lives, there is a progressive tendency to abandon simpler methods, techniques and equipment, often considered outdated by many users. As an example, we can mention the modern navigation devices, which in a single display gather several useful information to the navigator in a dynamic way and in real time, helping him during his decision-making, which is not possible when using paper nautical charts.

Although navigators rely more and more on these modern systems as a primary source to obtain their positioning, it is common, and often recommended or mandatory, to keep a supply of paper nautical charts on board and plotting the position in a conventional way. This practice makes it possible to confirm the position provided by the navigation aids systems, providing redundancy in navigation and thus working as a valuable form of back up in case of equipment failures [1]. Such an example aims to illustrate how not depending on complex systems can have notable advantages in certain situations.

Within this scope, considering a similar situation when observing technological advances in the context of marine aids to navigation (AtoN), it is worth highlighting the important role of traditional visual (or physical) AtoN, being accessible and easily understood by any user. In national waters, Brazilian Navy alone is responsible for inspecting approximately 1,626 fixed and 3,156 floating AtoN, distributed along the 7,367 km of the Brazilian coastline and over 19,000 km of economically navigable waterways [2]. Thus, given the magnitude of the responsibility of the Maritime Authority (MA) and the importance of the AtoN to the user, with each new technology that appears, a careful study is necessary on the adequacy of the current buoyage.

In this article, we will explore how the adoption of virtual AIS AtoN and the emergence of autonomous ships can affect the application of visual AtoN and, mainly, navigation safety, the main objective of the Maritime Authority and the navigator on the bridge. The following points will be addressed throughout the text: the advent of virtual nautical signals and their implications for navigation safety; the indispensability of visual AtoN to ensure maritime situational awareness; and the difficulties faced and necessary adaptations to buoyage so that ports can receive autonomous ships.

2 METHODOLOGY

In order to subsidize the arguments used in this study, the relevant information to the subject was obtained through the analysis of technical material, such as: normative and informative recommendations of the Brazilian Maritime Authority, of the International Association of Aids to Maritime Navigation and Lighthouse Authorities (IALA), the International Maritime Organization (IMO) and the Nautical Signaling Manual of the Brazilian Navy (MSN). In addition to also using discussions present in periodicals and conferences related to the subject, as well as practical knowledge in navigation on the part of the author and representatives of the Pilotage of Rio de Janeiro and the Amazon Basin.

3 AIDS TO NAVIGATION EQUIPPED WITH AIS

The ability to provide AtoNs signals using AIS technology is a significant technical development for AtoN service providers, as well as being of great use to the user, if they have equipment on board capable of processing the signal, interpret AIS messages and illustrate them on ENCs. Currently, according to IALA R126, AIS AtoN equipment is available in three operating modes, namely: Real, Synthetic and Virtual [3].

In the case of an AtoN Real AIS, its system is the simplest, being basically an AIS transmitter installed directly in the structure of a physically existing nautical signal, transmitting its own AIS messages. A synthetic AIS AtoN represents an AtoN that exists physically but does not have an AIS transmitter in its structure, the signal being transmitted remotely. Finally, there are the virtual AIS AtoN, being aids that exist only virtually in systems capable of displaying their symbology in digital format (ECDIS, radar, etc).

Regarding the virtual AtoN, due to its speed in implementation, such a solution is of great value in situations where time is critical to indicate something to local navigators, playing an important role in indicating new dangers, areas to be temporarily avoided, temporary indication of a physical AtoN removed from the site or changes in the local hydrography (variable sandbars). However, precisely due to its speed and simplicity, those responsible for these aids should not get used to opting for the easiest solution and using such aids differently from the recommendations, especially in regions where vessels of the most varied types frequent. Virtual AtoN have several peculiarities regarding their use that must be carefully evaluated and, from the moment your choice is made for convenience or cost reduction, mistakes can be made that affect precisely the safety of navigation. Due to the peculiarities that virtual AtoN present, they will be explored in greater detail throughout this article.

3.1 Challenges in the application of virtual AIS AtoN in restricted waters

Despite the many benefits in the application of virtual AIS AtoN, its adoption must be done in a well-planned way, concurrently with the study of the deployment area and the users affected by the service. In addition, there must also be an adequacy of both the equipment used on board and the regulations that may arise for its implementation. Considering these observations and with the objective of facilitating the understanding of the findings presented below, a scenario will be adopted where a maritime route in restricted waters is marked out mostly by virtual AIS AtoN, replacing traditional physical AtoN.

As stated in the SOLAS convention and in Resolution A.1106 (29) of the IMO [4], ships with a gross tonnage of less than 300, some fishing vessels, warships and State ships are not obliged to use the AIS transceiver, it being possible infer that such ships may not be able to receive the signal from a virtual AIS AtoN and generate an image. Consequently, in the event of accidents caused by the lack of these indications on the route, the crew of these vessels could not be judged as to the awareness of the dangers indicated there by virtual AIS AtoN, in view of their non-mandatory nature on board. In addition, even ships that are required to have AIS can have it turned off, which is authorized by the captain when he judges that his vessel is in a situation that could compromise the safety of his ship and of the crew or passengers on board, as well as in regions where piracy exists [4].

As already mentioned, the signal of an AIS AtoN will only be useful when detected and represented in some other equipment in operation that has a visual interface available to the navigator. For this to be possible, the vessel must be minimally equipped not only with AIS receivers, but with a visual display of the equipment itself, or be connected to a RADAR or an ECS/ECDIS [5], all operating without restrictions. In this sense, a virtual AtoN would only be accessible to those with a set of equipment working satisfactorily, which may not occur depending on the concern with their maintenance, whereas a physical AtoN is always available, guaranteeing that the information always reaches the final user.

In addition to the question of the different endowments of equipment on the part of the varied range of vessels that travel in port regions in Brazil, as well as in several other countries, there are also different levels of nautical knowledge and cultures practiced on board each of them by the navigator. On the north coast of the country, along the Amazon River, there are a large number of navigators who drive rustic boats using only the local knowledge acquired with years of experience in the region, often neglecting the information derived from their equipment or even not having them on board, albeit illegally. Within this perspective, we can conclude that a stretch presenting navigation hazard being marked mostly by virtual aids would not serve this class of navigator.

Regarding the positioning system, virtual signals depend strictly on the position obtained by the GNSS, which may be subject to errors in the system itself, such as errors in the ephemeris of the satellites and signal synchronization, or even attacks on the receiver, in the form of spoofing (generating a signal with false information) and jamming (emitting random signals on the same frequency as the receiver, preventing it from determining its position) [5]. Unintentional or criminal errors such as these can generate false impressions of proximity to shallow water hazards or narrowing roads. Given the increase in the size of ships and the ever-shrinking margins for maneuver in restricted waters, such situations, as they lead the navigator to erroneous decisions, can cause accidents, thus affecting port traffic.

Furthermore, some other problems also arise due to the non-standardization of the symbology by all AIS manufacturers, which can lead to difficulties in signal recognition and consequently affect the availability of AIS AtoN symbols. These discrepancies occur because the standardization of certain technologies is only established after some time in testing, for later verification by users and then effective adherence on board. Currently, on board some vessels there may still be equipped with AIS devices that uses virtual AtoN symbology that is not consistent with that determined by the IHO standard S-57, as indicated in IALA Guideline 1081.

Such a situation, for the short and medium term, can generate difficulties for the navigator in the immediate identification of a virtual signal represented in the nautical chart, as well as lead to the incorrect interpretation of the information to be indicated by him. Thinking about the long term, new equipment already follows the S-57 standard for symbology, and as more users acquire them, the more standardized will be the way in which a virtual AIS AtoN is being identified and interpreted by the navigator. As for the case of old equipment still in use, a simple remote update can solve the problem.

Regarding the evaluation of its Availability, R0126 suggests that multiple AIS stations should be established according to the necessary scope and recommends that the competent national authorities develop their own procedure to control the coverage area to be implemented. As an example, to evaluate the Availability of electronic AtoN, the Brazilian Navy establishes in its rules the condition of INOPERATIVE for the transmitter that is not operational, or the information is not captured by the onboard receivers (Radar, DGPS or AIS) [6].

Such a suggestion, by allowing greater autonomy to the maritime authorities to define their evaluation parameters, aims to respect the individual needs and peculiarities of each country, especially regarding obstacles that may interfere with the propagation of the radio signal transmitted by the AIS [3]. When looking at certain ports in Brazil, for example, such a need clearly noted, some with wide and less obstructed bays, such as Guanabara Bay in Rio de Janeiro, while others have a long and narrow navigation channel surrounded by the city or natural obstacles such as Santos and the Amazon Basin, respectively. These peculiarities require different evaluation parameters depending on the location where virtual AtoN is being applied.

When it comes to regional differences, for a country with continental dimensions like Brazil, it is also necessary to know the peculiarities of each location to define where virtual AtoN can be safely implemented. In the hydrographic region of the Amazon, with around 15,000 kilometers of economically navigable inland waterways [2], rules were specially created for the reality of the region, mainly regarding navigation rules and for buoyage. For example, additional rules to COLREGS can be found in the Maritime Authority Rules for Vessels Destined for Inland Navigation (NORMAM 02), while complementary signs for use in river and lake beaconing can be found in the Maritime Authority Rules for AtoN (NORMAM 17).

In case of the Amazon basin, a virtual AIS AtoN could be well used to indicate seasonal sandbanks or changes in the main navigation channel. However, when opting to delimit a significant part of the region in the same way, it would also be necessary to have a costly infrastructure to allow the propagation of the signal over long distances, also considering the obstacles imposed to propagation by the forest. In addition to the fact that, once again, buoyage would not be available to everyone, serving merchant ships in general but not being accessible, for example, to rustic fishing vessels. Therefore, the use of traditional and complementary AtoN, and mainly the local knowledge manifested by the mandatory pilotage in the region, continue to be economical, safe and accessible ways in differentiated regions such as the Amazon.

Therefore, with just a few examples, it is already possible to observe that the use of such aids is recommended only in specific situations and well defined by the authorities that regulate their application. In this way, the Brazilian Navy, based on Guideline 1084, in order to adapt the use of virtual AtoN to the reality of vessels navigating in Brazilian jurisdictional waters (BJW) and the difficulties imposed by the geography of the region, defines some requirements for those interested in establishing a virtual AIS AtoN. Some of those requirements are: a previous investigation of the traffic in the area, verification of the equipment carried on the ships and a consultation and consensus of the users of the maritime route [6]. The last requirement being extremely important, mainly for applications in regions of common use to all types of navigators, with the possibility of determining whether the interested public will effectively benefit from the aid, thus guaranteeing a greater degree of safety in navigation.

The approach to the considerations explored in the text is essential to define the limits of the use of these non-conventional AtoN and reinforces the importance of visual AtoN. Conventional aids is one of the main systems contributing to the safety of navigation, mitigating doubts or wrong decisions, and reinforcing maritime situational awareness.

3.2 Visual AtoN maintaining situational awareness

Situational awareness (SA) can be defined as being aware of what is happening inside and outside your ship, as well as interpreting facts that may affect the safety of your vessel. Such a concept is critical for browsers, being always necessary to be aware of the environment, understand it and then act correctly.

Therefore, it is necessary that the individual makes use of his senses and available tools (Radar, AIS, GNSS, radio, etc.) in order to always be aware of what is happening around him. Furthermore, when obtaining the same information from different sources, it will be possible to carry out cross-checks in order to guarantee greater reliability of this information [7].

In this sense, AtoN of all kinds collaborate in some way for a good maintenance of the SA. However, because physical AtoN have a well-defined meaning of their own, are clearly represented on nautical charts and do not require equipment to be identified, their essential function stands out in relation to others to strengthen an adequate situational awareness. Comparatively, virtual signals can leave room for doubt, caused by failures in data transmission or positioning errors, which in restricted waters can be the beginning of a sequence of misinterpretations that can lead to a risky situation for the vessel. In addition, the IALA Guideline 1081 corroborates with this statement, which recommends that, when using virtual AtoN it should be considered by users the need to maintain situational awareness by comparing electronic and non-electronic means and avoidance of reliance on single sources of information.

Therefore, despite the advantages and facilities provided by graphical interfaces and electronic means, it is not advisable for the navigator to settle down and leave conventional means of navigation aside. The more the navigator deposits all his trust in a single source of information, however complete or technological it may be, the more he tends to relax, and in these moments complicated situations can develop. Therefore, there are some practices that are still working and bringing good results, such as: maintaining good look-out; refer your ship to buoys, beacons and alignments in the region; or perform cross-checks using different sources of information and communicate via radio with surrounding ships to clarify or arrange a maneuver. Such practices must then be complemented by technology in order to raise the level of situational awareness and, consequently, navigation safety.

4 AUTONOMOUS VESSELS

The term “Maritime Autonomous Surface Ship” (MASS) is commonly used to describe an unmanned vessel, however varying degrees of autonomy exist. The classification society Lloyd's Register defined seven levels of autonomy (from AL 0 to AL 6), being grouped in four main blocks, given as follows: Manned ship; Remotely controlled vessel; Automated ship; and fully autonomous vessel [8].

The advantages of autonomous ships are plentiful. They eliminate human error, reduce crew costs, promote efficient use of fuel and do not expose humans to the risks inherent in life at sea, in addition to allowing more efficient use of space in ship design [8]. However, there are also several disadvantages and challenges imposed on its implementation, mainly regarding the adaptability of this technology to the current maritime infrastructure. Among the existing difficulties, this work will highlight the necessary adaptations to buoyage, mainly in port areas, where the margins for error are much smaller and the consequences of an accident are much greater when compared to coastal or oceanic navigation.

4.1 Adaptations to buoyage to suit the MASS

In Brazil, there has been a discussion since 2020 regarding the creation of specific legislation that regulates the operation of autonomous vessels in Brazilian waters, so that Brazil is legally supported regarding receiving this type of vessel. In this sense, the Directorate of Ports and Coasts (DPC) established in February 2020 the Provisional Regulation for the Operation of Autonomous Vessels through Ordinance 59/2020. This document aims to regulate the operation of autonomous vessels with a total length of less than or equal to 12 meters, which currently include small research vessels, hydrographic surveys and transport in short stretches. The regulation also clearly prohibits the traffic of vessels measuring more than 12 meters, which can be explained by the need for the various necessary adaptations and the greater degree of complexity and risk of operation in BJW [9].

However, in addition to the rules and regulations to be adopted to ensure the safety of these and other vessels navigating in the same environment, the current buoyage must also be adapted to receive autonomous vessels that navigate through areas with a large commercial flow. In this regard, the biggest challenge will be to ensure that AtoN are clearly identified and interpreted by intelligent recognition systems.

Several intelligent software applications already exist in autonomous cars control systems, obtaining their location from the GPS position and marking themselves by identifying objects, figures and shapes present in the external environment. In navigation, the principle would be the same, but the external references would be points on land, when close to the coast, other vessels and the existing beaconing itself.

The identification of the beaconing could be carried out in several ways, such as: optical (by cameras and light sensors), sound, radioelectric wave (direction finder), RADAR or radio (AIS). In each, there are pros and cons that should be carefully considered, but all must work together to provide as complete a picture of traffic as possible.

As an example, optical identification is a simple and effective method, provided that the location is under the influence of ideal visibility conditions and the sign presents a high degree of conservation of its physical characteristics, bearing in mind that these may be seriously degraded due to erosion or even to vandalism.

On the other hand, the use of sound or radio waves emitted by AtoN could be useful to determine at least its marking, having one more approximate source of its positioning. Despite the propagation of the signal, it is subject to adverse effects that can also interfere with the reliability of the information.

For RADAR detection, a simple radar reflector (passive), radar target enhancer (active) or RACON could increase signal conspicuity and make it easier to determine your position from bearing and distance [1]. However, when subjected to adverse weather conditions, such as a local heavy rain, interference could occur in the propagation of the signal, thus impairing the image of the generated return, or even its complete omission.

Finally, an AtoN together with the AIS signal could provide a reliable position to the autonomous navigation system and directly in digital form, which could be useful for transmitting the information simultaneously to all electronic navigation aids, in addition to overcoming the difficulties related to visibility conditions, the state of conservation and the physical characteristics of the visual AtoN. Thus, complementing other methods used simultaneously for enhancing detection of AtoN.

Therefore, the need arises to harmonize the operation of all these components, aiming to reduce the failure of each of these sources of information, which is possible through the establishment of a network integrating the ships and the beaconing. Such a network would have the objective of providing means to carry out cross-checks of information and serving as a decision aid for the on-board navigation systems. This integration could be achieved using VHF Data Exchange System (VDES), which operate in the radio spectrum for data communication between ships, land stations and satellites; or through an internet connection using 5G technology [10].

In addition, the ideal would be to make VTS available in all ports capable of receiving such ships, as long as there are duly trained teams to carry out communication with such vessels in a manner that is adequate to their degree of automation. In this sense, taking into account the above considerations, the implementation of e-Navigation, a concept that encompasses a wide range of integrated information systems and services, would be the starting point for promoting an adequate support structure for autonomous and conventional ships at the same time. Therefore, for this tool to be able to serve satisfactorily the MASS in the future, it is advisable that they are first in full operation for conventional ships nowadays.

For now, in relation to the national development of MASS, in addition to what is being developed by the private sector, it is already possible to observe a growing interest of the Brazilian Navy in learning more about autonomous vehicles. Projects such as “MB-2021”, managed by the Centro Analysis of Naval Systems (CASNAV) and in partnership with several public and private educational institutions aims to convert a manned surface vessel into a remotely piloted one and, later, into an autonomous vessel to carry out scientific research [11]. An autonomous vessel project in Brazil is of paramount importance for the maritime authority, as it will help to understand the demands generated by these vessels, being able to adapt the current infrastructure and standards in the best possible way to receive them safely in AJB.

Therefore, integrating the buoyage through robust communication systems, adapting the physical AtoN so that the sensors on board can better identify them and developing projects such as the MB-2021, it will be possible, gradually, to better understand all the systematics, difficulties and needs of an autonomous vessel and, therefore, create adequate solutions for national buoyage. Such advances, in the future, will benefit not only small vessels dedicated to research, but also a probable autonomous merchant fleet sailing in AJB

5 CONCLUSION

Throughout this article, it was possible to analyze from some perspectives the challenges inherent to the implementation of new technologies in AtoN in BJW. However, technological progress and innovative ways to ensure safe navigation are natural paths to be followed, practically inevitable, since the world is constantly changing and for that it is necessary to keep up with the same pace.

However, it is worth mentioning that regardless of how innovative and of the advantages brought by a certain equipment, system or concept, the focus will always be the guarantee of safe navigation. In this sense, it is up to the Maritime Authority to analyze and judge the positive and negative points of any innovation that may be installed in BJW, deciding what is best for navigation safety. Whether the necessary adaptations to receive autonomous ships or the growing number of virtual AtoN, such changes should bring benefits to waterway traffic without harming any segment of the nautical world.

Therefore, linked to the continental dimensions of Brazil and its various regional peculiarities, the effort to improve the conditions of the current beaconing must be joint. Both Maritime Authority and the other stakeholders interested in waterborne transport must find out solutions to the challenges mentioned here, adding the knowledge coming from their areas until reaching a consensus that raises the level of digitization and automation without giving up on safety.

Regarding the relevant function of the physical AtoN, they can be considered as the solid basis to comply with the definition contained in NORMAM 17, which is to help the navigator to determine his position, guide him in the right direction, warn of dangers to navigation present throughout its route and demarcate the limits of the navigation channels. They should not be replaced, but complemented by any new equipment that will expand its potential and help in the fulfillment of its function. At the same time, the use of virtual AtoN is an important tool due to its practicality and speed of implementation, with good applications in deep water regions and more restricted use in shallow waters, without forgetting the fact that they probably will not be available to all users.

Already thinking about the future of navigation with the addition of autonomous vessels, the conspicuity of the AtoN must be improved to facilitate identification by sensors on board and promote greater connectivity of the entire local infrastructure. A robust network for data exchange would be able to benefit not only autonomous ships, but the entire fleet of conventional ships sailing in their areas of responsibility. This proposal must be met with the development of e-Navigation.

All these considerations will certainly guide us towards a more harmonious future between the old and the new, making the most of technology and maintaining a high degree of maritime navigation safety.

6 ACKNOWLEDGEMENTS

First, I would like to thank God and my family, especially my father, mother and wife for all the support in carrying out this work. In addition, I would also like to thank my advisor for final paper, Guilherme Black, for his guidance. I would also like to thank the pilots Rafael Dracxler and Alexandre Albuquerque for giving me practical daily experiences that contributed to assist in the conclusions of this work and presentation.

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AUTHOR BIOGRAPHY

My name is Lucas Bassani da Silva, I am 28 years old and I'm a First Lieutenant in the Brazilian Navy. I undergraduated in Naval Science at the brazilian Naval Academy and supplemented my theoretical knowledge on board the ship Navio-Escola “Brasil” during the XXXIII Viagem de Instrução de Guardas-Marinha, which was a great opportunity to gain hands-on sailing experience visiting 14 countries around the world. I have pursued further training in Naval Communication and now have a graduate degree in Hydrography at Centro de Instrução e Adestramento “Almirante Radler Aquino” (CIAARA).

I have always been an enthusiast of the sea, which is why I decided to join the Brazilian Navy, with the aim of being able to contribute to the safety of navigation. Throughout my career as a navy officer, I had served for almost two years on Corvette "Júlio de Noronha" and for 3 months on Sailing Ship "Cisne Branco". Now, I am currently serving as an assistant in the Hydrography Department of the Hydrooceanographic Ship "Taurus".

I am committed to continually improving my skills and knowledge in order to contribute to the success of my profession. For this reason, my final paper at graduation was based on highlighting the importance of visual aids to navigation facing modern technological advances in aids to navigation in Brazil, which now becomes a talk and a paper at this conference. I am grateful for this opportunity and look forward to contributing in order to have a safe navigation around the world.

S101.1 Development of a unique AtoN supervision application (099)

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ABSTRACT

The monitoring of marine aids to navigation (AtoN) is a major issue for the French State, which ensures the buoyage and safety of maritime navigation in its territorial waters. Indeed, this monitoring allows both to improve the information process for navigators and to optimise the maintenance and servicing of AtoN, in order to have a maximum availability rate. In France, two aids to navigation monitoring tools are mainly used. Each tool operates with its own dedicated application without the possibility of communicating with each other. The French AtoN authorities and Cerema are working on the development of a single monitoring application. This application will make it possible to receive information from the two remote control and monitoring technologies in use in France and to easily add new equipment and new communication protocols.

The application works as follows: the monitoring tools transmit information in a known format to the application, which translates it into a single format understandable by the operators. The operators can define alert criteria according to the data values. The application will notify these alerts by e-mail or SMS to the officers in charge of managing the aids concerned so that they can act accordingly.

KEYWORDS: Monitoring, AtoN, Manager, On-call

RESUMEN DEL ARTICULO

En este documento, se describen los requisitos de formato para la 20ª Conferencia de la IALA. Revise este documento para obtener información sobre el formato del texto, los títulos de las tablas, las referencias y el método para incluir la información de indexación. Las actas de la conferencia se publicarán en formato electrónico. El trabajo completo en archivo MS Word se redactará de conformidad con estas instrucciones. En una etapa posterior, se convertirá a formato de documento portátil (PDF).

Un resumen de no más de 250 palabras debe aparecer en la parte superior de la primera página, después del título del trabajo en una sección titulada "RESUMEN" (sin número de sección), después de los nombres de los autores.

PALABRAS CLAVE: Monitoreo, AtoN, Gerente, Guardia

1 CONTEXT OF ATON MONITORING IN FRANCE

Since the 2000s, some AtoN were monitored in France (Figure 1). Different technologies had been used as it evolves.

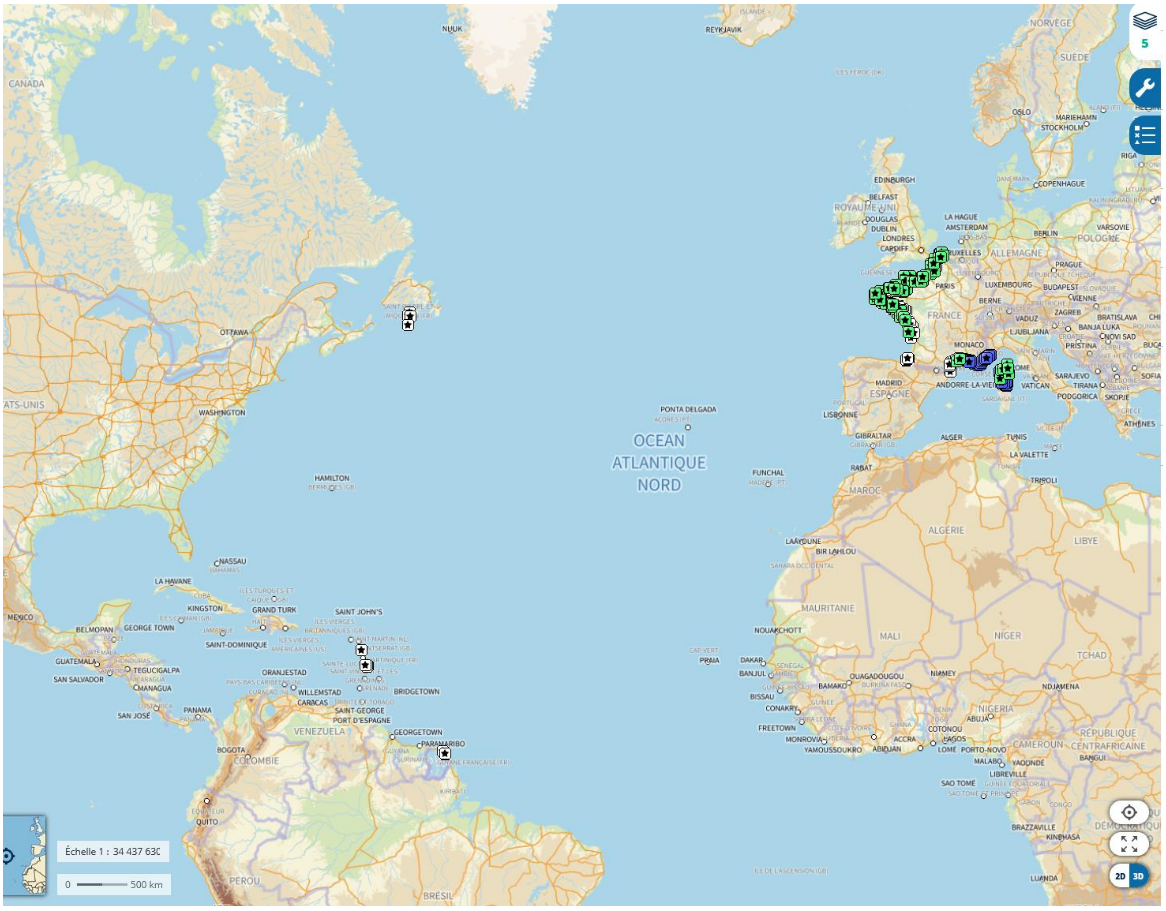

Figure 12 : Maps of monitored AtoN (green: KanAtoN, white: Serpe and blue: Telediag)

The first technology used in France (since 1995) communicated by VHF with a private frequency for this use (named Serpe). This hardware was developed specially for French use. Hardware and network are no longer maintained and is gradually disappearing. Currently, less than 100 AtoN are still monitored by this technology.

In 2011, French maritime authorities wanted to develop monitoring use in its local services. So, a new hardware had been developed: KanAtoN and ComAtoN (Figure 2). It uses AIS communication and provides messages 6 and 21 with standardized format. AtoN managers may follow AtoN status on a website (VigieAtoN). In case of failures, they may receive notification by SMS and/or email. In 2022, this technology is used on about 120 AtoNs. It is a success and the product gives complete satisfaction for far away AtoNs.

Figure 13 : KanAtoN and ComAtoN sensor

The scope of monitoring hardware had been augmented with a new technology: Telediag (Figure 3). It uses SIGFOX network and as KanAtoN, a website allows the following of AtoN status, their configuration, and user notification in case of failures. Sigfox is a private network with about 50 antennas covering only metropolitan France and not overseas. About 150 AtoN are monitored by Telediag.

Figure 14 : Telediag sensor

Currently, AtoN managers have two different websites to monitor their AtoN. These websites don't communicate with each other. Moreover, the handling of these two tools is different.

This AtoN monitoring allows both to improve the information process for navigators and to optimise the maintenance and servicing of aids to navigation, in order to have a maximum availability rate as explains in Guideline *G1008 Remote control and monitoring of aids to navigation* [1]. So, the French AtoN authorities and Cerema have chosen to develop one single monitoring application. Currently, this application will receive information from the two monitoring technologies: Kanaton and Telediag.

2 METHODOLOGY

The approach adopted by the French AtoN authorities and Cerema to develop this application was based on several working groups with users to best define their operational needs.

Initiated in 2020, Figure 3 shows the progress of the project to achieve the application.

Figure 15 : Project progress

The objective of this approach is to identify the needs of agents at all levels of use:

- manager of a fleet of navigation aids;
- operating agents who intervene on the aids;
- on-call agents who react in case of failure.

These working groups were completed by workshops for the co-construction of a model of the application to propose a first design version and to specify the needs directly with the final user.

These operational needs were completed by a specific point of view on the IT and security aspects. In fact, requirements have been added such as:

- differentiated access control according to the connection network: intranet/internet
- access to different functionalities according to the role assigned to the user
- development of the application in compliance with IT security rules
- ability to easily integrate new equipment into the application

3 FINAL FEATURES OF THE APPLICATION

The development of the application (OSCEAN for Outil de Supervision Centralisé des Aides à la Navigation in French) is almost finished. It already has all the final features. The architecture of the application is as follows (Figure 4).

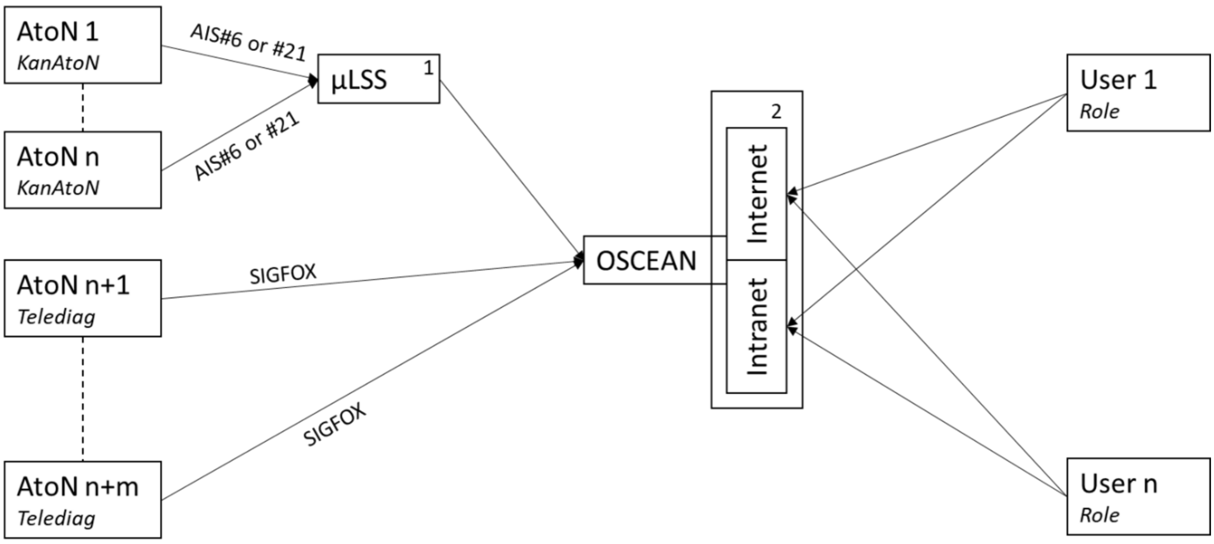

Figure 16 : Architecture of OSCEAN

The µLSS (component 1 in Figure 4) receives all the AIS streams from the physical shore stations and sorts the messages to provide only messages 6 and 21 to OSCEAN.

The connection to OSCEAN can be done from two networks: internet or intranet (component 2 in Figure 4). The functionalities offered by the application are restricted on the internet compared to the intranet.

Table 1 shows the functionalities of OSCEAN and the type of connection (intranet or internet) that allows access.

Table 2 : Functionalities of OSCEAN

Functionalities	Resume	Access
AtoN status	Dahsboard consultation	Internet + Intranet
	Historical consultation and download data	Internet + Intranet
	AtoN configuration	Intranet
On-call	Acknowledgement of alarms	Internet + Intranet
	Management of on-call schedules	Intranet
	On-call schedules consultation	Internet
	Modification of user parameters	Internet
	Territorial division configuration	Internet + Intranet

OSCEAN allows users to have a real-time visualization of the status of their fleet (Figure 6). In case of failure, on-call agents will be notified. They can then acknowledge the alarm on the application with a computer or a smartphone.

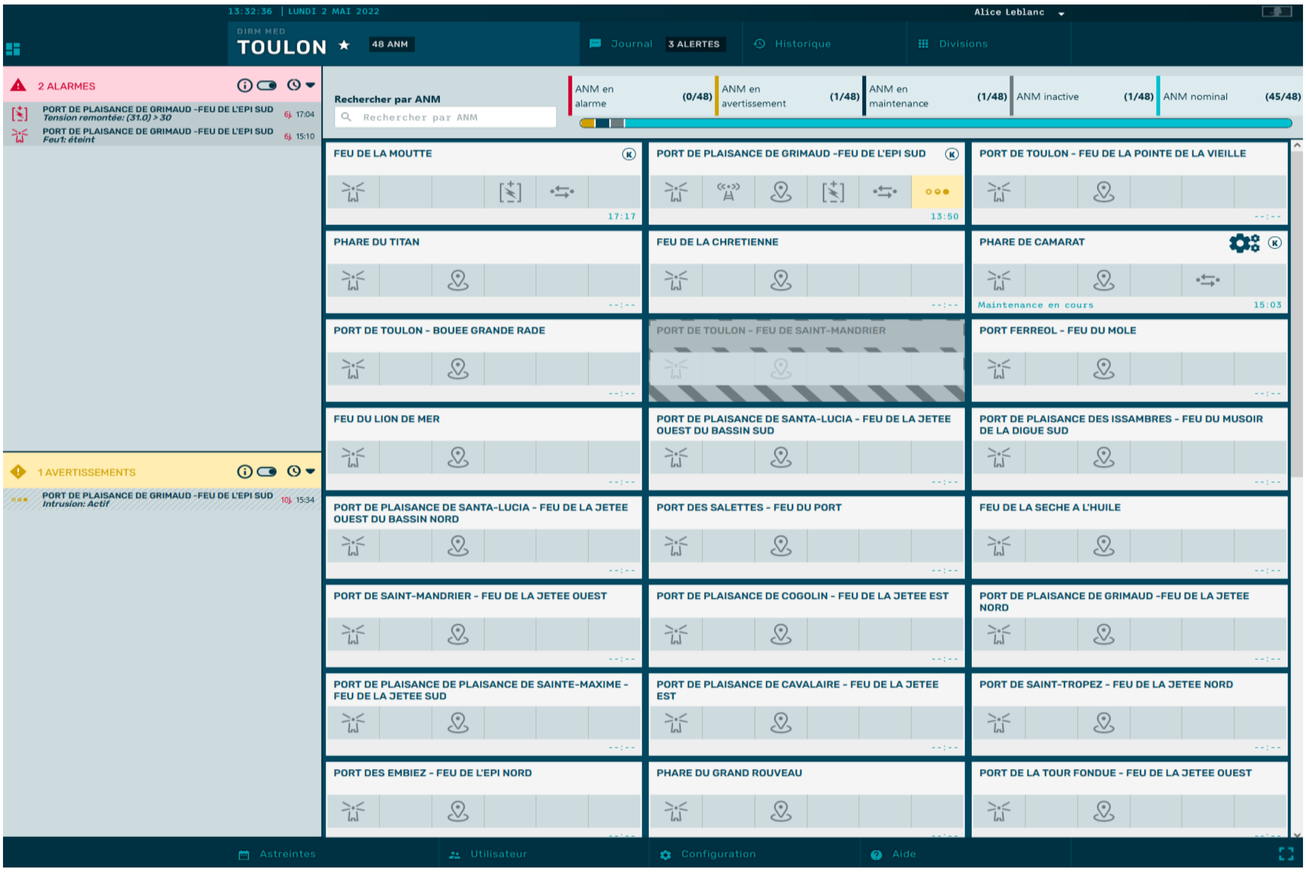

Figure 17 : Dashboard of AtoNs status

In addition, the application allows the manager to organize the agents' on-call schedule over several months (Figure 7). Notifications are then sent directly to the people identified on the schedule.

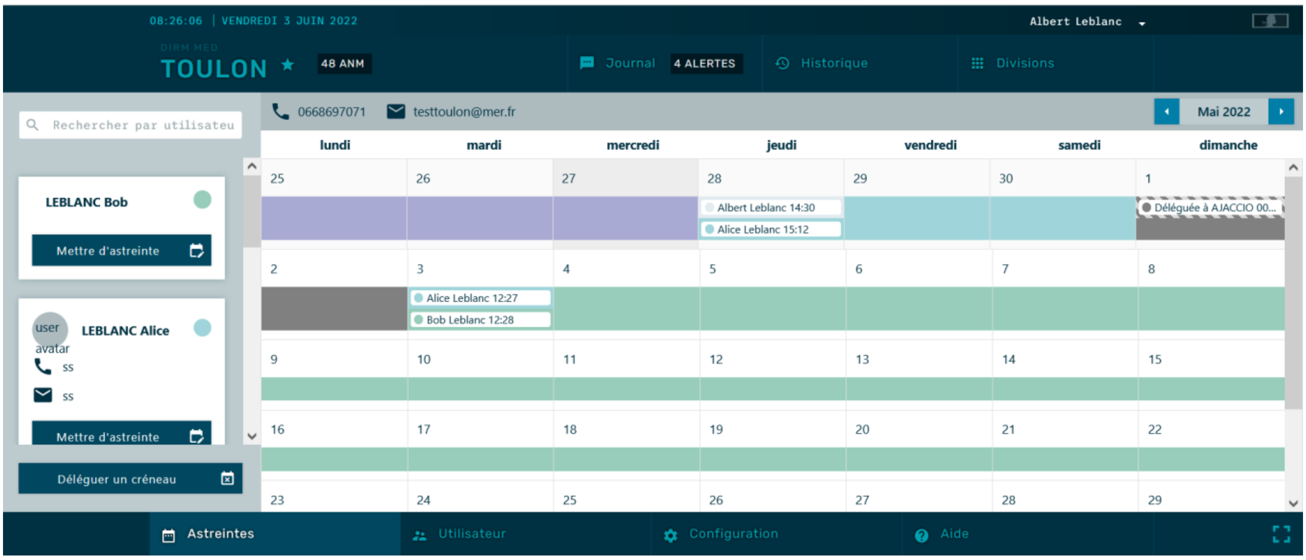

Figure 18 : Agents' on-call schedule

A special component on data and access security issues was integrated during the project. Penetration tests of the application are being conducted to ensure that unauthorized persons cannot access and modify the data.

4 PROSPECTS

This application should facilitate the remote monitoring of AtoNs. Its deployment should be accompanied by a guide on the strategy of monitoring of AtoN in France. The objective of this guide is to specify which aids are monitored and which data are recovered.

An increase in the number of monitored aids is therefore to be expected in the coming years.

Moreover, the way the application has been designed allows to easily implement new materials. It is thus planned to conduct a workshop with the agents on their needs in terms of monitoring sensors. New hardware can then be added to the application if necessary.

Finally, some evolutions of the application are already planned:

- the integration of the remote control with AIS technology to turn on or off light sources, generators, etc.
- the integration of a map of the aids and their status.

5 REFERENCES

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AUTHOR BIOGRAPHY

Emma Stéphan is an engineer and she holds a PhD in building rehabilitation. After several years working in the field of building, she then became involved in road safety issues. Finally, she joined the aids to navigation world in 2021. At Cerema she is in charge of DGNSS, AIS AtoN and modernization of aids to navigation. In particular, she is the project manager for the deployment of a unique AtoN monitoring application for the French maritime administration. In addition, she is also writing a guideline for the French Authorities on the strategy for AtoN remote control and monitoring.

S101.2 A Roadmap to implementing UKC systems under the Brazilian regulatory framework (025)

Dr Felipe Ruggeri, Argonautica Engineering and Research, Brazil

ABSTRACT

Interest from Brazilian ports and terminals in dynamic UKC Management systems has increased since the issue of a regulatory framework by the Brazilian Maritime Authority in December 2019 (NORMAM 33). This article presents an overview of projects under development nationwide, followed by a case study of the implementation in Porto do Açu including a description of associated equipment, challenges, results, and opportunities for further improvement.

(No paper submitted)

AUTHOR BIOGRAPHY

Dr. Ruggeri is graduated (2010), Master of Sciences (2011) and Doctor of Sciences (2016) degrees from the Naval Architect and Ocean Engineering Department of the University of São Paulo (USP), the last degree achieved by developing the thesis entitled "A Numerical Method for Non Linear Analysis of the Dynamics of Marine Systems under Gravity Waves and Current". In 2010, he was awarded as the best naval architect from CREA-SP (São Paulo State Engineering Council), SOBENA (Brazilian Society of Naval Architects) and Brazilian Navy. From 2008 to 2015, he worked as a research engineer at the Tanque de Provas Numérico of University of São Paulo (USP) developing projects on green ship shuttle tankers, high speed vessels for crew transportation, military ships, floating breakwater, floating ports, logistic hubs, FLNG and oil platforms for the Pre-Salt layer in Brazil. Dr. Ruggeri is one of the founders and director of ARGONAUTICA ENGINEERING AND RESEARCHES LTDA where he has been involved in hundreds studies for several ports in Brazil, conducting fast-time simulations for maneuvering/underkeel clearance analysis, ship-to-ship interaction, mooring analysis, planning and development of innovative numerical tools to improve operational safety and efficiency of ports, which includes, for example, the development of ReDRAFT® (Real Time Draft) and MeDuSa® (Mooring Design Tool) software packages. He was also one of the technical members of the committee for the revision of the Brazilian Standards (ABNT) regarding port planning and procedures.

S101.3 The model of improvement of the IALA MBS (176)

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ABSTRACT

The IALA Marine Buoyage System facilitates the introduction of safe and effective measures for the passage of vessels, the detection of hazards located underwater or at the sea surface, and the indication of safe waterways. Since its founding, the Marine Buoyage System has undergone a number of changes to improve the structure of position fixing and avoid dangers without fear of ambiguity. Nevertheless, there are still areas where substantial changes can be made, which further eliminates ambiguity, and helps the seafarer correctly identify aids to navigation. A survey of seafarers in this study found that the environmental factors (rain, swell, etc.) make it quite difficult for vessels to identify during the dark period of the day the characteristics of light exhibited from buoys or other navigational aids located on the sea surface.

The present paper proposes to overcome the complexity observed as a result of the study by making modifications to the characteristics of the aid to navigation. In particular, the emphasis is on establishing a system where the identification of buoys or other navaids located on the surface in the dark during the day will depend only on the colour of the light and their positioning and not on the rhythm or cycle of the exhibited light. Such a method will allow the seafarers to determine faster and accurately the purpose and type of the navigation mark and thus reduce the time to make on the appropriate manoeuvre and the number of maritime casualties.

KEYWORDS: IALA, Aids to Navigation, Maritime Buoyage System, Safe Navigation, Ship handling

Historically, a sea voyage was regarded as an adventure. Fortunately, nowadays, voyages are not adventures. The most essential issues for mariners today are navigation and safety—safely and effectively delivering the goods. The two commandments of navigation are essential for the modern maritime industry, which is striving to improve navigation as much as possible in a globalised world. The primary goal of improving navigation is to make it easier, safer, and more comprehensible for seafarers. This project focuses on simplifying navigational markings, such as buoys, to eliminate misunderstandings when determining their type and function.

The International Convention on the Safety of Life at Sea, Chapter V, Regulation 13, requires contracting governments to consider the recommendations and guidelines of IALA, including the Maritime Buoyage System (IMO SN.1/Circ.297). By removing ambiguity, the Maritime Buoyage System promotes the safety of navigation and the avoidance of hazards. The Maritime Buoyage System improves navigational safety and the avoidance of hazards by eliminating uncertainty.

IALA NAVGUIDE 2018 for the AIDS TO NAVIGATION MANUAL, ANNEX D Maritime Buoyage System, and Other Aids to Navigation Maritime Buoyage Systems comprises six different types of marks that can be used separately or in conjunction with others. Each mark or buoy has a specific shape, colour pattern, top mark, and light characteristics. In the daylight, everything is much easier; you can see the colour pattern, shape, and mark straight away and identify which AToN is it. However, at night, they are hardly identifiable without proper comparison of the exhibited light pattern (colour, rhythm, sequence, etc.) with characteristics described on a navigational chart or listed in publications such as the Admiralty List of Lights and Signals. Such Light patterns are: Isophase, occulting lights, Flashing, Quick Flashing Morse Code, etc.

The officer of the watch is required to read the light characteristics of buoys on the navigational chart using chart abbreviations and then to identify the buoy with an appropriate light pattern on sea surfaces. However, it takes a considerable amount of time while the vessel covers some distance. Another principal factor is that, in case of adverse weather, swell, rolling, or pitching, if the vessel descends after the first flash, we can miss out of sight the buoy and omit or misinterpret the light flash as well. Perhaps the restricted visibility could cause difficulty in observing the light pattern of a buoy or mark, and consequently incorrect identification of navigational aids.

An online survey was utilised to determine how simple or difficult it is to discern IALA marks by their light characteristics at night and to identify the key intervening factors. A questionnaire has been created and distributed to active seafarers performing watchkeeping duties on the navigational bridge. Almost 200 answers were received from all across the world. 55,4% had one to five years of navigation watchkeeping experience; 29,7% had five to fifteen years. 14.9% of participants have 15 or more years of experience. Ratings forming part of the navigation watch represent 24.6% of participants, while the majority are officers (OOW: 39.7%; Masters and Chief Mates: 35.6%). It is interesting to note that 35.1% of respondents rarely or only sometimes follow the buoys based on their light characteristics while navigating. 2.7% never use it to determine the buoy. But nonetheless, the majority of those surveyed mention that they have never had difficulty correctly and quickly identifying the type of IALA Aids to Navigation during the dark period of the day.

The following factors were identified as important impediments to identifying AToN light characteristics: Overlap of navigation lights with shore-based or ship-born lights is considered one of the most interfering factors by seafarers. The second-most significant impediment is noted as atmospheric precipitation. The next major inconvenience is the motion of navigation marks caused by sea state.

According to survey outcomes, it is considered to be the most difficult to differentiate between the period (e.g., flashes per minute or number of flashes in a group, etc.) and the Class (Revolving, Occulting, Altering, etc.) of displayed lights' rhythmic characteristics.

The results obtained are shown in Figure 1. The responses range from "easy" to "average." However, determining the Rhythmic Characteristics of Exhibited Lights of Cardinal and Isolated Danger markings is the most challenging for respondents. These are followed by safe water markings, with a slight difference.

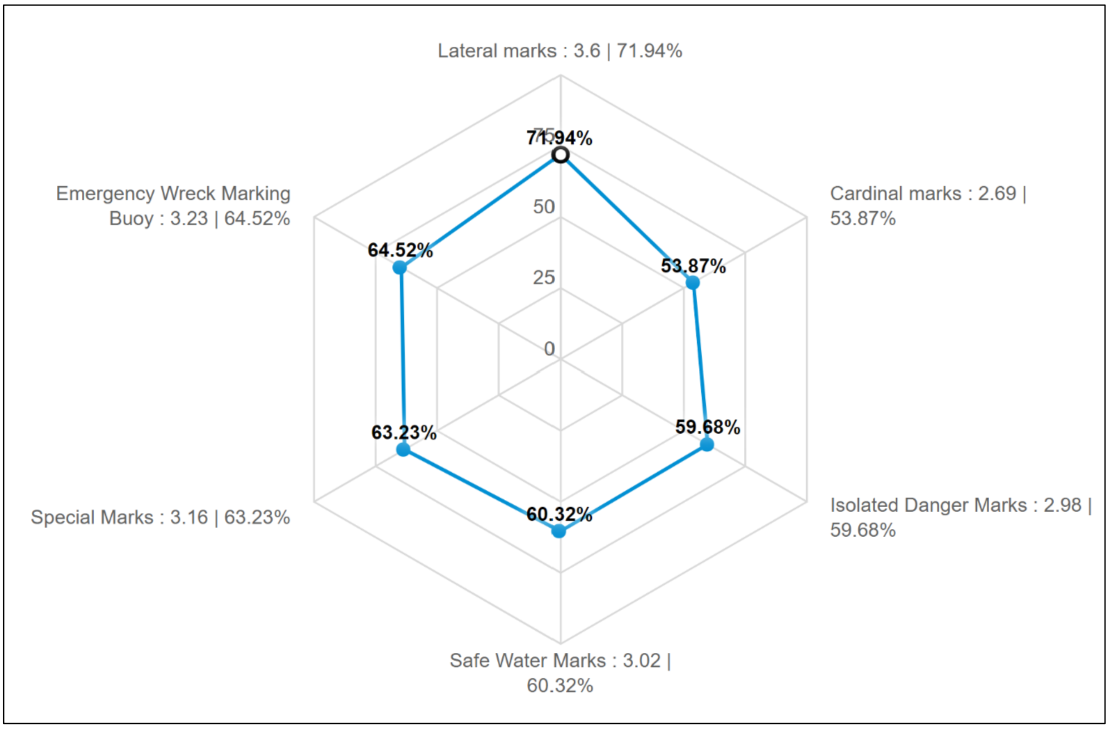

Figure 1. Complexity of identification of MBS marks

Finally, 85.5% of participants would like to see a revision in the rhythmic character of IALA MBS marks, which would make it easier and faster to identify them in adverse weather or in regions with excessive obstructing light.

The current project proposes a method for improving the lighting characteristics of IALA Maritime Buoyage systems. Particularly, the method to modify them in such a way is to have the possibility of distinguishing the mark by the colour and positioning of Exhibited lights rather than by rhythm, cycle, sequence, or similar hardly observable parameters.

Here below in Figure 2 and Figure 3 are proposed more simplified light characteristics of each type of MBS marks, where only colour and position of lights are main parameters of lights. However, rhythm and Cycles are not playing the leading role in distinguishing those buoys in the hours of darkness. All proposed lights, except for Lateral System Preferred Channel lights are fixed and All-round.

NEW DANGER MARK

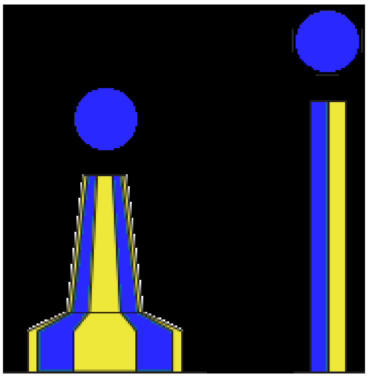

Figure 2 Proposed Light: One, Intensive Blue All- Round lights

SPECIAL MARK

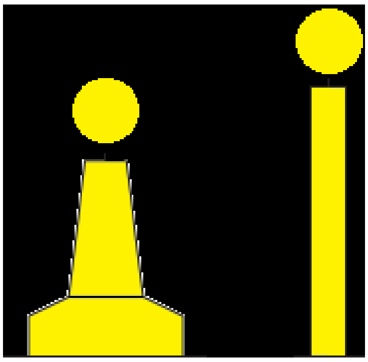

Figure 3 Proposed Light: One, Yellow All- Round lights

It's worth noting that while purple is included in the CIE colour chart, it is not used as a standard colour for marine navigation aids, including those used in the IALA Maritime Buoyage System. Purple is also a distinct and recognizable colour, which could help reduce confusion with other marks. It could improve visibility and aid identification of Cardinal marks in low-light or adverse weather conditions. Figure 4 proposes more light characteristics of Cardinal Marks.

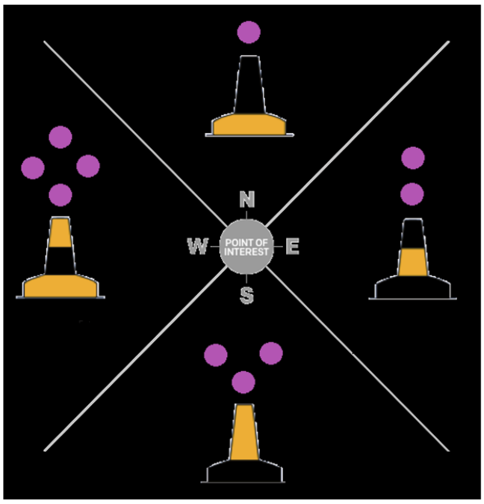

Figure 4 Proposed light characteristics of Cardinal Marks

The proposed light are as follows:

- North Cardinal Mark: Three All-round Purple light. Two of these lights shall be positioned on one horizontal line, and one below but at equidistance and right angle of those horizontally positioned lights.

- West Cardinal Mark: Two All-round Purple lights, positioned on one vertical line.
- South Cardinal Mark: One All-round Purple light.
- East Cardinal Mark: Two of these lights shall be positioned on a horizontal line, and one of them below and above, but at equidistant and at a right angle from the horizontally positioned lights.
- East and West will exhibit Even lights, whereas North and South ‐ ODD ones

To enhance the effectiveness of multiple lights on navigation marks, it is critical to prevent the merging of light spots at certain distances. As such, it is imperative to define clear technical specifications for the horizontal and vertical spacing between lights. To address this, the following technical specifications are proposed for light locations and spacing: If two lights are to be positioned in a vertical or horizontal line, they shall be spaced no less than 2 metres apart, with the lowest light positioned at a height no lower than 4 metres above the sea surface.

Adoption of additional purple lights could potentially aid seafarers in identifying Cardinal marks in adverse weather or low-light conditions, any proposed change to the established IALA Maritime Buoyage System (MBS) would need to be carefully evaluated to determine its potential impact on navigation safety. Any proposed change to the MBS would need to be thoroughly evaluated and tested to determine its potential impact on navigation safety.

Apart from modifying the exhibited light colour on Cardinal marks, this project proposes modifying the light positions to allow for identification based solely on their colour and positioning, rather than their rhythmic characteristics. Such modifications could improve clarity and ease of identification, particularly in low visibility conditions where it may be difficult to distinguish between the flashing periods or rhythms of different marks. Additionally, it could help to reduce the cognitive workload on mariners who may need to quickly identify a mark and react accordingly. Figure 4 shows the proposed modified light characteristics and positions of Cardinal marks.

The new approach of the provided paper is the proposal to modify the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Maritime Buoyage systems' light characteristics to simplify their identification at night. Through the survey, it was found that the most significant impediments to identifying AToN light characteristics were the overlap of navigation lights with other lights, atmospheric precipitation, and the motion of navigation marks caused by sea state. Based on the results, the proposed modification would make it easier and faster to identify marks in adverse weather or regions with excessive obstructing light by distinguishing them through the colour and positioning of exhibited lights rather than by rhythm, cycle, sequence, or similar parameters.

It's important to consider the potential drawbacks of introducing a new colour for Cardinal marks. Any change to the established IALA MBS could create confusion for mariners who are accustomed to the existing colour scheme. Additionally, introducing a new colour could require a significant investment in new equipment and training for those involved in the production, maintenance, and operation of marine navigation aids. Any proposed change to the MBS would need to be thoroughly evaluated and tested to determine its potential impact on navigation safety.

AUTHOR BIOGRAPHY

I Gogi Tsivadze, was born in Georgia, the city of Batumi. My parents are Jimsher Civadze (who is a Marine Engineer by profession) and Guranda Shamilishvili (who is a professor at Batumi State University). In 2015, I graduated from Ilia Chavchavadze #1 public school. In the same year, I entered Batumi State Maritime Academy and received a bachelors degree in Navigation in 2019. Since 2020, I have been working as a Cadet at Columbia. Currently, I have been promoted to 3rd Officer. During my studies at the academy and afterwards, I gained experience in various scientific conferences. Projects that I have worked on:

Development potential of modern social work: methodology and technologies: materials of the V International Scientific and Practical Conference 2021, 12-13 March Ukraine, Kiev.

My report paper was also published in the proceedings of the international conference The Impact of Work Stress on the seafarers Mental Health, Development potential of modern social work: methodology and technologies, Kyiv: Taras Shevchenko National University, 2021. - 221 c. The following scientific paper was also published with my participation: G. Shamishvili, G. Chaganava, M. Loria, D, Jincharadze, G. Tsivadze , ,,The Impact of Work Stress on the seafarers Mental Health and safety ‘’, BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES vol. 15, no. 4, 2021 "Council of the National Academy of Sciences of Georgia", vol. 15, No. 4, 2021, P.g. 156-162, the work is indexed in Scopus databases. El Adress http://science.org.ge/bnas/vol-15-4.html . Also, I am the author of several projects and inventions.

S101.4 A proactive approach to the provision of the Maritime Navigation Aid service (128)

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ABSTRACT

The need to guarantee access at any time to a first-class port on the north-western coast of the Republic of Cuba led the Aids to Maritime Navigation Service to take a theoretical-technological leap with the conception of a proactive approach that combined the benefits currently offered by the different technologies used in the field of Aids to Maritime Navigation with an organizational model that would allow to get the most of them. From the very conceptual ideas of this approach to its materialization, compliance with the basic principles of the provision of such a service was taken into consideration in terms of increasing the safety of human life at sea, the safety to navigation, the efficiency in the manoeuvres of vessels and the protection of the environment. This document shows the positive results of the application this proactive approach in the substantial improvement of the provision of the Aids to Maritime Navigation Service in terms of the increase in the General Availability index of an AtoN system, in addition to providing other value-added functionalities very useful for mariners.

KEYWORDS: proactive, approach, navigation, provision, efficiency, safety, functionalities

RESUMEN DEL ARTICULO

La necesidad de garantizar el acceso en cualquier horario a un puerto de primer nivel de la costa noroccidental de la República de Cuba propició que el servicio de Ayuda a la Navegación Marítima diera un salto teórico-tecnológico con la concepción de un enfoque proactivo que combinase las bondades que ofrecen actualmente las diferentes tecnologías que se emplean en el ámbito de las Ayudas a la Navegación Marítima con un modelo organizativo que permitiese obtener el máximo provecho de éstas. Desde las propias ideas conceptuales de este enfoque hasta su materialización, se tomó en consideración el cumplimiento de los principios básicos de la provisión de tal servicio en cuanto al incremento de la seguridad de la vida humana en el mar, de la seguridad a la navegación, de la eficiencia en las maniobras de los buques y de la protección del medioambiente. Este documento permite demostrar los resultados positivos de la aplicación de dicho enfoque en la mejora sustancial de la prestación del Servicio de Ayuda a la Navegación Marítima en términos del incremento del índice de Disponibilidad General de un sistema AtoN, además de proporcionar otras funcionalidades de valor agregado de gran utilidad para los navegantes.

PALABRAS CLAVE: proactivo, enfoque, navegación, provisión, eficiencia, seguridad, funcionalidades

RESUME DE L'ARTICLE

La nécessité de garantir l'accès à tout moment à un port de première classe sur la côte nord-ouest de la République de Cuba a conduit le service d'Aide à la Navigation Maritime à faire un saut théorique et technologique avec la conception d'une approche proactive qui combine les avantages actuellement offerts par le différentes technologies qui sont utilisées dans le domaine des Aides à la Navigation Maritime avec un modèle d'organisation qui permet d'en tirer le meilleur parti. Des idées conceptuelles mêmes de cette approche à sa concrétisation, le respect des principes de base de la fourniture d'un tel service a été pris en compte en termes d'augmentation de la sécurité de la vie humaine en mer, de la sécurité à la navigation, de l'efficacité dans manœuvres des navires et de la protection de l'environnement. Ce document permet de démontrer les résultats positifs de l'application de ladite approche dans l'amélioration substantielle de la fourniture du Service d'Aide à la Navigation en termes d'augmentation de l'indice de Disponibilité Générale d'un système AtoN, en plus de fournir d'autres fonctionnalités à valeur ajoutée d'une grande utilité pour les navigateurs.

MOTS CLÉS : proactif, approche, navigation, provision, efficacité, sécurité, fonctionnalités

1 INTRODUCTION

The proactive approach for the provision of the Aid to Navigation Service began to take shape in 2015 as a qualitatively superior scheme from the technological, organizational and operational point of view. After the process of designing and implementing this approach, it is possible to assess its results in a port on the north-western coast of Cuba, which currently serves as a national reference due to the substantial increase in the safety and efficiency of maritime navigation evidenced in this waterway given its contribution to the elimination or mitigation of the risks to which vessels are subjected.

Without neglecting the mainly visual service that was provided, from the technical point of view the radio-electric service also started to be provided, as a complement to compliance with Rules 13.1 and 13.3 of Chapter V of SOLAS Convention, responding to the requirements of modern navigation with work methods adapted to the specific operating conditions of this waterway and designed on the basis of hazard identification and risk assessment based on the use of IALA Guideline 1018 [1].

2 SUMMARY OF THE STRUCTURE AND LEVELS OF SERVICE STABLISHED IN THE CUBAN AIDS TO MARITIME NAVIGATION SERVICE

The Cuban Aids to Maritime Navigation Service provides 1095 visual aids: 84 lighthouses, 494 beacons, 448 buoys and 69 leading and sector lights, in addition to 18 radio-electric aids. To maintain these aids that contribute to safe navigation around the Cuban archipelago and in its national waterways, there are 14 maintenance stations and 34 national, regional and local vessels. The Hydrographic and Geodetic Service of the Republic of Cuba, formed by the National Office of Hydrography and Geodesy and GEOCUBA, is in charge of the maintenance and development of this service.

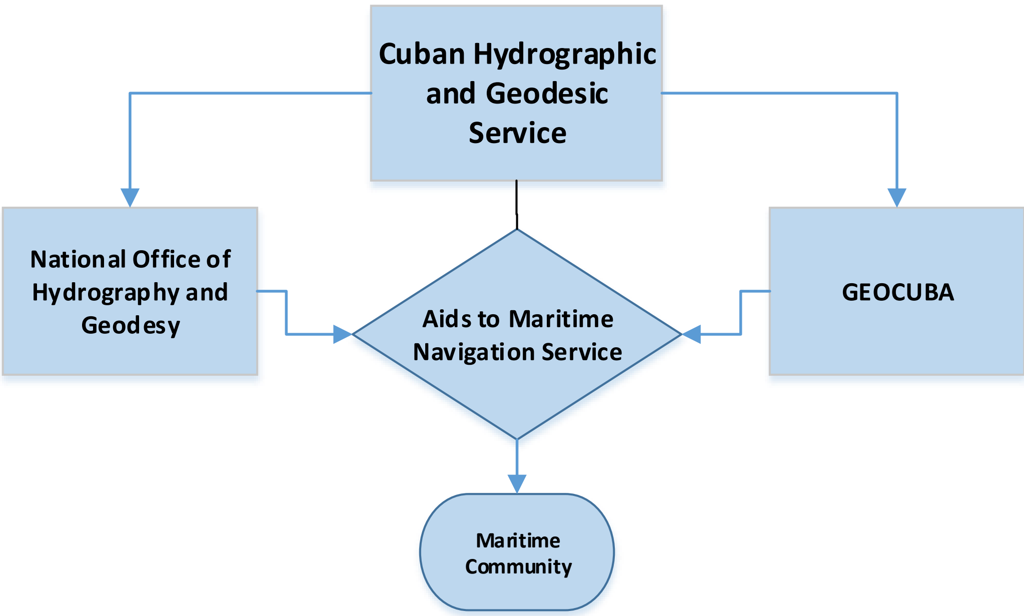

Figure 19: General structure of the Cuban Aids to Maritime Navigation Service

Decree-Law 55 of the Council of State of the Republic of Cuba [2] establishes that the Level of Service is provided according to the following four types of service:

- Level of Service 1: Passage Aids to Maritime Navigation
- Level of Service 2: Approach Aids to Maritime Navigation
- Level of Service 3: Interior Aids to Maritime Navigation
- Level of Service 4: Specific Aids to Maritime Navigation

Except for the first level of service mentioned, which, due to its importance for international navigation, must maintain a minimum Availability index corresponding to the First Category (0.998), the rest of the types of services can be integrated by individual Aids to Navigation with minimum Availability indexes that vary according to those established by IALA Recommendation R0130 [3]:

- First Category 0.998
- Second Category 0.990
- Third Category 0.970

3 PROACTIVE APPROACH

The need to guarantee access at any time to the Mariel Bay Container Terminal, a first class port on the north-western coast of the Republic of Cuba, led to the use of IALA Guideline 1018 for risks to navigation analysis in the different areas of this waterway. The initial result of this analysis under the existing conditions showed an unacceptable level of risk for the level of service required by users and maritime authorities for future operations of the port facility, which included First Category Availability for all Aid to Maritime Navigation involved in the access to the Mariel Container Terminal.

The risk analysis carried out identified a series of natural, technical, operational and use hazards of maritime spaces with the potential capacity to generate all types of losses and involve most of the risk factors related to maritime navigation listed in IALA Guideline 1018.

In the process of assessing the risk control measures to meet such expectations, it was concluded that a change of approach to the provision of the Aids to Maritime Navigation service on this waterway was essential. For this reason, the Hydrographic and Geodetic Service of the Republic of Cuba was requested to design and implement a new approach for the provision of such a Service, which was later named The Proactive Approach, to achieve anticipation of the occurrence of failures that could be prevented through real-time monitoring and evaluation of the equipment's operating parameters, acting before the occurrence of failures and reducing the response time to non-preventable failures by combining the application of a series of technological, organizational and operational measures, among which are, for the specific case of this waterway:

- The establishment of an AIS base station, with its software for cartographic representation, storage and management of information.
- AIS transceivers located in the AtoNs considered vital to maintain the level of service expected in the waterway, and synthetic AIS AtoNs for other Aids.
- Virtual AIS transmissions for various situations (emergencies, dredging, among others).
- The establishment of a hydro-meteorological station on a navigation buoy located in a decisive position so that mariners could receive in real time the status of variables such as wind and surface current velocity and direction, air temperature, relative humidity, atmospheric pressure and direction and height of waves.
- LED technology in all luminous AtoNs.
- A structural support based on navigation buoys of dimensions and characteristics in correspondence with the navigation requirements in the area and a leading line designed following IALA Guideline 1023 [4].
- Creation of a Monitoring and Control Center with its Maintenance Team, a service vessel and an a 4 x 4 vehicle for the attention to the AtoN system.
- Establishment of cooperation with the Users and Authorities of the locality to facilitate the tasks of Aton’s maintenance and repair.

- Establishment of a Response Plan in the event of a failure.
- Analysis of Key Performance Indicators and design and approval of improvement actions.

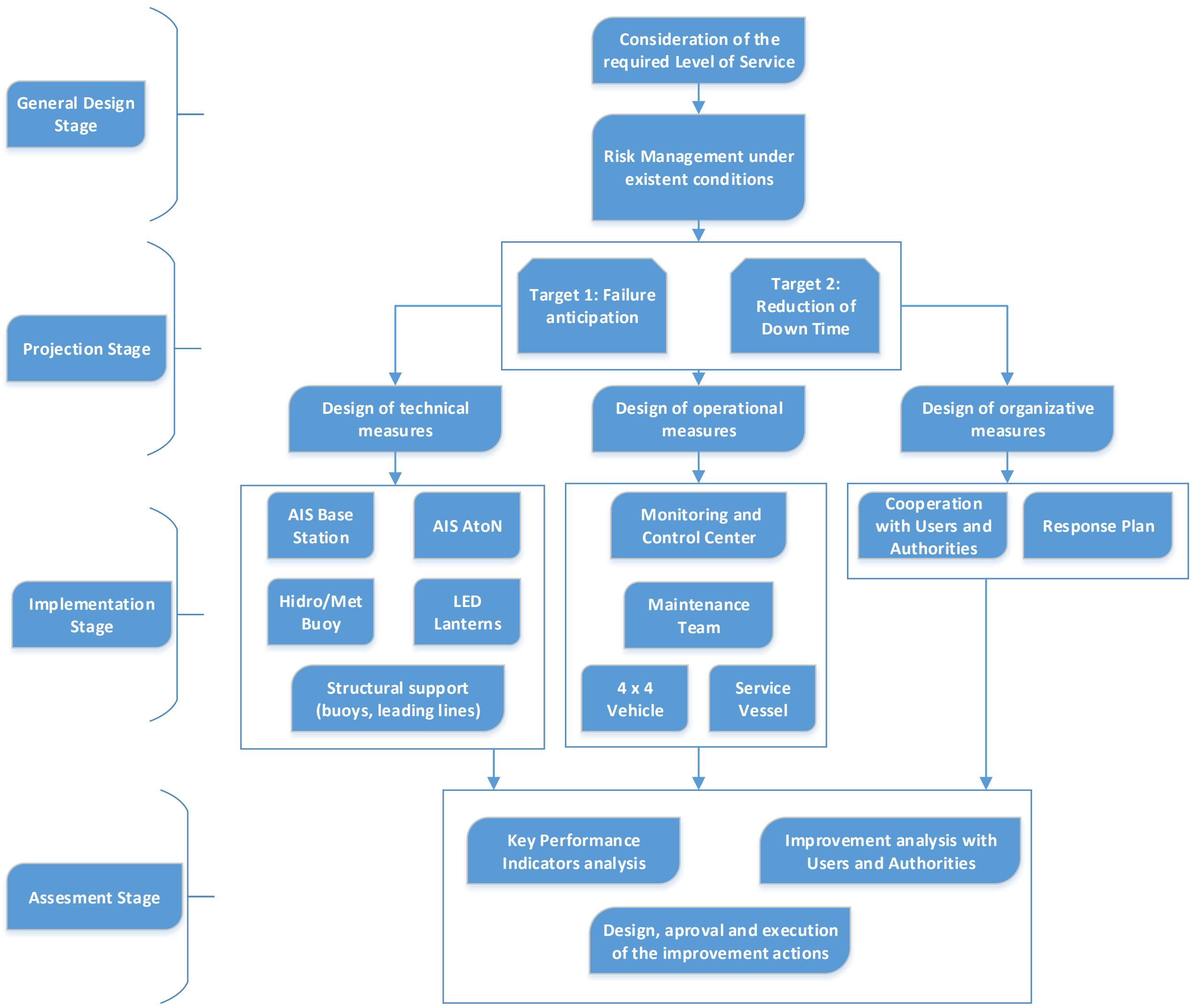

Figure 20: General structure of the Proactive Approach for the access to Mariel Container Terminal

A subsequent analysis of the risks, considering the application of the proactive approach, resulted in the elimination of more than 80% of the risks identified in the first analysis and the reduction of the rest to acceptable levels.

4 CONCLUSION

The use of the Proactive Approach fostered:

- A substantial increase in the General Availability of the Aids to Navigation System that satisfied the needs of maritime traffic in the area:

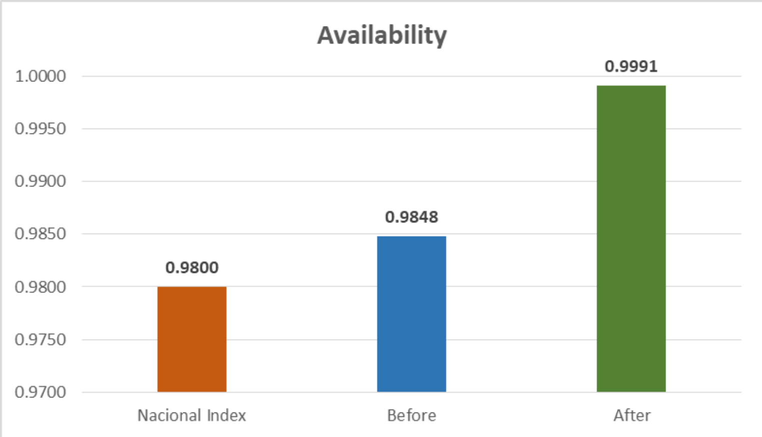

Figure 21: Availability Indexes before and after the implementation of the Proactive Approach

- Real-time monitoring of the individual AtoN operating parameters and the establishment of notifications, warnings and alarms on different events in the system,
- Recording and deferred reproduction of the navigational situation in a selected period,
- The availability of reliable information on the state of maritime traffic, the operation of AtoNs and the existing hydro-meteorological conditions, shared in real time among the members of the maritime community for decision-making processes.
- Multiple methods of orientation for mariners: visual (day and night) and radio-electric (radar reflector and AIS)
- Basic elements for the probabilistic and dynamic evaluation of the Aids to Maritime Navigation Service.

5 ACKNOWLEDGEMENTS

The author thanks all the managers, technicians and specialists who have endorsed the Proactive Approach to the provision of the Aid to Navigation Service by working hard on its design and implementation. He also thanks IALA and the Directorate of Hydrography and Navigation of the Brazilian Navy for the opportunity to present the Cuban experience in this event.

6 REFERENCES

[1] OMI, SOLAS Convention.

[2] IALA, Guideline G1018 Risk Management.

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[4] IALA, Recommendation R0130 Categorization and Availability Objectives for Short Range Aids to Navigation.

[5] IALA, Guideline G1023 Leading Lines Design.

AUTHOR BIOGRAPHY

After Julio Fidel Sierra Almaguer graduated as an engineer on Hydrography and Oceanography from the Cuban Naval Academy in 1997, he joined the Hydrographic and Geodetic Service as Aids to Navigation specialist for the Entrepreneurial Group GEOCUBA, being promoted to Chief of the Aids to Navigation Projects Department in 2000 and Chief of Operations in 2004. MSc. in Geomatics in 2005, he has been systematically contributing to the implementation of IALA´s latest applicable technical documents on the Cuban AtoN service, also working as new projects designer and maintenance operations supervisor. During different sessions of international technical events held in Cuba, such as GEOMATICA, MARCUBA and AGRIMENSURA, he has lectured about the benefits of the combination of costumed AtoN maintenance and service delivery methods with the implementation of technologies such as LED light sources and AIS for a wide range of purposes. He has prepared and delivered three national thematic AtoN Courses for the Cuban AtoN personnel and has received three IALA WWA Level 2 Certificates. He has attended to all IALA Conferences since the 17th IALA Conference held in 2010 in Cape Town, South Africa and to several EEP Committee sessions, including those virtually held during the COVID-19 pandemic. In charge of the translations from English and French to Spanish from 2004 to 2008 for the IALA printed Bulletin, during the current IALA Work Programme he has been actively participating in EEP Committee meetings.

S101.5 The importance of Accredited Training Organizations (ATO) in the training of Technical Personnel (045)

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ABSTRACT

The Hidrovia Academy for Training on Aids to Navigation was recognized in June 2017 and in accordance with the standards established by the IALA - World Wide Academy, as an Accredited Training Organization (ATO) by the Argentine Naval Hydrography Service, in its role as the Competent Authority in Argentina, for teaching Model Courses L2 for Technical Personnel. In this way Hidrovia Academy becomes the only ATO in America to have these capabilities plus the fact that the courses are given in Spanish. L2 courses has been given uninterruptedly since 2017.

This successful experience in Latin America validates the strategic vision of the World Wide Academy to develop, in a standardized way and in a global level, technical capacities and aptitudes of the human resource that participates in tasks of maintaining Aids to Navigation. In this way a network of shared content and experience that generates synergy was created in pursuit of a safe navigation.

The participation of the Organizations in the implemented training programme is reflected in the attendance of 190 members of 15 countries: Argentina, Chile, Costa Rica, Cuba, Ecuador, USA, El Salvador, Spain, Guatemala, Nicaragua, Panama, Uruguay, Peru and Venezuela.

KEYWORDS: Academy, training, technical personnel, ATO, WWA, L2.

RESUMEN DEL ARTÍCULO

La Academia Hidrovia de Capacitación en Ayudas a la Navegación, fue acreditada en junio del 2017 como Organización de Capacitación Acreditada (ATO) por el Servicio de Hidrografía Naval en su rol de Autoridad Competente en la Argentina según los estándares establecidos por la World Wide Academy (IALA-WWA) para impartir los Cursos Modelo L2 al Personal Técnico. De esta manera la Academia Hidrovia es la única ATO en América acreditada para hacerlo potenciando la fortaleza de impartir los cursos en idioma español. Los cursos L2 se dictan de manera ininterrumpida desde el 2017

Esta exitosa experiencia en América Latina convalida la visión estratégica de la World Wide Academy por desarrollar de forma estandarizada y a nivel mundial capacidades técnicas e idoneidad del recurso humano que participa en las tareas de mantenimiento de las Ayudas a la Navegación. Se crea así una red de divulgación de contenidos técnicos y experiencias compartidas generando sinergia en pos de una navegación segura.

La participación de las Organizaciones en el programa de capacitación implementado se ve reflejada en la asistencia de 190 miembros de 15 países : Argentina, Chile, Colombia, Costa Rica, Cuba, Ecuador, EEUU, El Salvador, España, Guatemala, Nicaragua, Panamá, Uruguay, Perú y Venezuela.

PALABRAS CLAVE: Academia, Capacitación, Personal Técnico, ATO, WWA, L2

1 IALA VISION

It is important to highlight how the vision of IALA to create the World Wide Academy (WWA) reflects the need of the Organizations which provide AtoN services that their technical and professional personnel acquire a quality and standardized training.

This situation identified by IALA emerges from the differences in the applied knowledge used by the technical personnel when performing AtoN maintenance tasks. Also, the lack of specific training courses for personnel involved in the maintenance tasks could have negative effects while providing a service. In this light, the community involved in providing AtoN services has found in WWA a training opportunity for the personnel to certify them in categories L1 or L2 with experience and theorical-practical updated knowledge.

2 ATO´S CREATION

In order to achieve what was mentioned before, in 2012 IALA created the World Wide Academy (WWA) whose aim is to train the personnel working with AtoNs, delegating the authority of the training accreditation to the National Members as Competent Authorities of the different countries.

To do so, the WWA, by means of Guideline No. 1100, Recommendations R-0141 and R-0149 for the accreditation and validation of the Training for Technical Personnel in Aids to Navigation and the Accredited Training Organizations (ATO) provides the perfect setting in which Competent Authorities becomes the first to accredit the training given with a IALA standards. Likewise, Competent Authorities are able to delegate this opportunity to an Accredited Training Organization (ATO) which should go through an audit and certification process done by the Competent Authority prior to the accreditation in order to fulfil that strategic role for IALA-WWA.

At present, 16 ATOs dedicated to Aids to Navigation Training, encompassing 14 countries, have been registered.

Table 3 AtoN-Accredited Training Organization

Country	Training Organization	Accreditation	Since	Language
Argentina	Academia Hidrovia de Capacitación en Ayudas a la Navegación	L2	2017	Spanish
China	MSA AtoN Training Center	L1.1	2015	English
England & Wales	Trinity House Training Department	L1.1	2019	English
		L2	2017	English
France	Le Centre de Valorisation des Ressources Humaines	L1.1	2014	French
India	Marine Navigation Training Institute	L1.1	2018	English
Korea	Korean Aids to Navigation Training Institute - Korea Maritime and Ocean University	L1.1	2015	English
Malaysia	Maritime Transport Training Institute	L1.1	2015	English
Portugal	Nucleo de Formacao de Faroleiros Escola da Autoridada Maritima	L2	2018	Portuguese
Spain	Puertos del Estado - Area de Ayudas a la Navegación Marítima	L1.1	2014	Spanish
	Mediterráneo Señales Marítimas Academy	L2	2015	Spanish
	GMV	L2	2015	Spanish
South Africa	Transnet National Ports Authority	L1.1	-----	English
Pacific Community	GeoScience, Energy and Maritime Division	L1.1	-----	English
Suriname	Suriname AtoN Academy	L1.1	2017	English
United Arab Emirates	Abu Dhabi Maritime Academy	L1.1	2019	English
		L2	2019	English
Ukraine	Odessa Maritime Academy Ministry of Education and Science of Ukraine	L1.1	2015	English
		L2	2015	English

Table 1 shows that Accreditation of ATOs are primarily aimed at teaching Model Course L1, for Aids to Navigation Managers in English. To a lesser extent, the ATOs aimed at teaching Model Course L2 for Technical Personnel. Hidrovia Academy from Argentina is the only ATO that offers L2 courses in Spanish in Latin America.

2.1 Resources and Knowledge Synergy

It is evident that the joint work of the ATOs, Competent Authorities and the WWA generates an added value permitting the optimization of economic and human resources while focusing on teaching Model Courses with skilled professionals and experts on the topics to be covered.

In this light, Hidrovia Academy, has promoted the cooperation with the Spanish Speaking ATO MSM Academy, and, with the Argentina Naval Hydrography Service.

3 ATO´S: SCOPE AND AIMS

The education and training programmes should give access to any person able to show prior experience in the area, knowledge and general or specific interest in topics related to Aids to Navigation. Specific background knowledge is required for students willing to start a training programme in accordance with the Model Course to be chosen.

In this context, the ATO should be committed to the continuous improvement of the education and training processes for an efficient and effective achievement of its aims according to the standards and requirements established by IALA and the Competent Authority by constant monitoring, evaluating and controlling students and teachers, their methods, resources and the infrastructure that builds up the education and training programme.

Students will gain knowledge, they will develop skills and they will also absorb foreign experiences generating a synergy that will allow them to comprehensively develop themselves in their tasks during the operation and maintenance of Aids to Navigation Systems, generating a benefit in their Organizations providing AtoN services by improving their technical personnel's skills.

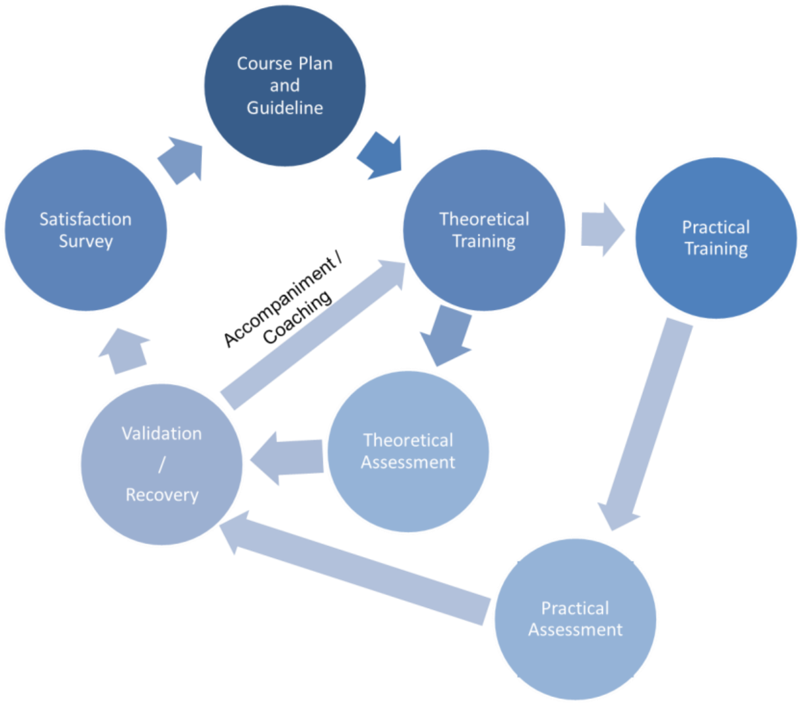

Figure 22: Training Method

3.1 Aims

The specific aims of the education and training programme should be focused on:

- Keeping an education and training programme based on the requirements established by IALA-WWA and the Competent Authority to guarantee a level of service appropriate to international standards.
- Satisfying students' needs, requirements and expectations, efficiently providing the service through monitoring, evaluating and controlling processes for a continuous improvement.
- Evaluating and enhancing the personal and professional development of the people who guarantee the service as the main excellence driving force.
- Satisfying the physical infrastructure needs and the necessary human, bibliographic, technological and IT resources for the development of activities.

4 SPANISH LANGUAGE TRAINING POTENTIALITY

Particularly, Hidrovia's Academy training plan in Spanish has allowed the capitalization of needs in Latin America which was initially identified by IALA and linked to the standardization of the given knowledge since:

- It is a reality that there are more Technical Personnel than AtoN Managers.
- It does not exist specific training in certain technical areas.
- Technicians are the ones who directly work with Aids to Navigation (installation, maintenance, etc.).

It should be considered that there are 20 Spanish-speaking countries (18 countries in Latin America, 1 country in Europe and 1 country in Africa) and that technicians do not necessarily have a technical English language proficiency to follow efficiently and accurately a training in that language. Under these premises, the implementation of the training plan in Spanish, result in a more convenient way to acquire a better understanding, gain knowledge, and grasp the concepts more easily than if the course is given in English. Likewise, this creation of strengths for the technical personnel contributes positively to the translation of the IALA documents with the exact same aim:

- Providing the members of IALA with the documents written in Spanish for a better comprehension.

For that matter, since the dissemination of the information on the L2 training programme and the joint work with the Argentine Naval Hydrography Service, it was achieved a continuous collaboration from the Organizations in the implemented training programmes which was reflected in the attendance of 190 members from 15 countries: Argentina, Chile, Colombia, Costa Rica, Ecuador, EEUU, El Salvador, España, Guatemala, Nicaragua, Panama, Uruguay, Perú and Venezuela.

Table 2 represents the evolution of the participation of the attendees during the period 2017 - 2022 and the modality used (onsite or online). It shows how the change in the modality of teaching during the pandemic facilitated and benefited the Organizations so that their technical personnel were able to have access to formal training approved by IALA in their own native language. Due to this fact, there was a significant increase in the number of attendees to the online modality course.

The reason for this particular growth is that in most cases, the expenses in transport, accommodation and food increase the cost and also hinder the possibility to attend the onsite courses. Thus, being just the course fee the only variable to consider, the Organizations can increase the quantity of the technical personnel to be enrolled, expanding, even more, the Spanish-speaking network of technicians in Aids to Navigation with IALA accreditation. However, besides the emergence of online training as a mitigating measure in response to the pandemic due to Covid-19, onsite training continues to be the best way to disseminate theoretical and practical content and build the relationship between the attendees and keep their active participation in the training.

Table 2: Participation of the attendees to Courses L2.

Countries/Year	2017	2018	2019	2020	2021	2022
Argentina	5	5	8	11	10	9
Chile	--	--	--	10	2	--
Colombia	7	--	--	5	--	--
Costa Rica	--	--	--	1	--	--
Cuba	1	--	2	2	2	--
Ecuador	--	--	1	4	5	3
USA	1	--	--	--	--	--
El Salvador	--	--	1	1	1	1
Spain	7	--	12	1	3	--
Guatemala	2	--	1	2	1	--
Mexico	--	--	--	--	4	--
Nicaragua	--	--	--	2	--	--
Panama	2	3	1	--	3	--
Peru	--	--	2	4	1	--
Uruguay	2	2	3	5	5	1
Venezuela	--	--	--	3	15	5
Total	27	10	31	51	52	19
Modality	**Onsite**	**Onsite**	**Onsite**	**Online**	**Online**	**Onsite**

5 CAPITALIZATION OF EXPERIENCES

Linked to the multiplicity of nationalities that participate in each course, it emerges as an advantage for the attendees the sharing of their personal experiences, encountered difficulties, and work methodologies, as well as the type of solutions used in case of equipment failures and in which conditions they are working, among others. All of these aspects can be considered as an added value to the course.

Clearly, these situations typical of the maintenance tasks turn out to be a key learning factor given that the attendees find themselves in an ideal environment that allows them to share their experiences, describe the adopted solutions forced by the geographical environment or by the weather, quite normal situations in the installation, operation and maintenance task of an Aids to Navigation system.

Even when the courses include the class load oriented to practice it is common to set up groups of two or three attendees in order to foster the exposition of their work methodologies and, as a matter of fact, the exchange of knowledge. Some examples can be mentioned to make this exchange visible:

- Mooring lines assembly
- Safe manoeuvring of Aids to Navigation self-contained lanterns setting.
- AIS-AtoN and Racon equipment setting.

6 CREATION OF A KNOWLEDGE NETWORK

In parallel with the beginning of the training activities in 2017, Hidrovia Academy fostered cooperation and active participation between attendees including teachers, creating a contact network and promoting the integration standing out as a beacon in the region for the creation and dissemination of knowledge related to Aids to Navigation.

This situation, which is generated as the course is being held, is much more developed during the onsite modality with regards to the online modality since the former turns out to be a better learning condition for the attendees allowing them to bridge the gap between their knowledge, and also sharing their experiences acquired while performing the maintenance tasks of an Aids to Navigation system.

In this context, the delivery of each course generates the exchange of emails and implies the creation of a WhatsApp group to keep in touch after finishing the course, providing a friendly environment to the attendees so that they can stay connected, ask questions about different issues, consult the teachers, and thus, create networks of contact and knowledge for the technical personnel associated to the maintenance of AtoN system.

7 HISTORY OF THE L2 COURSES

The previous experience of the ATOs in the Model Courses L2 given in Spanish indicates how was the interaction between Hidrovia Academy from Argentina; MSM Academy, from Spain; and the national members from Argentina, the Naval Hydrography Service and Chile the General Directorate of Maritime Territory and Merchant Marine (DIRECTEMAR) complying with the following schedule:

- 2017 – Module 7 (Racon) and Module 8 (AIS), Argentine;
- 2017 – Module 1 (Introduction to AtoNs), Spain;
- 2018 – Module 2 (Power Supplies), Argentine;
- 2019 – Module 3 (Marine Lanterns) – Argentine;
- 2019 – Module 8 (AIS) and Module 10 (Monitoring and Remote Control) System, Spain;
- 2020 – Module 8 (AIS), Argentine, Spain and Chile (online);
- 2021 – Module 3 (Marine Lanterns), Argentine and Spain (online);
- 2022 – Module 1 (Maintenance of Aids to Navigation), Argentine.

Figure 23: Group photo

The photo was taken in 2019 during Model Course L2.3, Marine Lanterns, and shows the whole group, attendees and teachers, in a friendly environment that the Historic Hall at the Escuela de Ciencias del Mar offers. This institution belongs to the Argentine Navy and it is the location where the courses are given.

8 ATO EVOLUTION DURING COVID-19

It cannot be denied that the pandemic, which took place worldwide during 2020 and 2021, introduced changes and produced adaptations, as well as made us evaluate the training scheme that was already considered to be something established. The maritime safety had to adapt itself to the world pandemic under the premise of being an 'essential sector.' And, as Charles Darwin said: 'It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change'; we have verified such a statement with specific facts.

In this context, the Competent Authority (Naval Hydrography Service), Hidrovia Academy, Training Academy in Aids to Navigation (Argentina) and the MSM Academy (Spain), these ATOs have continued fostering the training of the technical personnel L2 in Aids to Navigation adapted to the given circumstances due to the pandemic that implied an adaptation challenge: content adequacy, and process and production of this module in an online version, always following the WWA standards.

8.1 Training Tools

The implementation of a digital platform divided in virtual rooms specifically designed for this purpose turned out to be vital to adapt successfully the onsite courses to the online modality given that this method enables the management of the course, the academic monitoring of the attendees, the control of absenteeism, the conduction of surveys (students' satisfaction and teachers' performance) as well as the materialization of a digital library.

9 CONCLUSION

The success of the ATOs as Accredited Training Organizations by the WWA-IALA is based on the support of the National Members as Competent Authorities and in the institutional framework given by the World Wide Academy who fosters the evolution of the ATOs and their associated training programmes.

This process of joint work is vital for guaranteeing success in the learning chain validated by the trust that has been vested in by the organizations who are responsible to provide AtoN services by means of the active participation of their technical personnel.

Among the most relevant aspects to be pointed out in the evolution of the ATO Hidrovia Academy, the following can be highlighted:

- Model Courses L2 are given in Spanish;
- There is a continuity between courses.
- The teaching staff comprises experienced professionals in the area.
- The bibliography is updated regularly.
- The active participation of the attendees adds value to the shared content and experience.

10 REFERENCES

[1] IALA Guideline No. 1100 for the Accreditation and Validation of the Training of Technical Personnel in Aids to Navigation.

[2] IALA Recommendation E-141 for the Education and Certification of the Technical Personnel in Aids to Navigation.

[3] IALA Recommendation R-0149 for the Accreditation of Training Organizations.

AUTHOR BIOGRAPHY

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SESSIONS 2 AND 102 - ATON MANAGEMENT (CONTINUED)

S2.1 Using Big Data Analytics to improve AtoN Management in Malaysia (007)

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ABSTRACT

Aids to navigation (AtoN) are critical for safe and efficient maritime transportation. AtoN include various navigational aids such as buoys, beacons, lighthouses, and radar stations, which provide important information to ship captains and navigators, helping them to navigate safely and efficiently. The management of AtoN systems is therefore crucial to ensure their effectiveness. In recent years, there has been an increase in the amount of data generated by modern AtoN systems, creating a growing opportunity to use big data analytics to improve AtoN management.

The management of aids to navigation (AtoN) is critical to ensure safe and efficient maritime transportation. With the increasing amount of data generated by modern AtoN systems, there is a growing opportunity to use big data analytics to improve AtoN management. This paper presents an overview of how big data analytics can be applied to AtoN management, including data collection, storage, processing, analysis, and visualization. The potential benefits of using big data analytics for AtoN management are discussed, including enhanced safety, improved efficiency, and reduced costs. The paper also explores some of the challenges associated with using big data analytics for AtoN management, such as data quality, privacy concerns, and technological limitations. Overall, the paper concludes that big data analytics has the potential to significantly improve AtoN management and enhance maritime safety and efficiency.

KEYWORDS: Systems, big data, analytics, safety, efficiency, management

11 INTRODUCTION

Aids to navigation (AtoN) play a critical role in ensuring safe and efficient maritime transportation. With the increasing amount of data generated by modern AtoN systems, there is a growing opportunity to use big data analytics to improve AtoN management. Big data analytics involves the collection, storage, processing, analysis, and visualization of large and complex data sets to extract valuable insights and knowledge. By applying big data analytics to AtoN management, it is possible to enhance safety, improve efficiency, and reduce costs. However, there are also several challenges that must be addressed, including data quality, privacy concerns, and technological limitations. This paper presents an overview of how big data analytics can be applied to AtoN management and explores the potential benefits and challenges associated with this approach.

12 DATA COLLECTION, STORAGE AND PROCESSING

Collect data from modern AtoN systems, including real-time data on vessel movements, weather conditions, and navigational hazards. Store the collected data in a secure and easily accessible database. Use big data analytics tools to process and analyze the data. This can include data cleansing, transformation, and integration.

12.1 Data Collection

Modern AtoN systems generate vast amounts of data, including data on vessel movements, weather conditions, and navigational hazards. This data can be collected in real-time or near real-time through a variety of sensors, including Automatic Identification System (AIS), radar, and weather stations. Collecting this data allows AtoN managers to gain a better understanding of maritime traffic patterns, environmental conditions, and potential navigational hazards.

12.1.1 Automatic Identification System (AIS)

AIS is a mandatory navigation safety device that transmits and receives vessel information, including vessel identity, position, speed, and course. AtoN managers can collect AIS data from vessels in real-time, allowing them to monitor vessel movements, track vessel routes, and analyze vessel traffic patterns.

12.1.2 Radar

Radar is a widely used sensor technology that emits radio waves and detects their reflections off objects, including vessels. AtoN managers can use radar data to track vessel movements, detect potential navigational hazards, and monitor weather conditions.

12.1.3 Weather stations

Weather stations can collect real-time data on environmental conditions, such as wind speed and direction, wave height, and temperature. AtoN managers can use this data to monitor weather conditions and predict potential hazards, such as high winds or rough seas.

12.1.4 Other sensors

AtoN managers can also collect data from other sensors, such as cameras, sonar, and acoustic sensors. For example, cameras can be used to monitor vessel movements in port areas, while sonar and acoustic sensors can be used to detect underwater obstructions or hazards.

Collecting data from these sensors allows AtoN managers to gain a better understanding of maritime traffic patterns, environmental conditions, and potential navigational hazards. By analyzing this data, AtoN managers can make informed decisions on the placement and maintenance of buoys and beacons, predict and avoid potential hazards, and improve the efficiency of vessel traffic management. Additionally, this data can be used to develop new technologies and services that can further enhance the safety and efficiency of maritime transportation.

12.2 Storage

Once the data is collected, it needs to be stored in a secure and easily accessible database. This database should be designed to handle large volumes of data and be scalable as the amount of data increases over time. The database should also be designed with data privacy and security in mind, to ensure that sensitive information is protected from unauthorized access or disclosure.

12.3 Processing

After the data is collected and stored, it needs to be processed and analyzed to extract meaningful insights. This can involve data cleansing, transformation, and integration. Data cleansing involves identifying and correcting errors or inconsistencies in the data. Data transformation involves converting the data into a format that is suitable for analysis. Data integration involves combining data from multiple sources to create a unified view of the data.

1. The first step in processing the data is to clean it. Data cleansing involves identifying and correcting errors or inconsistencies in the data. This could include correcting incorrect or missing values, removing duplicates, and resolving data formatting issues. The goal is to ensure that the data is accurate and consistent, which is critical for generating reliable insights.
2. The next step is to transform the data into a format that is suitable for analysis. This could involve aggregating the data at different levels, such as by vessel type, by geographical region, or by time period. It could also involve transforming the data into a format that can be easily visualized, such as

graphs or charts. Data transformation is important because it allows the data to be analyzed more easily and effectively.

3. Data integration is also an important step in the analytics process. AtoN managers may collect data from multiple sources, such as AIS, radar, and weather stations. Data integration involves combining data from these multiple sources to create a unified view of the data. This allows AtoN managers to analyze the data more comprehensively and gain a more complete understanding of the maritime traffic patterns, environmental conditions, and potential navigational hazards.

13 DATA ANALYSIS, VISUALIZATION AND DECISION-MAKING

Apply statistical and machine learning techniques to the data to identify patterns and trends that can be used to enhance safety, improve efficiency, and reduce costs. Present the analyzed data in a meaningful and easy-to-understand way, using graphs, charts, and other visualizations. Use the insights gained from the data analysis to inform decision-making in AtoN management, such as optimizing the placement of buoys and beacons, predicting and avoiding potential hazards, and improving the efficiency of vessel traffic management.

13.1 Data Analysis

Once the data has been processed, it can be analyzed using big data analytics tools. This can involve applying statistical and machine learning techniques to identify patterns and trends in the data. For example, AtoN managers can use machine learning algorithms to predict vessel traffic patterns and identify potential navigational hazards.

13.1.1 Statistical analysis

This analysis can be used to identify correlations and trends in the data. For example, it can help identify the most frequent routes taken by vessels in a particular area, or the most common weather conditions that can affect navigation. Statistical analysis can also help identify patterns in the data that may not be immediately visible, such as the correlation between the presence of certain marine life and vessel traffic patterns.

13.1.2 Machine learning

Machine learning technique such as clustering and classification algorithms, can help identify complex patterns in the data that may be difficult to detect using traditional statistical methods. For example, machine learning can be used to identify vessels that are at higher risk of accidents or that are more likely to violate safety regulations.

13.2 Visualization

To make the insights gained from the data analysis more accessible and actionable, the results can be presented using visualizations such as graphs, charts, and maps. These visualizations can help AtoN managers better understand the data and make informed decisions.

13.3 Decision-Making

Once the data has been analyzed using statistical and machine learning techniques, the insights gained from the analysis can be presented in a meaningful and easy-to-understand way, using graphs, charts, and other visualizations. This can help AtoN managers identify trends and patterns quickly, and make informed decisions about how to improve safety and efficiency. Finally, the insights gained from the data analysis can be used to inform decision-making in AtoN management. For example, AtoN managers can use the analysis to optimize the placement of buoys and beacons, predict and avoid potential hazards, and improve the efficiency of vessel traffic management. By using data-driven insights, AtoN managers can make more informed decisions that can help enhance safety, improve efficiency, and reduce costs.

14 CONCLUSION

Big data analytics has the potential to revolutionize AtoN management by enabling more effective use of data generated by modern AtoN systems. By collecting and analyzing data, it is possible to identify patterns and trends that can be used to enhance safety, improve efficiency, and reduce costs. However, to realize these benefits, it is crucial to address the challenges associated with data quality, privacy concerns, and technological limitations. With appropriate data management and advanced analytics tools, big data analytics can be a valuable tool for improving AtoN management and ensuring safe and efficient maritime transportation.

In conclusion by using big data analytics, AtoN management can benefit from enhanced safety, improved efficiency, and reduced costs. For example, by analyzing vessel movements and weather conditions, AtoN managers can better understand and predict the navigational hazards and make informed decisions on the placement and maintenance of buoys and beacons. Additionally, by optimizing the placement of AtoN equipment, vessel operators can reduce fuel consumption and emissions, resulting in lower costs and a more sustainable maritime industry.

AUTHOR BIOGRAPHY

Burhanudin Abdullah is the Assistant Director of the Malaysian Government Marine department and is currently responsible for the AtoN in Malaysian waters. He is a Master Mariner having complemented his time as a Navigation Officer with the Malaysia International Shipping Company with further studies at the Malaysia Maritime Academy Malacca.

S2.2 Digital information related to AtoN through NAVDAT (180)

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ABSTRACT

When an Aid to Navigation is not operative the situation should be reported to navigator through Maritime Safety Information which is one component of GMDSS. More than ten years ago, the IMO decided to modernize GMDSS. The outcome of this tremendous task was amendments to SOLAS chapter IV "Radiocommunications" and the review of more than 40 instruments related to GMDSS. The GMDSS functional requirements are adapted to any format of communication (Telex, analogue or digital) and any radiocommunication system (terrestrial or spatial). The way forward now, and in line with the e-navigation strategic implementation plan, is to introduce digital communications. If there are many other digital solutions, NAVDAT is the very first digital radio system in the maritime sector. It is a basic radio digital system, but it is a tremendous step forward in the transmission capacity and with many flexible possibilities in comparison to NAVTEX to enhance Maritime Safety Information. In May 2023, at NCSR 10, China, France and Ireland submitted a working document named proposals on NAVDAT.

KEYWORDS: GMDSS, e-navigation, NAVDAT, MF, HF, digital

1 INTRODUCTION

In the Ancient times, more than 5000 years ago, shipping was a real autonomous means of transportation for the crew was totally isolated from land and has to rely on its own resources and capacity to face the danger of navigation. It is only more than a century ago that wireless communications appeared with the "*Marconi Wireless Telegraph Company*". In the end of the 19th century, Guglielmo Marconi had put forward the idea of maintaining a permanent link between land and ships at sea. He had thus set up an international network of coastal radio stations and radio operators on board ships. At the beginning of the 20th century it was possible to communicate not only between ships, but also between land and a ship and to use ship stations to relay a message from one continent to another across the seas and oceans. Nowadays, in the XXIst century the last safety measure available to all ships is search and rescue (SAR). The *International Convention on Maritime Search and Rescue, 1979* [1] (SAR 79) was adopted in Hamburg in April 1979. Resolution 6 of SAR 79 proposed to develop a global maritime distress and safety system (GMDSS).

GMDSS was prepared at ITU in order to be used by all ships, and the international maritime organization (IMO) adopted on 9th June 1997 *MSC.1/Circ.803 participation of non-SOLAS ships in the GMDSS* [2]. GMDSS was introduced progressively and entered into force on 1st February 1999 for all SOLAS ships.

GMDSS covers distress, urgency and safety communications including Maritime Safety information (MSI) which includes navigational warnings and Meteorological information. Navigational warnings should be provided in accordance with the standards, organization and procedures of the International Hydrographic Organization (IHO) and Meteorological information should be provided in accordance with the World Meteorological Organization (WMO) technical regulations, recommendations, and procedures. For instance, when an Aid to Navigation is not operative the situation should be reported to navigator through navigational warning. And the two principal methods used for broadcasting navigational warnings as part of MSI in accordance with the provisions of the *International Convention for the Safety of Life at Sea, 1974, as amended* (1974 SOLAS Convention) [3], are NAVTEX broadcasts in coastal waters; and Enhanced Group Call (EGC) broadcasts in geographical sea areas covered by a recognized mobile satellite service. And whatever the system for broadcasting the MSI is still delivered to ships in telex format nowadays.

Ten years ago, the IMO decided to modernize GMDSS. The outcome of this tremendous task was amendments to SOLAS chapter IV "*Radiocommunications"* and the review of more than 40 instruments related to GMDSS. The GMDSS functional requirements does not changed, they are adapted to any format of communication (telex, analogue or digital) and any radiocommunication system (terrestrial or satellite).

The gap-analysis of e-navigation identified the need to present information in graphical format. In that respect the old system of HF facsimile, still operative, delivers a graphical information to mariner in the form of weather or ice charts. There are still more than thirty HF radio stations in the world broadcasting facsimile.

But The way forward now, and in line with the e-navigation strategic implementation plan [4], is to introduce digital communications. Digital can deliver graphical information, but can also be integrated to navigation systems. If there are many other digital solutions, NAVDAT is the very first digital system in the maritime sector.

2 BACKGROUND

2.1 ITU

The ITU has prepared different technical recommendations for a long time with applications in the maritime sector in particular:

- In November 2011, *Recommendation ITU-R-M 2010, NAVDAT 500 kHz* [5];
- In February 2014, *Recommendation ITU-R M.2058, NAVDAT HF* [6]; and
- In November 2018, *Report ITU-R M.2443, NAVDAT Guidelines* [7].

In November 2019, the world radio conference (WRC 19) confirmed the use of all frequency bands for NAVDAT: 500 kHz, 4226 kHz, 6, 8, 12, 16, 18/19, 22 & 25/26 MHz.

2.2 IMO

In January 2020, following China and France presentation of test measurements of NAVDAT system under real conditions at IMO Sub-committee on navigation, communications and search and rescue (NCSR), there was a full support to include NAVDAT as a new output for GMDSS.

In May 2021, the MSC 103 agreed to include in its post-biennial agenda an output on "Development of performance standards for a digital navigational data system (NAVDAT)".

In May 2023, at NCSR 10, China, France and Ireland submitted a working document named *proposals on NAVDAT* [8] detailing how to broadcast information on NAVDAT and how to receive info by NAVDAT.

2.3 Why using a terrestrial system?

GMDSS is based on the use of maritime mobile service (terrestrial) and mobile satellite service (spatial). In particular for the broadcast of MSI two major areas have been defined in *Resolution MSC.468(101)) amendments to promulgation of maritime safety information* [9]: coastal warning areas and NAV/METAREAs.

Coastal warning areas can be covered by terrestrial systems (NAVTEX or NAVDAT) up to 200 nautical miles in average. Coastal warning areas concentrate heavy traffic, consequently more danger and need naturally to be provided with more MSI than in the deep sea. In NAV/METAREAs MSI are broadcasted by enhance group call (EGC) of recognized mobile satellite service. There is also an interest to balance the flow of information between coastal warning area and NAV/METAREAS with the different communication systems.

It should be recalled HF narrow band direct printing (NBDP) may be used to promulgate MSI in areas outside EGC and NAVTEX coverage as indicated in *MSC.1/Circ.1645 Guidance for the reception of maritime safety information and search and rescue related information as required in the Global Maritime Distress and Safety System (GMDSS)* [10].

In short: Broadcast the appropriate information in the appropriate area, at the appropriate time and with the appropriate communication system.

3 NAVDAT BROADCAST

3.1 General

If we may compare the NAVDAT technology to the NAVTEX technology, for a 10 minutes NAVTEX slot at 50 bits/s, the maximum volume transmitted is 30 kbits (kilobit) or 3,75 kB (kilobyte), but in telex only. For a 10 minutes NAVDAT slot at an average flow of 20 kbits/s, the maximum volume transmitted is 12 000 kbits or 1 500 kB, and for different digital file formats.
Another interesting point is a NAVDAT coast radio station can easily transmit NAVTEX message, and thus preparing smoothly the transition to future of digital broadcast directly into S-100 format. Because not all ships will be equipped at the same time with a NAVDAT receiver or even an ECDIS. But the transition from NAVTEX to NAVDAT could be operated from the same coast radio station. Considering the age and wear of international NAVTEX coast stations, it is important to consider what kind of equipment to renew NAVTEX coast stations and to prepare the digital future at the same time.
On board ships, a new receiver is needed to receive NAVDAT messages. But the receiver can be a black box integrated to a computer and the navigation equipment. The figure 1 below summarizes the dual capacity of a NAVDAT coast radio station and the capacity to deliver navigational warning in S-124 format from the navigational warning provider to the receiver on board the ship and the ECDIS by *integrated communication system (ICS)* [11]. As hydrographic offices will work with S-100 files, it will be more and more time consuming to use NAVTEX for navigational warning should be converted into a telex message to be used with narrow band direct printing (NBDP). It should be noted there are already available NAVTEX coast radio station equipment ready to be adapted for NAVDAT.

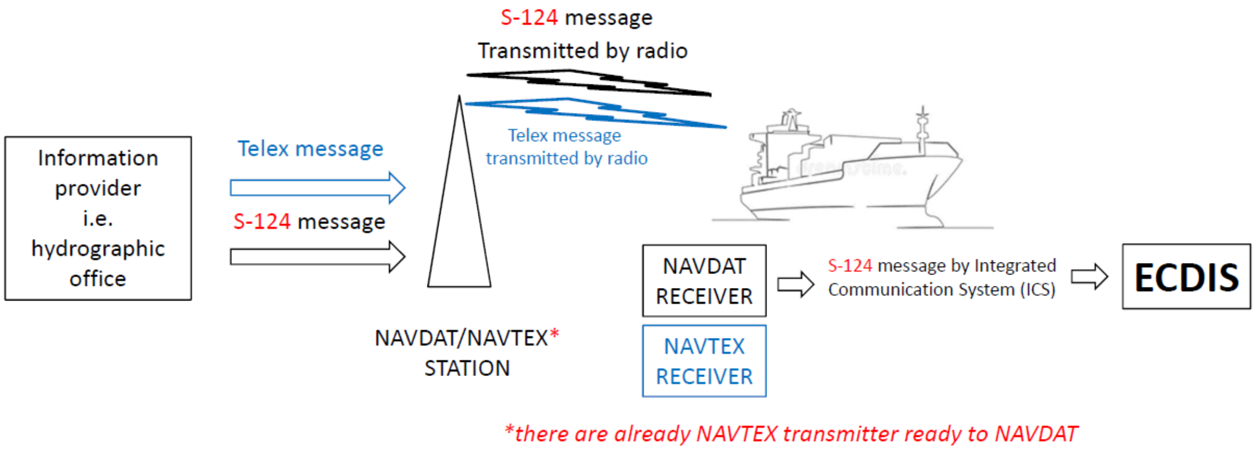

Figure 1: Broadcast of S-124 navigational warning by NAVDAT

3.2 Test measurements of NAVDAT

During 2008 and 2009, studies and development were carried out in France of an Internet Protocol for Boat Communication (IPBC) digital radio transmission system operating in the MF and HF bands. As a follow-up to this work, France proposed a revision of *Recommendation ITU-R M.1798* [12] to introduce a new digital modulation, at ITU-R Working Party 5B (WP 5B) in April 2010.

At the same time, the French delegation of WP 5B, wondered how to reuse the historical frequency of 500 kHz, previously assigned as maritime frequency of international telegraphic distress. Then it was proposed to study a system of broadcasting messages intended for ships, such as NAVTEX, but in digital modulation. As part of the study, a temporary transmitter station was installed at Plougastel Daoulas, Brittany, France, and a test receiver was installed onboard the car-ferry *PONT AVEN* of *Brittany ferries* plying from France to United Kingdom, Ireland and Spain. A report of these tests was published in *Report ITU-R M.2201* [13] in November 2010.

In the continuity of this work, France proposed in June 2011 a working document which lead, after validation by WP 5B, to Recommendation ITU-R M.2010 published by the ITU in March 2012 describing the NAVDAT system. The World Radiocommunication Conference 2012 (WRC-12) confirmed the exclusive use of the 495 kHz to 505 kHz frequency band worldwide in the Radio Regulations.

In the continuity, France proposed a recommendation also for the NAVDAT system but in HF maritime bands. This Recommendation, ITU-R M.2058, was validated by the ITU and published in February 2014. At the same time, Appendix 17 to the Radio Regulations, which lists the available HF frequencies for coast stations and ships, was revised during WRC-12 with the particular assignment of digital transmission sub-bands.

France and China volunteered at WP 5B to develop performance standards of shipborne equipment for NAVDAT system. In that respect a test measurement campaign of NAVDAT HF was carried out in France during 4 months in addition to the test measurements of NAVDAT MF carried out in China.

Test measurements were conducted in France from a MF/HF coast station in Ushant island belonging to MRCC Corsen. A server was installed at MRCC Corsen, located at the West end of Brittany. This server was accessible via an internet connection. One generator/modulator was piloted by a controller, and installed on the transmission site on Ushant island (île d'Ouessant). And two receivers were installed on fishing vessels *BARA LOODEN* and *BARA BREIZH* with the kind permission of the owner *ARMEMENT BIGOUDEN* of Guilvinec harbour, Brittany, France. The centre frequency used for the experiments was 4347 kHz. The files broadcasted on NAVDAT were provided by French weather office (Météo France) and French hydrographic office (SHOM). It is particularly interesting to demonstrate the good reception on board a fishing vessel of digital files, because the electromagnetic compatibility (EMC) is not particularly optimal on this type of ships. Thus, if the reception of digital files works on a fishing vessel, it should definitively work on a merchant ship. Figure 2 below indicates the area covered during test measurements of NAVDAT system under real conditions in France.

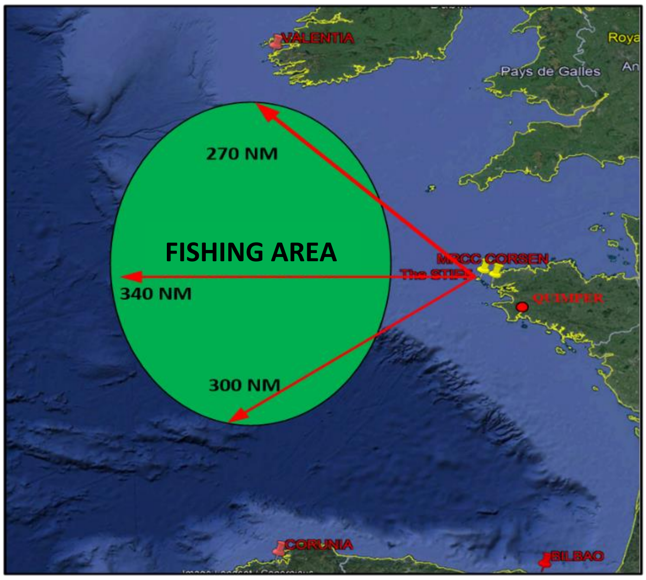

Figure 2: area covered during NAVDAT 4 MHz test in Ushant island, France

China started its research of NAVDAT in 2014, with equipment and system mainly developed by the *East Sea Navigation Guarantee Centre*, Ministry of Transport of China and *Shanghai Advanced Avionics Company Ltd*. (SHAV). The NAVDAT equipment and system are designed according to the Recommendation ITU-R M.2010 and developed based on Orthogonal Frequency Division Modulation (OFDM) with Quadrature Amplitude Modulation (QAM) communication technology. It operates in 500 kHz with a bandwidth of 10 kHz. In 2015, China, in its pilot project of application of NAVDAT, established a NAVDAT test broadcast station, a monitoring station and installed NAVDAT receivers in some ships sailing in the East China Sea. After verification, the project officially started its testing and application demonstrations in following year. In 2016, three new onshore monitoring stations were built for the statistical analysis of broadcast quality.

In 2017, China conducted a study on the broadband MF transmitter, and developed a 1 kW transmitter.

During 2018 and 2019, China has undertaken consistent research on the 3 kW transmitter and NAVDAT/NAVTEX integrated receiver. At the same time, substantial progress was also achieved, jointly by China and France, in ITU-R with update of ITU-R Recommendation M.2010 and the release of Report ITU-R M.2443 NAVDAT guidelines. Figure 3 below indicates the areas covered during test measurements of NAVDAT system under real conditions in China.

Figure 3: area covered during NAVDAT 500 kHz test in Shanghai, China

3.3 NAVDAT broadcasting modes

Broadcasting NAVDAT files can be done by:

.1 general broadcast (to all ships);

.2 selective broadcast (to ships located in a specific area, or for groups of ships according to the ships' position, MMSI or group identification); and

.3 dedicated message (according to ship's MMSI).

There are possibilities of encrypting sensitive files in the three modes of broadcasting. In that respect there are different possibilities to use NAVDAT, not only in GMDSS (SAR and MSI) but also for national security messages, fishing information (regulations, special map of fishing areas, quota information), pilot services, tug services, port support services or VTS…

Concerning the broadcast of MSI by NAVDAT, the system will follow the common international practise adopted by IMO, IHO and WMO of general broadcast as it is the case now with NAVTEX. An example of the use of the 3 broadcasting modes would be with SAR related information. An RCC could make a general broadcast to relay a MAYDAY to ships at sea; implement a selective broadcast only to ships involved in a SAR operation to indicate them a search pattern for instance. Then the RCC could used a dedicated message only with the on-scene coordinator (OSC) in charge to coordinate the SAR operation on scene.

3.4 Single Frequency Network

The NAVDAT system offers the possibility of operating in Single Frequency Network (SFN) mode. This network uses several transmitters operating on the same frequency and broadcasting the same information at the same time. This simplifies the distribution of the time slots, increases the effectiveness of the broadcast which can be longer and limits the potential interference. But when building an SFN network, particular attention will be paid so that the messages are preferably generated by a common server.

4 CONCLUSION

The NAVDAT system with MF and HF broadcast demonstrates the ability to transmit by radio digital files. It demonstrates the ability of NAVDAT system to supersede not only NAVTEX and HF narrow band direct printing (NBDP), but also HF facsimile. Graphical information can be provided to navigator in order to facilitate the interpretation and the further integration of digital information into the electronic charts display and information system (ECDIS).

Modern digital signal processing technology allows faster data transmission and therefore more information to broadcast. Current NAVTEX coast stations encounter difficulties as there is no possibility to allot enough broadcast time to transmit important maritime safety information (MSI). In addition, many facilities of NAVTEX coast stations need to be replaced due to their long time in service. It could be considered appropriate to change old NAVTEX coast stations to NAVDAT coast stations, as for the same transmitter can be used to broadcast NAVTEX and NAVDAT messages.

NAVDAT offers the prospect of more comprehensive information delivered quicker to ships in a flexible way and a more user-friendly display. In particular, graphical information provided to the navigator has been clearly identified in the e-navigation gap-analysis. The technology allows important data rate with regard to the frequency band: rates up to 18 kbit/s are possible with NAVDAT, compared with the 50 bit/s of NAVTEX.

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[12] Recommendation ITU-R M.1798 Characteristics of HF radio equipment for the exchange of digital data and electronic mail in the maritime mobile service

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AUTHOR BIOGRAPHY

Jean-Charles Cornillou has ten-year experience at sea on different types of ships. He joined the French Maritime Administration in 1994. After one-year training he was directly appointed in in Fort de France to develop an MRCC, dealing with all Windward Islands in West Indies. He appointed in a ship inspection service in Rouen in charge of Flag State Implementation (FSI) and Port State Control (PSC). He also was responsible of the implementation of STCW and ILO conventions for the seafarers in the harbour of Rouen. This experience drives him as PSC coordinator in France where he was representing France at Paris MoU, European Union, ILO and IMO. He was in charge of combined marine operation centre in Corsen (CROSS Corsen) which is a VTS (Ushant Traffic) and an MRCC in Brittany at the west entrance of the Channel (La Manche). During that time, he performed IMO technical consultancy missions on SAR and GMDSS in different countries. Jean-Charles is now project director in maritime safety at the Centre for expertise and engineering on risks, urban and country planning, environment and mobility (Cerema), which is the technical department of the French maritime administration. He is particularly involved with the modernization of GMDSS.

S2.3 Case Study – Inspection of Floating AtoN by Drone (153)

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ABSTRACT

Over the last decade, the Danish Maritime Authority (DMA) have evaluated the utility of drones for inspection of lighthouse structures and other AtoN related maintenance tasks. Today, prior to building maintenance, drone inspections are routinely used for a safe and low-cost way to obtain useful status information for planning and preparation of maintenance on stationary AtoN. Based on the successful results using drones for building inspection, DMA assessed that it might be beneficial to apply drones for the inspection of some floating AtoN. A buoy tender traditionally performs inspection of floating AtoN but it is time and fuel consuming to do so. A drone inspection seems to be swift and low-cost with limited energy consumption. Drone inspection possibly including artificial intelligence (AI) for handling the results gives an outstanding way to digitalise data from previously obtained inspections with data automatically streamed and uploaded seamless to a server during the inspection. To verify the method DMA has run trials to investigate and verify the method in practice.

This paper discuss the planning, procedures and experience of one of the latest trial concerning inspection of 85 floating AtoN in Danish Waters by an external company and discuss advantages and disadvantages of the method.

KEYWORDS: drone, inspection, AtoN, floating, digitalisation

1 INTRODUCTION

The Safety of Navigation Department (SIFA) within the Danish Maritime Authority (DMA) is responsible for ensuring navigational safety in Danish waters. The responsibilities of the DMA includes inspection of all Aids to Navigation (AtoN) in Danish waters, counting AtoN owned by the government, community, or private entities. Aids to Navigation include lighthouses, buoys, beacons, and other markers that help to guide vessels, safely through the waterways. By maintaining these Aids to Navigation, SIFA helps to ensure the safety of maritime traffic in Danish waters.

This paper and the case described concerns the inspection of privately owned floating AtoN. Inspections of floating AtoN are carried out as periodic condition checks of the AtoN. SIFA use a variety of methods to ensure the inspection of all the floating AtoN numbering 4,651 entities. Presently we use the buoy tender, its associated workboat, staff from SIFA offices, specially hired part-time crew on smaller workboats and the Marine Home Guard to inspect the floating AtoN. We supplement this with an option for pilots, seafarers and leisure boats to report failures within an observed or missing AtoN by homepage or direct phone calls to report any observed failures.

The floating AtoN owned by the Danish Maritime Authority are inspected both visual and physical including mooring chain, sinkers and underwater condition of the buoy, anodes etc. as well as the colour, top mark, lantern and general condition. The privately and community owned floating AtoN are only visually inspected, which is why a drone inspection is an interesting option of doing that.

A goal of DMA is to ensure digitalising of all data in order to efficiently assess the data, make analysis, study tendencies and keep data for documentation.

The buoy tender “POUL LØWENØRN” is regularly present in many of the Danish waters in order to ensure inspection and maintenance of the government owned floating AtoN, numbering 1,275 entities.

In 2021, DMA carried out a trial on 22 of government owned AtoN. This trail went well; the drone found the AtoN and the documentation was very good.

To broaden and harvest further experience on use of drone for inspections DMA decided to do a new trail entailing inspection of private owned AtoN. Experience shows that the AtoN not owned by the government more frequently deviate in deployed geographic position and in general condition (colour, top marks, reflex band etc.). Consequently, a trail with inspection using a drone seems interesting in connection with the 3,376 AtoN privately owned AtoN, that normally means that the buoy tender must deviate from it's planned voyage to perform the inspections or activating the use of other collaboration partners.

2 EXPECTED OUTCOMES

The expected outcomes identified for using drone-assisted inspection of floating AtoN's are:

- **Increased efficiency -** Drone assisted inspections of floating AtoN carried out independently of DMAs buoy tender "POUL LØWENØRN", reduces the time, and (in some inspection areas) the cost associated with traditional inspections leaving the buoy tender available for other operational purposes as well as reducing consumption of fuel and running hours of main engine and on board machinery.
- **More accurate and consistent data -** The drone equipped with camera and Real Time Kinematics (RTK) module is able to capture high-quality images and record accurate geo-data, providing more detailed and consistent information about the buoyage in the inspection area.
- **Uniform administration and enhanced data analysis -** Data analysis and documentation in conjunction with administration of the buoyage is streamlined by a uniform data set in relation to processing of inspection data and follow-up, which can be stored in the new AtoN register compatible with the S-201 standard.
- **High quality imagery and geo location data** enables better and quicker identification of potential issues or anomalies of the inspected buoyage.
- **Long-term data analysis**, taking into account the development of artificial intelligence and machine learning algorithms, which could enable drone-based inspections and data analysis, carried out at some level of autonomy under operations and in post processing.
- **Improved safety -** Drone-assisted buoyage inspections can help and reduce risks to the crew and equipment of the DMA Inspection vessel "POUL LØVENØRN" by allowing inspections carried out at safe distance with minimal risk to humans and equipment.

3 CASE DECRIPTION

SIFA decided to opt for an external company to handle the actual flying of the drone, in order to ensure new robust technology used in the drone, the camera and the gathering of and availability of the data.

The drone used for this inspection will be the DJI M300 se figure 1.

Figure 1: The DJI M300 drone

SIFA wants to test the concept of "drone-assisted buoy inspection" in an area, where the buoy tender will need to make a deviation compared to the normal voyage planning. We wanted an area, where there was a documented need due to the number of commercial and leisure vessels entering into the area.

One of these areas is Vejle Fjord, where the number of commercial vessels passing is approximately 350 each year. The number of leisure boats is infinitely much higher although unknown, as many leisure boats do not carry AIS equipment for tracking.

The following parameters are decisive in relation to the visual condition assessment of the AtoN.

- Position (is the AtoN in the correct position in relation to the Sea Chart and the Danish Maritime Authority's AtoN register?)
- Colour (to what extent the AtoN has faded compared to being able to identify it/state of reflective tape?)
- Shape (Is the AtoN significantly damaged which has or may affect the position of the marking in the water?)
- Top Mark (Is the top mark on the AtoN in place and intact/correct?)

The inspection includes 85 privately owned AtoN. The inspection is performed by overflight of the individual AtoN with deliverance of a data set including five pictures, one from each corner of the compass and one as a top view of the buoy. The pictures must have a sufficiently high resolution thus a proper assessment of the condition of the buoy as well as status of colour.

The other data deliverance is the position of the AtoN (See figure 2, 3 and 4) and a circle round the position called the *Authority Circle* (Figure 5). The *Authority Circle* is the boundary, where SIFA accepts that the position of the floating AtoN is correct, allowing for a reasonable swing circle.

Latitude	Longitude	Name	AFM_NAVN	AFUFORKORT	BESKRIVELS	EJER	SERVICECOR
55,69855	9,593617	1512-6-480	Vejle Yderrende bb. 9	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,69905	9,59055	1512-6-511	Vejle Havnerende stb. 1A	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,699383	9,58755	1512-6-512	Vejle Havnerende stb. 1B	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,699133	9,586283	1512-6-520	Vejle Havnerende bb. 2	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,7006	9,582117	1512-6-530	Vejle Havnerende stb. 2	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,70035	9,579983	1512-6-540	Vejle Havnerende bb. 3	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,701667	9,575883	1512-6-550	Vejle Havnerende stb. 3	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,702467	9,57135	1512-6-640	Vejle Havnerende stb. 4	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,701767	9,570933	1512-6-650	Vejle Havnerende bb. 5	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,677267	9,7454	1512-6-210	Træskohage	SPEC u/top	Specialafmærkning	Sejlklubben Neptun	Sejlklubben Neptun
55,6983	9,624783	1512-6-410	Vejle Yderrende bb. 2	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,698267	9,620533	1512-6-420	Vejle Yderrende bb. 3	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,6983	9,616333	1512-6-430	Vejle Yderrende bb. 4	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,69835	9,611933	1512-6-440	Vejle Yderrende bb. 5	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,6984	9,607333	1512-6-450	Vejle Yderrende bb. 6	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,698433	9,60285	1512-6-460	Vejle Yderrende bb. 7	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,698483	9,59855	1512-6-470	Vejle Yderrende bb. 8	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,703033	9,565617	1512-6-660	Vejle Havnerende bb.	PORT m/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,703433	9,565533	1512-6-670	Vejle Havnerende stb. 5	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,704417	9,560617	1512-6-690	Vejle Havnerende stb. 6	STAR m/top	Styrbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,698517	9,66845	1512-5-300	Holtserhage	PORT u/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,680883	9,746583	1512-3-200	Træskohage Fyrtårn	SECT LGHT	Vinkelfyr	Skov og Naturstyrelsen	Skov og Naturstyrelsen
55,693033	9,7234	1512-6-240	Ullerup Skov Fortøjningstønde	SPEC u/top	Specialafmærkning	Dansk Sejlunion	Dansk Sejlunion
55,678367	9,690067	1512-6-256	Brejninge Hoved Fortøjningstønde	SPEC u/top	Specialafmærkning	Dansk Sejlunion	Dansk Sejlunion
55,698267	9,62945	1512-5-400	Vejle Yderrende bb. 1	PORT u/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,698717	9,588667	1512-5-500	Vejle Havnerende bb. 1	PORT u/top	Bagbord sideafmærkning	Vejle Havn	Vejle Havnevæsen
55,699117	9,572883	1512-3-491	Vejle Yderrende Formærke	FRNT BCON	Sejladsforbåke	FRV	FRV
55,7035	9,597833	1512-6-510	Brønsodde SW Kapsejladsafm.	SPEC m/top	Specialafmærkning	Neptun Sejlklub	Neptun Sejlklub
55,706	9,6345	1512-6-505	Kongeskov S Kapsejladsafm.	SPEC m/top	Specialafmærkning	Neptun Sejlklub	Neptun Sejlklub
55,707667	9,672	1512-6-508	Storeskov SE Kapsejladsafm.	SPEC m/top	Specialafmærkning	Neptun Sejlklub	Neptun Sejlklub

Figure 2: AtoN information given to drone pilots

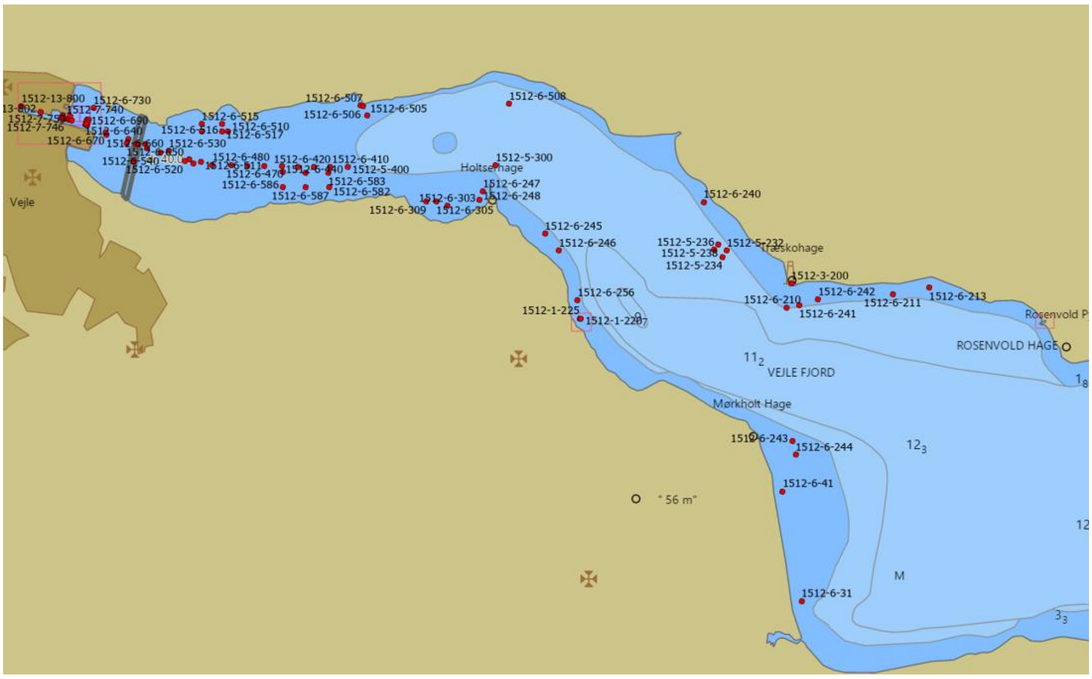

Figure 3: Vejle Fjord

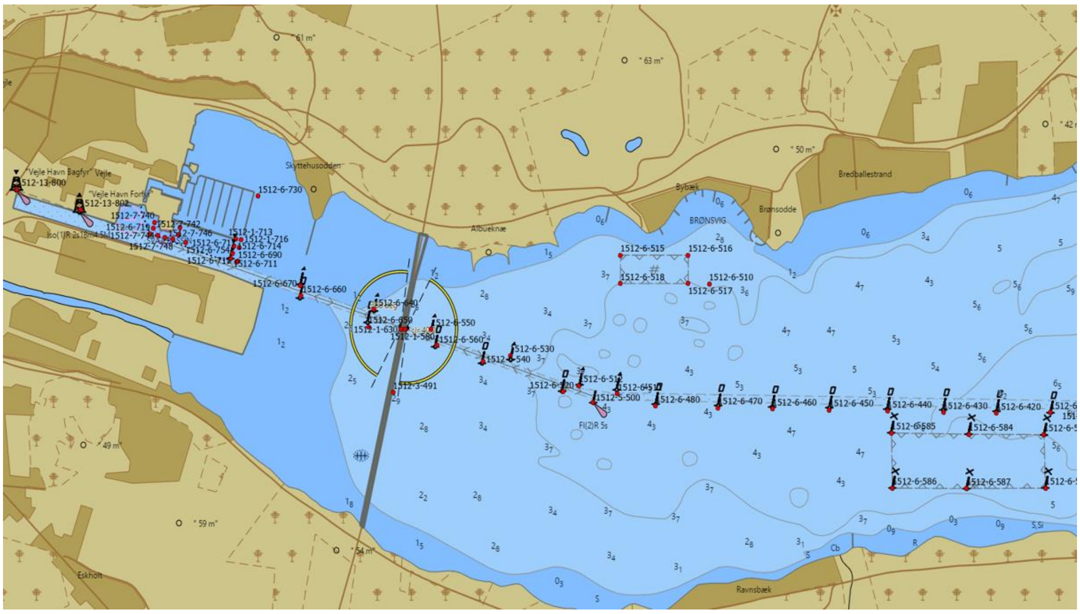

Figure 4: Inner part of Vejle Fjord

3.1 Authority Circle

Floating AtoN, are typically deployed with a chain length of 2 – 2.5 times the current water depth.

Adjustments of the chain lengths are done in relation to the predominant conditions in local waters, such as surface currents and the aim of acquiring as accurate a positioning as possible in areas with narrow straights and channels.

Given these predominant conditions, it is necessary to assess how big a deviation from the official geographical position is acceptable to the authorities.

To determine a baseline of an acceptable position deviation the buoyage's maximum swing radius (authority circle) we use a simple formula taking into account the water depth and the buoyage's chain length.

Calculation of the *Authority Circle* is as shown below and depictured in figure 5:

$$r_m = \sqrt{L^2 - D^2}$$

r_m = swing-radius (*Authority Circle*)

L = Chain length (typically 2 – 2.5 times water depth)

D = Water depth

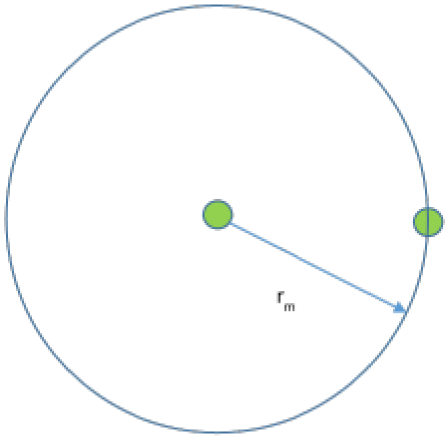

Figure 5: Calculated Authority Circle

In the case of privately owned floating AtoN, typically the chain length is unknown by the DMA. Therefore, the *Authority Circle* can only be an estimate based on the prevailing water depth in the area and the importance of the given AtoN for ensuring safe navigation in the area in question (e.g. Narrow straights and channels).

3.2 Deliverance

All deliverances are loaded in an easy implementation format (a KML file) for assessment and documentation into the AtoN register (S-201).

KML (Keyhole Markup Language) is a file format used to display geographic data in an Earth browser such as Google Earth, Google Maps, and other mapping software. KML files can be easily shared and opened on various platforms, making them a convenient format for delivering geographic data, such as the location and condition of floating AtoN

Using KML files to deliver data, collected by drone-assisted inspections, into the AtoN register improves the efficiency and effectiveness of the inspection process and aid in the post case processing and management of the AtoN in Vejle Fjord.

DMA can chose to assess the data asynchronously as well as streamed in real time, if this is of interest. Streaming the overflight will most likely not be convenient unless it concerns another type of inspection by drones, such as an emergency inspection with a reported AtoN failure of a very important AtoN in a safety of navigation sensitive area.

Figure 6-9 shows the deliverance in the database, the drone company have developed. It is possible to choose different report schemes during the assessment of the collected data. This means that finding areas with common defects or tendencies become obvious and can be addressed in an effective manner:

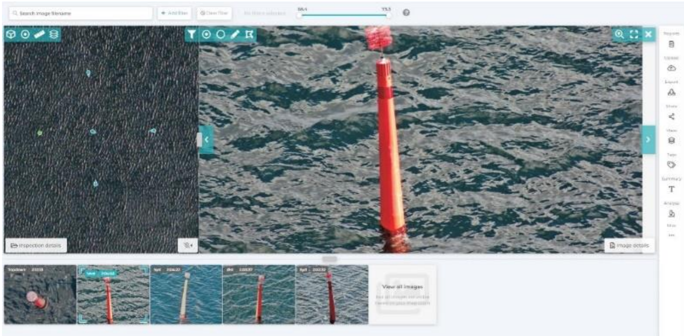

Figure 6: Red side mark from side

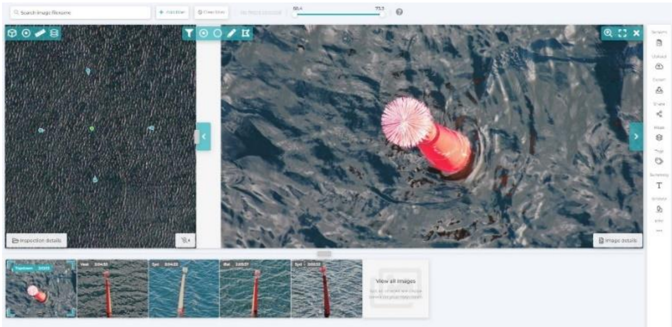

Figure 7: Red side marking from above

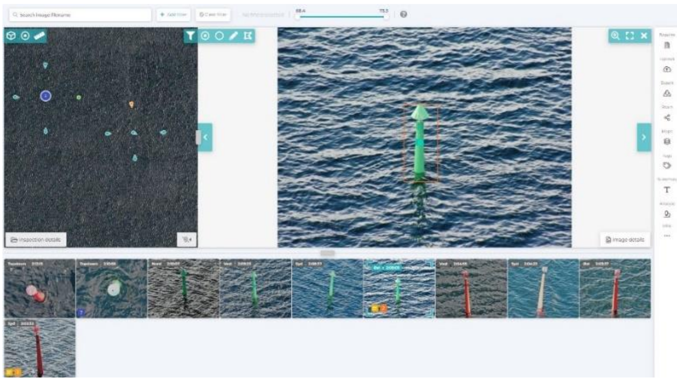

Figure 8: Green side marking from side

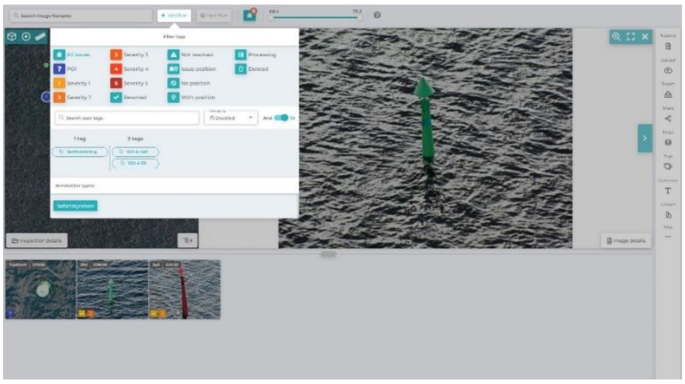

Figure 9: Different options of obtaining information on a green side marking.

4 PRELIMINARY CONCLUSIONS

The DMA's preliminary conclusion are as follows:

- Drone-based buoyage inspection has the potential to become a valuable asset for DMA. By using drones to inspect buoys, the DMA can improve the accuracy and quality of the collected data. Furthermore, there is potential to enhance efficiency of inspections while increasing safety and reducing costs in some areas.
- In the mid- to long term commitment, drone-based data can be analysed by using advanced technologies, such as artificial intelligence and machine learning algorithms. This can provide more accurate and detailed information about the inspected AtoN, allowing the DMA to identify potential issues earlier and take appropriate actions.
- It is important to note that there are still some challenges needs to be addressed before drone assisted AtoN inspections can become more widespread implemented in Danish waters. These challenges include regulatory barriers, operational limitations, and the state of development of *Artificial Intelligence* and machine learning.
- Despite these challenges, the potential benefits of drone assisted buoyage inspections are significant, and with continued innovation and advancements in technology, the use of drones as an operational asset in maritime inspections are expected to become more common in the near future.

5 ACKNOWLEDGEMENTS

We would like to thank Jørgen Royal Petersen from Danish Maritime Authority, Safety og Navigation, National Waters for initiation the first drone trail in 2021 and for supporting this second trail, with his extensive knowledge and competency.

AUTHOR BIOGRAPHY

Ulla Bjørndal Møller is educated as Master Mariner followed by a degree as MSc in Marine Technology and Exam Art of Humanities. She was 10 years in the merchant navy, 15 years as lecturer at a Maritime Academy and 8 years as Head of Fleet / Director, Nautical & HSE Management at A2SEA. Her work included compliance of ISM, ISPS, ISO 9001/14001/ OHSAS 18001, STCW, MLC, national, local and IMO rules and regulations also following and influencing industries best practice and handling flag, class and clients during tender, planning and execution of projects. She was appointed Manager of Operations, Safety of Navigation – National Waters within the Danish Maritime Authority in 2018. The appointment involves a range of different topics from direct handling of maritime issues, navigational warnings and information to decision support managing. She is responsible for all floating AtoN in Danish National Waters and the operation of the buoy tender vessel and her crew. The Operations section is highly dedicated to digitalisation and the implementation in 2023 of an Aton register compliant to S-201, and a MSI system that creates data-packages in S-124 and S-125 standards. Ulla attends as a national member the IALA Aids to Navigation Requirements and management committee (ARM) under WG 2, and workgroups arranged by IALA with partners outside the committee meetings relevant to S-100. She also follows the work in WG 3 during meeting of the E-Navigation Information Services and Communications committee (ENAV), as this is highly relevant to her responsibilities.

S2.4 Introduction of New Aids to Navigation Monitoring System (029)

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ABSTRACT

Aids to Navigation (AtoN) installed on the sea including light buoys shall indicate the position of traffic routes and obstacles for the purpose of safe navigation of vessels. In the case of extinction of lights, removal or being washed away of these AtoNs due to natural disasters and contact with vessels, as AtoNs themselves become obstacles, there are concerns about occurrence of secondary disasters such as contact with the vessels navigating in the vicinities.

Therefore, Japan Coast Guard (JCG) performs remote monitoring of maritime AtoNs by radio communication in order to promptly correspond to provide information to the vessels and recovery operation of such AtoNs in the event of occurrence of abnormalities including extinction of lights of maritime AtoNs on the sea. However, due to deterioration in monitoring system and discontinuation of production of parts for such system by manufacturer, introduction of substitute system thereof has become an issue.

Recently, JCG has established Aids to Navigation monitoring system utilizing information communication technology (ICT) including IoT (Internet of Things), cloud service and mobile phone communication system and promote substitution for the existing monitoring apparatus. This article will describe about the difference between the existing monitoring procedures and the new ones.

KEYWORDS: secondary disasters, remote monitoring of maritime AtoNs, IoT (Internet of Things), cloud service, mobile phone communication system

1 INTRODUCTION

The AtoNs installed on the sea including light buoys shall indicate the position of traffic routes and obstacles, for the purpose of safe navigation for vessels in the congested vessel traffic routes and ports. As of March 2022, JCG maintains 1,339 AtoNs installed on the sea. In the case of extinction of lights, removal or being washed away of these AtoNs due to natural disasters and contact with vessels, as AtoNs themselves become obstacles, there are concerns about occurrence of secondary disasters including not only contact with the vessels navigating in the vicinities but also about running aground on shallows and obstacles. The accident state of maritime AtoNs resulting from natural disasters and contact with vessel during the last five years shall be shown in Table 1 and 2.

For the purpose of prompt corresponding to information provision to vessels navigating and recovery operation for AtoNs in the event there is any abnormality including extinction of lights of such AtoNs, JCG has been performing remote monitoring by utilizing radio communication.

In the next section, the methods for remote monitoring shall be explained.

Table 1. Number of Accidents for Maritime AtoNs Resulting from Natural Disasters

	2017	2018	2019	2020	2021
Extinction of lights	1	10	3	2	1
Light quality failure	1	1	0	0	0
Movement	7	32	8	4	6
Washed away	1	1	0	0	0
Drift	0	0	0	2	0
Falling off	0	4	4	0	0
Submerging	0	0	0	0	0
Sinkage	0	1	0	0	0

Reduction in intensity of light	0	0	0	0	0

Table 2. Number of Contact between Maritime AtoNs and Vessels and Number of Accidents for Maritime AtoNs Caused Thereby

	2017	2018	2019	2020	2021
Contact with vessels	49	48	47	45	33
Extinction of lights	1	3	4	1	2
Light quality failure	0	0	0	1	0
Movement	1	3	2	0	2
Washed away	0	0	0	0	0
Drift	0	0	0	0	0
Submerging	0	0	1	0	1
Wrecking	1	1	0	0	1
Sinkage	0	0	0	1	0
Reduction in intensity of light	0	0	0	0	1

2 CONVENTIONAL ATON MONITORING PROCEDURES

The conventional monitoring procedures currently used include installation of the primary station to the office to manage AtoNs and the secondary station to AtoNs subject to monitoring, between which the radio communication of 60MHz band has been performed. In the case where the distance between the stations exceeds 30km, communication can be performed via the relay station only once.

By monitoring information regarding on/off of equipment on the side of AtoN (secondary station), other than reporting lighting state of the light to the management office (primary station), report shall be performed to the primary station in the event of the state change in the sensors etc. that detect the contact of AtoNs with vessels.

On the side of management office (primary), monitoring control terminal device has been installed, which can transmit the command (request for monitoring state, resetting of the device etc.) to operate the secondary station and the device thereof.

Figure 1 shall indicate the system structure of these procedures.

Due to discontinuation of production of the parts by the manufacturer, it has been required to consider the substitute methods. Additionally, in these procedures, as the license for the station is required in line with the Radio Act as the Japanese domestic law upon installation of such station, there is a problem concerning the workload associated therewith.

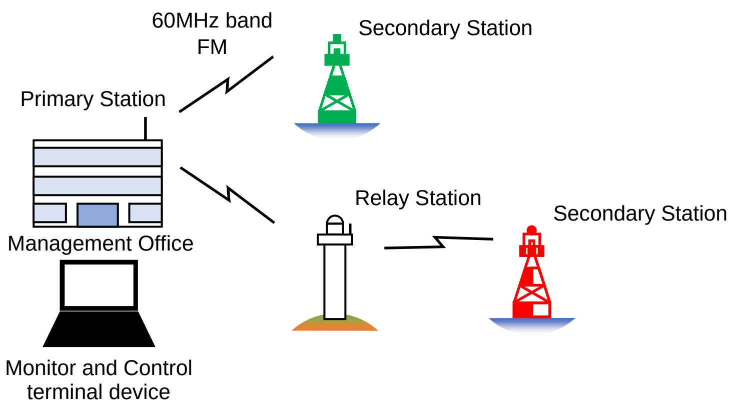

Figure 1. Conventional AtoN Monitoring System

3 NEW ATON MONITORING PROCEDURES

By new monitoring procedures whose introduction has been currently promoted, it has become possible to manage numerical data including battery voltage and positional information based on GPS, as well as information on on/off of the device by utilizing IoT technology. The data measured on the side of AtoNs (secondary station) is integrated on the cloud service through the Web via LTE system. The maritime AtoNs outside of LTE communication service area shall be connected with the cloud service via the gateway station which is located in the area where LTE communication is available by using power saving communication utilizing 920MHz band called LoRa. Additionally, the radio station of LoRa requires no license for the station in line with the Radio Act.

On the management office side, with PC connectable with the Web, it is possible to transmit the command (request for monitoring state, resetting of the device etc.) to operate the secondary station and the device thereof, by the same procedures as the conventional ones, as well as to confirm the status of AtoNs from the cloud service.

Figure 2. shall indicate the system structure of these procedures.

In these procedures, as the movement of the position of AtoNs can be found regardless of whether vessels contact with AtoNs or not in addition to lighting state of the light and contact of AtoNs with vessels which could be monitored by the conventional procedures, it has become possible to promptly correspond to providing information to vessels navigating and recovery operation for AtoNs. Furthermore, by monitoring battery voltage, it has become also possible to conduct preventative maintenance against voltage reduction.

Table 3 shall indicate the comparison between the new procedures using the cloud service and the conventional ones.

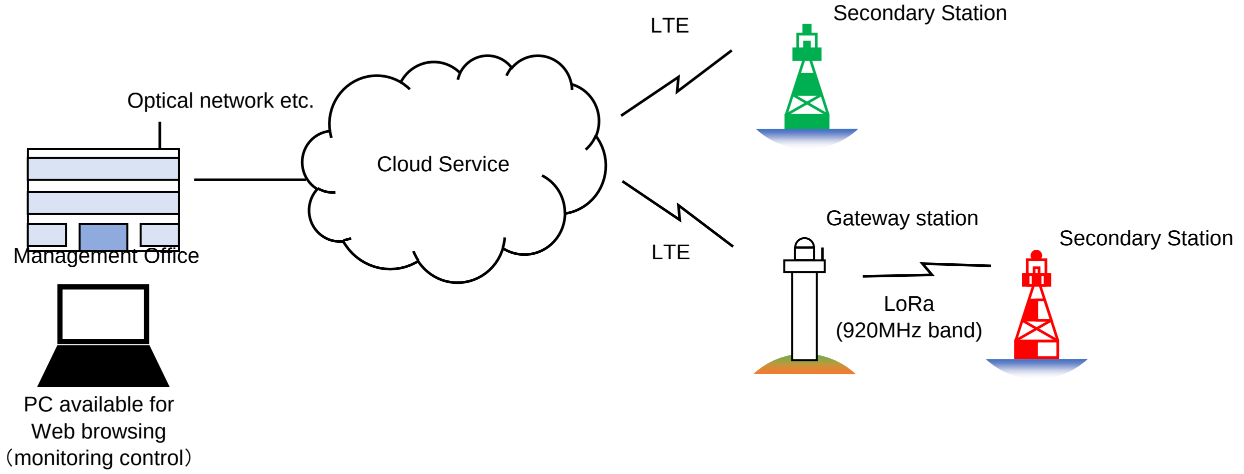

Figure 2. New AtoN Monitoring System

Table 3. Comparison between new and conventional monitoring systems

<table>
<tr><th colspan="2"></th><th colspan="2">New system (cloud monitoring)</th><th>Conventional system (warning device for lighting out)</th></tr>
<tr><td colspan="2">Output signals of secondary station</td><td colspan="2">On/off: 6 items at maximum
Numerical data: 2 items
(GPS Position, Battery Voltage)</td><td>On/off: 22ch at maximum</td></tr>
<tr><td rowspan="2">Network</td><td>Information report destination</td><td colspan="2">Cloud service</td><td>Management office (primary station)</td></tr>
<tr><td>Radio Communication Network</td><td>LTE (VPN on public network)</td><td>LoRa (private network)</td><td>60MHz (
private network)</td></tr>
</table>

	The range where the secondary station can be installed	Within the service area of mobile wireless carrier	Approximately 10km from the gateway station	20km to 30km from the primary station (extended up to approximately 50km by installing relay apparatus)
Monitor Terminal		PC available for web service		Monitor and control terminal for management office (primary station)
Information report timing		At the time of occurrence of abnormalities, of requesting, of preset time.		At the time of occurrence of abnormalities, of requesting, of preset time.
Remarks		Has been introducing since 2018.		Production of spare components has been discontinued from 2013.

4 CONCLUSIONS

This article has introduced the new Aids to Navigation monitoring system whose establishment JCG has been promoting.
For the future, along with substitution of conventional monitoring device, the installation of the new monitoring devices shall be promoted to the places where such devices have not yet been installed.

AUTHOR BIOGRAPHY

RADM Awai Tsuguo is a Senior Director of Int'l Maritime Security Strategy Group of the Japan Coast Guard. He has attended the Council meeting since the 69th session and assumed the duties as the IALA councilor for Japan in August 2022. He has led a wide range of international activities of the JCG with his comprehensive knowledge and experience, not only in coast guard services but also in international maritime fields to cover the policy and technology aspects. He started his professional career in 1984 when he graduated from the Coast Guard Academy and was given a first assignment on board JCG Cutter as a radio officer. Since then, he has engaged in a variety of shore/sea services of the JCG across the country. He had also served in the Maritime Safety Division of the International Maritime Organization in London from 1989 to 1991 as a professional officer in charge of GMDSS, SAR and STCW. He has finished the Special Auditor Course in Electronics/Engineering at Tokyo University. In addition, he is proficient in English and French.

He has authored wide-ranging writings relating to maritime civil security, marine engineering and geo-politics and has become well known as a JCG key person in international activities. He has also engaged in supporting a variety of IALA activities, including the regional capacity building, etc.

S102.1 The importance of the design depth to Marine Aids to Navigation projects analysis (017)

Lieutenant Commander Guilherme Pires Black Pereira, Brazilian Navy, Aids to Navigation Center "Admiral Moraes Rego" (CAMR), Brazil

ABSTRACT

The use of Global Satellite Navigation Systems (GNSS) has become a primary source of real time geographic positioning information and its association with raster and vector charts has allowed greater situational and spatial awareness of maritime navigation, specially to large draft ships. This facility improved the risk about safety navigation perception and provided the starting conditions to megaships port access feasibility, in the past. Beyond navigation, GNSS systems are also primary source of position data for the production of elements of the nautical cartography aiming at vertical and horizontal datums data standardization and the adequacy Marine Aids to Navigation establishment national records. Still, IMO required accuracy of the position for different applications and phases of navigation often requires even greater accuracy than GNSS single frequency performance could offer, specially related to hydrographic surveys standards.

High accuracy bathymetric data are quite limited in marine geospatial domain of the world's coastal waters and therefore it is also a relevant consideration. Probabilistic models of megaships accessibility evaluation generally rely on real time simulations and generally do not take into consideration many associated parameters uncertainties. As consequence it underestimates the necessity of severe risk mitigation measures and safety margins. This last parameter is usually considered ultraconservative and faced as an obstacle to maritime transportation efficiency enhancement. It is a fact that the use of simulators and simulation may imply in the use of models and data of unknow accuracies – the "black box systems", which aims to replicate real conditions and natural effects. Although "black box" simulations can achieve apparent good results, its is considered very natural to fail on safety issues, due to the complexity of process of nature machine copy. Like most of simulations it requires simplifications and even the assumption of certain premises. Naturally, the production of doubtful results and information is a real possibility.

From the point of view of the Coastal State, the efficient establishment of AtoN, including visual marks has become one of the most essential maritime service on the behalf of navigation safety, that naturally by definition foster safe and efficient maritime transportation, considering that the dimensions of Project Ships have grown greatly in the last fifty years and the infrastructure of the access channel and they are already operating in a very high risk operation environment, which possibilates some emphases on navigations safety issues. Several considerations were described about the importance of visual marks under the design aspect of navigation channels and their dimensioning, for which consideration should be given to the limitations of positional accuracy provided by GNSS and the perception that there is an excessive confidence of users-navigators of the information produced by this system and that it is associated with the various elements contained in navigation systems and nautical charts, for which navigation channel designers and Marine Aids to Navigation Administrations should be aware.

Considerations on the accuracy of the navigator's position, bathymetric data (referred depth to a established vertical datum) accuracy as well as the accuracy of the position of floating nautical signs establishment were presented not only by its contribution to AtoN awareness for all navigators, but also because it produces critical mass over some kinds of navigation projects, including marine signalling evaluation. It has been demonstrated there are implications of the selection of the Design Ship and the depth to be defended by nautical signs (Design Depth) to support navigation safety parameterization and evaluation. Such elements are essential to a proper establishment of nautical visual signs and are supported by the application of international engineering guidelines and best practices related to maritime access channels design, specially, if simulation studies cannot be properly validated.

(No paper submitted)

AUTHOR BIOGRAPHY

Born at Rio de Janeiro in 1984, Guilherme Pires Black Pereira active Lieutenant Commander in the Brazilian Navy, joined the Naval School in 2000; holds a degree in Naval Sciences and Electronics specialization at Naval College, completed in 2007; in 2010, carried out an improvement course in Hydrography for officers (CAHO) of the Directorate of Hydrography and Navigation (DHN); in September of 2019, participated at the IALA model course "Aids to Navigation Manager Course – Level 1", from China Maritime Safety Agency (China MSA); in December of 2021, completed an accredited by IALA VTS Operator course (VTS-103/1 – Operator Training Course); still at the end of 2019, obtained the title of Master in Oceanic Engineering at the Federal University of Rio de Janeiro (COPPE/UFRJ).

Since 2020, has been teaching the discipline "Aids to Navigation" of the Improvement Course in Hydrography for Officials (CAHO), coordinated by the "Aldmiral Radler de Aquino" Instruction Center (CIAARA), subordinated to DHN; Throughout his career, has worked in the following organizations of the Brazilian Navy: Frigate "Niterói", Oceanographic ship "Antares", Navy Hydrography Center (CHM) and Aerodrome Ship "São Paulo". Since July of 2019, has been in charge of the Electronics and DGNSS Division at the "Admiral Moraes Rego" Aids to Navigation Center (CAMR). As a Hydrographer, his professional skills are in Operational Oceanography obtained over three years' experience on board. In the last 3 years has focused his professional work on dealing with matters related to marine Aids to Maritime Navigation (AtoN) of interest to the Brazilian Maritime Authority, at CAMR.

S102.2 Analysis of buoy migration rule based on telemetry data (074)

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ABSTRACT

The accuracy of the buoy's position is of great importance to ensure the safety of ship's navigation. The buoy observed by the navigator is the position of the floating body, while the buoy position issued by the buoy maintenance department is the position of the sinker, which are not consistent with each other. How to make these two positions as close as possible is the buoy maintenance department's efforts to pursue the effect of navigational aids. Using the buoy telemetry position data, the vector centre position of the buoy displacement is calculated, and the deviation between the probable migration position of the buoy and the sinker position is derived, whereby the position of the sinker of the buoy is adjusted so that the actual observed position of the buoy by the navigator is as consistent as possible with the publicly announced position of the sinker. Taking Y0# buoy and Y9# buoy in Xiamen port as an example, the above method is used to adjust the sinker position, and the experimental results show that the centre point of the adjusted buoy's probable offset position is closer to the sinker position released to the public, which indicates that the method can be used as an auxiliary decision-making method for fine operation of buoy adjustment, and also provides a new way of thinking for promoting the application of big data in navigation safety.

KEYWORDS: Buoy, big data, position data, navigational performance

1 PROBLEM PRESENTATION

The buoy is tied to the seabed by the sinker, generally the floating body moves near the sinker under the action of wind, current and other external forces. The buoy seen by the navigator is the position of the floating body, while the buoy position issued by the buoy maintenance department to the public (the position of the buoy indicated by the chart) is the position of the sinker of the buoy, which are not consistent, so the position of the floating body observed by the navigator has a certain migration from the position of the buoy indicated by the chart[1-2]. Generally speaking, as the buoy is only an aid to navigation, in open water, the migration basically will not affect the navigation safety of the ship, but the deviation between the actual position of the floating body and the published position of the buoy set up in narrow water, side markers at the boundary of artificial channel and near dangerous objects should be given full attention, if the floating body position deviation is too large and not detected in time, sending inaccurate aid to navigation information to the ship and so on, it will directly affect the navigation safety of the ship.

Taking the main channel of Xiamen port as an example, based on the observation of the maximum drift distance of buoys in the main channel of Xiamen port for three consecutive days from May 29 to May 31,2022, the distance between the centre of buoy migration cycle (the position of sinker) is shown in Table 1.

Table 1 The statistical of the distance between buoys and the sinkers in the main channel of Xiamen port

No.	Name of the buoy	Label	Migration Distance
1	No.3	Right hand mark	20m
2	No.4	Port hand mark	45m
3	No.5	Right hand mark	25m
4	No.6	Port hand mark	45m
5	No.7	Right hand mark	20m
6	No.8	Port hand mark	80m
7	No.201	Right hand mark	60m
8	No.9	Preferred mark	25m
9	No.10	Port hand mark	65m
10	No.11	Right hand mark	10m
11	No 11A	Right hand mark	15m
12	No.12	Port hand mark	20m
13	No 12A	Port hand mark	45m
14	No.13	Right hand mark	30m
15	No.14	Port hand mark	30m
16	No.15	Right hand mark	45m
17	No.16	Port hand mark	40m
18	No.17	Right hand mark	60m
19	No.18	Port hand mark	35m
20	No.19	Right hand mark	20m
21	No.20	Port hand mark	50m
22	No.21	Right hand mark	45m
23	No.22	Port hand mark	45m
24	No 22A	Port hand mark	20m
25	No.23	Right hand mark	35m
26	No.24	Preferred mark	35m
27	No.28	Port hand mark	35m
28	No.29	Right hand mark	15m

The water depth in the main channel of Xiamen port is between 15-25m, According to the analysis of anchor chain length and water depth, generally speaking, when the buoy deviates more than 45m from the sinker, it indicates that there is an abnormal position of the buoy. According to the statistical data in Table 1, there are 10 buoys with an drift value greater than or equal to 45 m, which indicates that, there is a big gap between the buoy position actually seen by the navigator and the buoy position marked on the chart (the buoy position announced to the public, that is, the position of sinker), which affects the navigable water judgment of the navigable water area by the navigator, will bring certain potential trouble to the ship's navigation safety.

The buoy position accuracy is one of the important indicators to evaluate the buoy effectiveness. It is the responsibility of the buoy management department to make the buoy's published position as consistent as possible with the actual position of the floating body seen by the ship's pilot, so that the buoy's risk avoidance and navigation effectiveness can be effectively played. Therefore, it is necessary to further improve the refinement of the operation method of buoy position adjustment so as to improve the accuracy of the buoy position[3].

2 THEORETICAL METHOD-FINDING THE CENTER POINT OF BUOY DRIFT POSITION BASED ON CONVEX HULL

2.1 Acquisition of high-frequency buoy position data

The buoy drifts in the water near the sinker under the action of external forces, in the process of movement, the frequency of passing through different location points in its active water range is different, because the wind and current have certain rules, under the action of wind and current, the buoy may frequently pass through a location point, while some other location points, may only occasionally be "passed through ". For example, at the edge of the buoy's active waters, the frequency of the buoy drifting to this point is obviously smaller than the centre of the active waters. Therefore, by calculating the frequency of buoys at different location points, the migration rule of buoy in active waters relative to the sinkers can be found.

In general, within the buoy's active waters, it reaches the marginal waters less frequently, and the location points of the buoy in reaching the marginal waters are more dispersed. In order to analyze the migration rule of the buoy in active water relative to the sinker, this paper finds the centre of the geometry of the buoy position point in the buoy active water based on not less than 80% telemetry data, and analyzes the position of the centre migrating from the sinker. The ratio of each buoy position point to all position points is sorted from high to low, frequency is p1, p2, p3, ... pn, select the minimum set, so that the sum of the frequencies of these positions is not less than 80% , that is m, so that: $p_1 + p_2 + ... + p_m >= 80\%$, and $p_1 + p_2 + ... + p_{m-1} < 80\%$. In each buoy position data set, the data set of the first 80% occurrence times is taken out, and the data set containing not less than 80% position data points in the buoy position data set is obtained. The processing steps are as follows:

[1] Data pre-processing is first performed to remove anomalous points, i.e. points where the distance from the sinker location exceeds the length of the anchor chain;

[2] Rounding the latitude and longitude of all data to 4 decimal places;

[3] Data grouping, such as grouping M, each group of data of the same latitude and longitude;

[4] Let k = 1;

[5] For a single data set count the frequency of occurrence of each data set, storing the number of occurrences of each data in a natural order from highest to lowest;

[6] Remove the highest frequency data set from the remaining groups to form a new data set;

[7] If the sum of the frequencies of the removed data sets is greater than 80%, the first k sets of data are taken as the final result set, output, and the algorithm ends;

[8] k=k+1;

[9] Repeat step 6.

2.2 Finding convex packets of buoy position data

After obtaining the data set containing not less than 80% position data points,a convex package is used to find the centre coordinates of this geometry, and the procedure is as follows[4] :

(1) In all points, choose the point H with the smallest y coordinate as the base point. If there are multiple points where the y coordinate is the minimum, the point with the lowest x coordinate is selected. Points with the same coordinates should be excluded. Then the angle of the x-axis and the vector <H, p> formed by the other points p and base point is sorted, scanning angle from large to small clockwise, otherwise anticlockwise

scanning. In reality, the included angle is not needed, but the module of the vector can be obtained according to the inner product formula of the vector.

For example, in Figure. 1, the base point is H, and the order is H, K, C, D, L, F, G, E, I, B, A, J according to the angle from small to large. Now do a counter-clockwise scan.

(2) the line segment <H, K> must be on the convex hull, then C is added. Let's assume that the segments <K, C> are also on the convex hull, because in terms of H, K, and C, their convex hull is made up of these three points. But then you add D, and it turns out that the segment < K, D> is on the convex hull, so if you exclude the segment < K, C> , the C point can't be a convex hull.

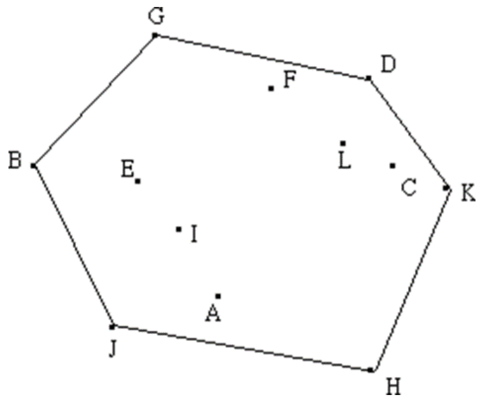


Figure 1 Schematic diagram of the scanning process

(3) When adding a point, it must be considered whether the preceding line segment will appear on the convex package. Starting from the base point, the rotation direction of each adjacent line segment on the convex package should be the same and opposite to the direction of the scan. If it is found that the newly added point makes the new line segment change the direction of rotation with respect to the upper line segment, it can be decided that the last point must not be on the convex package. The implementation can be judged by the vector fork product, where the newly added point is p_{n+1}, the previous point is p_n, and the next point is p_{n-1}. If the fork product of vectors <p_{n-1}, p_n> and <p_n, p_{n+1}> is positive when scanning clockwise (and negative when scanning counterclockwise), the previous point is deleted. The deletion process requires backtracking, removing all previous points with opposite sign of the fork product, and then adding the new point to the convex packet, as shown in Figure 2.

In Figure 2, when point K is added, since the line segment <H, K> is rotated clockwise with respect to <H, C>, point C is not on the convex package and should be deleted and point K is retained. Next, when adding point D, since line segment <K, D> is rotated counterclockwise with respect to <H, K>, point D is retained. Follow the above steps to scan until all points in the point set have been traversed, i.e., the convex packet is obtained.

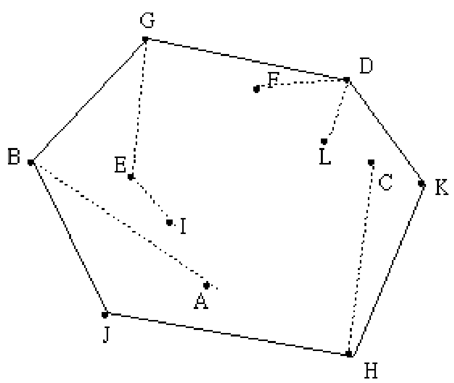


Figure 2 Schematic diagram of inserting new points

2.3 Buoy high frequency position data center point

Assuming that the coordinates of the points on the convex packet of the buoy position points are $\mathrm{P}(x_i, y_i)$, and $\mathrm{P}(x_0, y_0)=\mathrm{P}(x_n, y_n)$, n is the number of vertices of the convex packet, the area S of the packet, and the coordinates of the center of the high frequency secondary position points (C_x, C_y) are:

$$\mathrm{S}=\frac{1}{2}\sum_{i=0}^{n-1}(x_i \times y_{i+1} - x_{i+1} \times y_i)$$

$$\mathrm{C}_x=\frac{1}{6S}\sum_{i=0}^{n-1}(x_i + x_{i+1})\times(x_i \times y_{i+1} - x_{i+1} \times y_i)$$

$$\mathrm{C}_y=\frac{1}{6S}\sum_{i=0}^{n-1}(y_i + y_{i+1})\times(x_i \times y_{i+1} - x_{i+1} \times y_i)$$

3 APPLICATION PRACTICE - XIAMEN PORT EXAMPLE APPLICATION

Xiamen port is a major freight port on the southeast coast of China, the port waters distribute with well laid buoys. However, due to the large current velocity in Xiamen Bay, and larger wind in the outer sea area, by the wind, current and other external forces, especially after the passage of the typhoon, the buoy sinker may have the possibility of displacement. After this happens, it is necessary for the buoy maintenance department to timely adjust the position of the buoy, in order to make the buoy as close as possible to the position announced to the public and the actual position seen by the mariner.

3.1 Refined operation process of buoy position adjustment based on historical position data

During the buoy inspection process of Xiamen aids to navigation department in Xiamen port in February 2022, the position of Y0# and Y9# are deviated from the position of sinker far away, which indicates that these two buoys may have shifted and their positions need to be adjusted. In order to verify the above-mentioned use of buoy telemetry historical position data in the application of buoy position adjustment refinement operations, two buoys in Xiamen port Y0# and Y9# were selected for experiments. The buoy-related underlying data is shown in Table 2 and its location is shown in Figure 3. As this is an experimental project, the data collected in the data collection phase were not used for one year, but for three months (March to May,2021) to analyze the extent to which the two buoys deviated, determine the new position of sinker displacement. The effect of the buoy position adjustment was analyzed by collecting the 3-month data (March to May, 2022) after the sinker displacement of Y0 # and Y9 # buoys in Xiamen port.

The buoy telemetry position data is derived from remote control system at the Xiamen Aids to Navigation Management department, and remote control terminal is installed on the body of each buoy. Therefore, the telemetry position data of the buoy is the position data of the buoy body, that is, the buoy position that the navigator or the buoy using and maintaining personnel see. The telemetry data is collected at a frequency of 1 time per hour, that is, each buoy collects 24 positions of data every day.

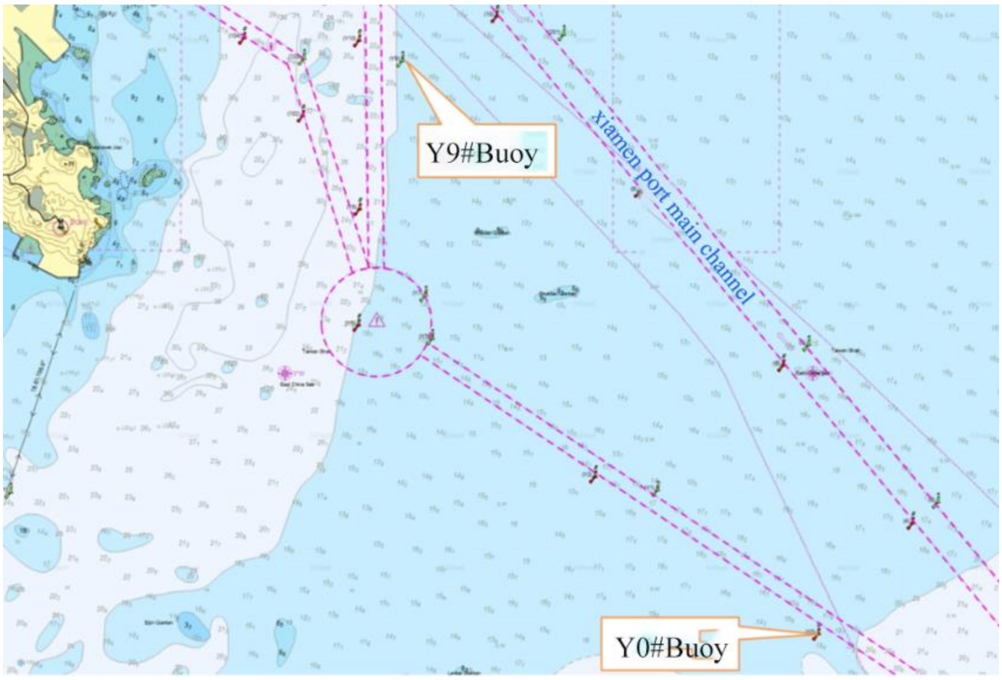


Figure 3 Location of buoys Y0# and Y9# in Xiamen port

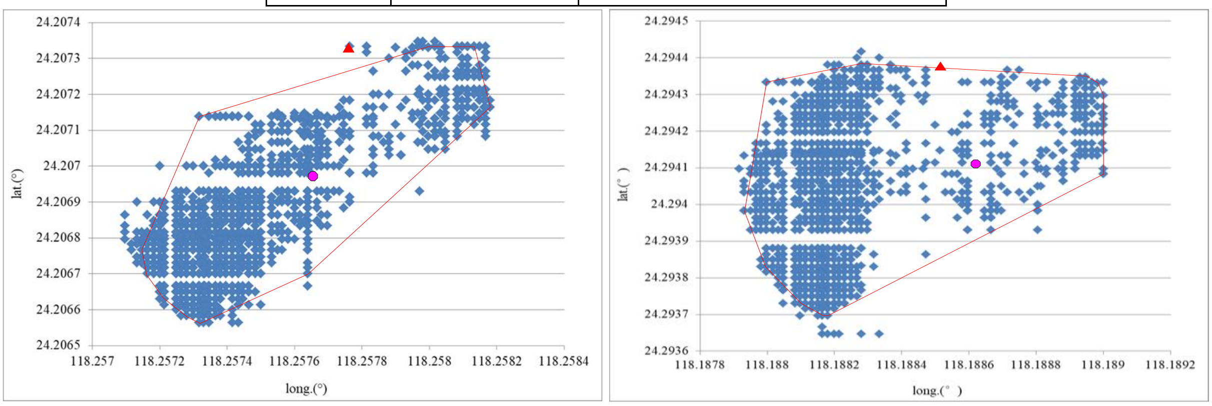
3.2 Experimental buoys and experimental data

3.2.1 Determination of the location of the sinker displacement

According to the telemetry data of Y0 # and Y9 # buoys in Xiamen port, the relationship between the buoy position and the relative position of the sinker before the displacement of the sinker is shown in figure 4. In the image, the red triangle is the sinkhole position, the red polygon is the convex boundary of the high frequency position, and the red circle is the center position after considering the frequency of the buoy position.

Table 2 basic data of Y0 # and Y9 # buoys

Name	Water depth	Posting location
Y0#	19.4m	24°12′26.4″N/118°15′28.0″E
Y9#	19.0m	24°17′39.8″N/118°11′18.8″E



(a)Y0# buoy (b)Y9# buoy

Figure 4 Scatter plot of Y0# buoy and Y9# buoy March-May 2021 position data

According to the telemetry position data, the centre coordinate of the high frequency position point is calculated, and the migration distance and azimuth of the centre point of the buoy's high frequency position relative to the sinker are obtained, as shown in table 3. From Table 3, it can be seen that the position data center point of Y0 buoy in March-May 2021 deviates from the position of the sinker by about 45m with a bearing of 199°. Therefore, in order to make the Y0 buoy deviated by wind, current and other external forces around the external release position as much as possible, the sinker needs to be shifted so that the center of the high frequency position point after shifting is consistent with the external release position. The new position of the sinker of Y0 buoy in Xiamen port is 24°12′27.67″N/118°15′28.50″E after shifting. Similarly, the sinker of Y9# buoy in Xiamen port was also shifted, and the new position of Y9# buoy after shifting was 24°17′40.85″N/118°11′18.64″E.

Table 3 The distance and orientation of the centre point of the high frequency position off the sunken stone

Name	Published location	The point centre coordinates of the high frequency positions	The distance from the sunken stone	Deviation from the orientation of the sinker
Y0 buoy	24°12′26.4″N 118°15′28.0″E	24°12′25.08″N 118°15′27.48″E	45m	199°
Y9 buoy	24°17′39.8″N 118°11′18.8″E	24°17′38.76″N 118°11′18.96″E	38m	163°

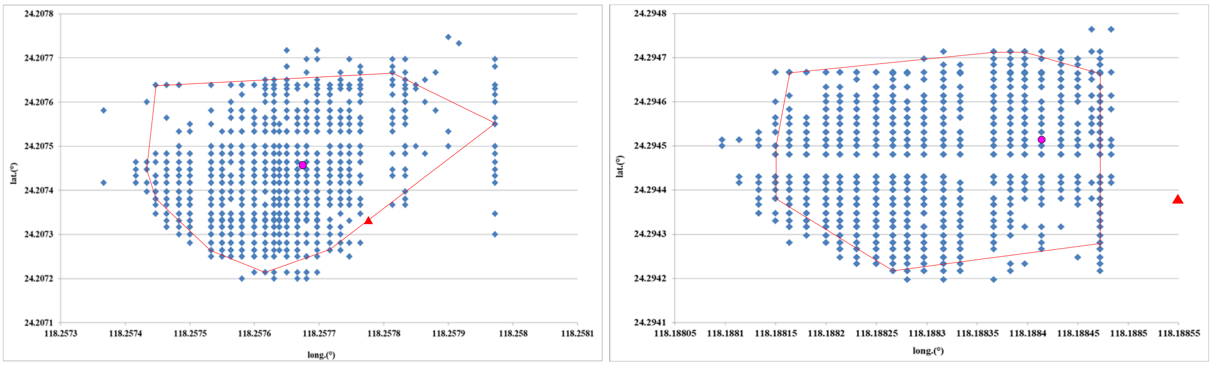
3.2.2 Analysis of the effect after sinker adjustment

In section 3.2.1 of this paper, based on the telemetry position data of Y0# buoy and Y9# buoy in Xiamen harbour from March-May 2021, as well as the position announced to the public, an adjustment proposal is made to make the buoy high-frequency position point as close as possible to the sinker position adjustment of the buoy announced to the public. On February 28, 2022, Xiamen Aids to Navigation Management Department adjusted the position of Y0# and Y9# buoys in Xiamen Port. After the adjustment, continuous observations were made for these two buoys and telemetry position data were collected for three months from March to May 2022. The convex hull and centre point of Y0 # buoy and Y9 # buoy are shown in Figure 5. After adjustment of the sinker position, the centre point coordinate of the high frequency position, the distance and azimuth of the centre point of the high frequency position from the published position are shown in table 4.

Table 4 The distance and orientation of centre point of the HF sub-position from the sinker after adjustment

Name	Published location	The point centre coordinates of the high frequency position	The distance from the sinker	Deviation from the orientation of the sinker
Y0 buoy	24°12′26.4″N 118°15′28.0″E	24°12′26.82″N 118°15′27.60″E	17m	320°
Y9 buoy	24°17′39.8″N 118°11′18.8″E	24°17′40.26″N 118°11′18.30″E	18m	318°

Comparing Table 3 and Table 4, it can be seen that the centre point of the high frequency position point is obviously closer to the externally announced buoy position after the adjustment of Y0# float and Y9# float sinker position, which indicates that the buoy drifts more frequently near the externally announced position under the action of external forces after the adjustment of the sinker position, which shows that the method of using the buoy telemetry position data based on the buoy and combining the HF position centre point to adjust the buoy position to make the buoy HF position closer to the externally announced position is feasible.



(a)Y0#buoy (b)Y9#buoy

Figure. 5 Scatter plot of position data of Y0# buoy and Y9# buoy in March-May 2022

4 BUOY POSITION ADJUSTMENT RESPONSE CLASSIFICATION MANAGEMENT

Based on the application of buoy telemetry big data and daily management experience, Xiamen Aids to Navigation Management Department has developed a buoy position adjustment refinement operation software based on the above method. During the buoy inspection and maintenance, when abnormal buoy position is found, the vector center position of buoy displacement is calculated based on the historical telemetry position data of the abnormal buoy, and the deviation between the maximum possible probable position of the buoy and the position of the sinker is derived, according to which the position of buoy sinker is adjusted accordingly. In terms of fine adjustment, a buoy position emergency response classification system is formed, mainly as follows:

(1) Immediate action: When the buoy drifts out of position, or the floating body enters the danger area of isolated hazards, or the boundary line of the channel, it indicates that the buoy has lost its corresponding function of aiding navigation, and needs to be repaired immediately by the maintenance department of the buoy.

(2) Timely repair: When the distance between the buoy and the sinker is greater than the swinging radius of the buoy, but no drift loss, it means that the position marked by the buoy may be inaccurate and needs to be adjusted in time.

(3) Coordinated response: When the floating body's position deviation does not exceed the swinging radius, but it is a little far from the sinker, it shows that the position marked by the buoy is basically accurate and can be adjusted according to the actual situation during the next on-site inspection.

(4) Close attention: When the buoy position migration is basically within the possible probable position of the buoy, it means that the position of the buoy is basically accurate, and the buoy position can be adjusted more precisely according to the method in this paper during the next lifting.

5 CONCLUSION

Ensuring that the position of the buoy seen by the mariner is as consistent as possible with the position of the buoy announced to the public is the endeavor of buoy maintenance department. Due to the installation of the buoy telemetry terminal, the data accumulation of the moving trajectory of the buoy around the swinging radius can be realized, and the algorithm proposed in this paper can calculate the general probability position of the moving process of the buoy, and then get the deviation of the position of the buoy and the position of the buoy published to the public, according to which the position of the sinker can be reasonably adjusted for several times to reduce the migration of the buoy, which can make the position of the buoy seen by the navigator and the position of the buoy published to the public gradually converge, thus improving the maintenance efficiency and quality of the buoy.

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AUTHOR BIOGRAPHY

Xiang Lu is the Director of Xiamen AtoN Department of Eastern Navigation Service Center of CHINA MSA, engaged in AtoN management for 40 years. Mr. Xiang led the writing work in 2016 for Guideline of AtoN at west part of Taiwan Strait, which is the first publication for comprehensive AtoN service in China. As well, his Navigation-aids Information Service in the e-Navigation has been one of the papers of 18th IALA Conference.

Mr. Xiang also is the deputy secretary general of AtoN committee of China Institute of Navigation.

This paper is cooperated by technicians of Xiamen AtoN Department and researchers of AtoN Research Centre of Jimei University. After several years remote control data collection with 100% AtoN facilities within jurisdictions of Xiamen AtoN Department, this team applied convex hull algorithm based on big data to obtain the difference between high-frequency position of floating buoy’s body and sinker, thus, offering advice and ways of adjusting floating buoy for reference.

S102.3 Modernization of Aids to Navigation in Malaysia (008)

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ABSTRACT

The Aids to Navigation division of the Malaysia Marine Department (MMD) is responsible for the management and maintenance of all AtoN's along Malacca Straits, Peninsular Malaysia, and Labuan. Malacca Straits is one of the busiest straits in the world and has more than 80,000 vessel movement per year. In addition, MMD is also responsible for improving the technology of Navigation Aids so that it is constantly updated, in line with current developments and is at an optimal level of efficiency as well as adopting the guidelines set by International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). The existing infrastructure consisted of a variety of AtoN's often installed in earlier years by various organizations and end-users, resulted in a complex inventory of equipment and rising maintenance costs with little benefit for the yachtsmen and shipping industry.

Where the previous maintenance was carried out based on a basic preventive maintenance schedule and an on-demand corrective maintenance, there was a strong need for a more structural approach to meet the current IALA guidelines and recommendations. This approach creates more attention to the need of innovation, integration of cost efficiency in design, developing of a long-term vision and the interaction with the end-user. MMD has embarked on a robust Safety of Navigation Procurement plan with the establishment of 298 AIS based remote monitoring system (AIS AtoN), an upgrade of 117 marine lantern to a new LED types, establishing a mercury free for all its lighthouse lights system, and introduce LiFePO4 batteries as replacement to heavy lead acid batteries.

1 INTRODUCTION

Aids to Navigation (AtoN) play a crucial role in ensuring safe navigation for vessels in the maritime industry. In recent years, Malaysia has been actively modernizing its AtoN infrastructure to enhance the safety and efficiency of maritime transportation. The modernization efforts include the installation of new technologies, such as Automatic Identification System (AIS) and Global Navigation Satellite System (GNSS), which have significantly improved the accuracy and reliability of AtoN services. These developments are crucial for Malaysia's maritime industry, which plays a significant role in the country's economy, including trade, transportation, and tourism.

AtoN in Malaysia are managed by the Malaysian Marine Department (MMD) under the Ministry of Transport. The AtoN infrastructure in Malaysia includes lighthouses, buoys, beacons, and other visual aids. The primary function of AtoN is to provide navigational information to mariners and ensure the safety of vessels in Malaysian waters.

This essay will explore the modernization efforts of AtoN in Malaysia, the impact it has on the country's maritime industry, and the challenges faced during the modernization process.

2 OVERVIEW OF ATON DEVELOPMENT IN MALAYSIA

Aton have played a vital role in maritime navigation for centuries. They help in guiding ships, boats and other vessels, and thus preventing accidents and loss of life. With the advent of technology, remote monitoring systems have been developed to help manage lighthouses effectively. This paper provides a historical overview of lighthouse remote monitoring system development in Malaysia.

2.1 Development of Aton Remote Monitoring System in Malaysia

The earliest lighthouse in Malaysia was built in 1794 in Pulau Pinang, which was then known as Prince of Wales Island. The lighthouse was manually operated, and the lighthouse keeper had to physically climb the tower to light the lamp every night. It was not until the 20th century that lighthouses in Malaysia started to use more advanced technology.

In the 1990s, the Malaysian government began installing remote monitoring systems in lighthouses to increase efficiency and safety. The system used GSM to transmit data, including the lighthouse's status, and other relevant information. This information was received by a control center in Port Klang, which monitored the lighthouse's status and alerted the authorities if there were any issues.

In the 2000s, a remote monitoring system using satellite communication technology was introduced, which enabled the transmission of data for sites that were located beyond GSM coverage. This system was more reliable and efficient than the previous one, but the monitoring data is limited to 12 times a day to save transmission costs.

In 2004, the MMD introduced AIS ATON, which was a centralized system for monitoring all lighthouses in the country. The AIS ATON used the Global Positioning System (GPS) and Geographic Information System (GIS) to provide accurate location information for each aton. The system also included sensors to monitor the aton's status, including the light source, battery, and other equipment.

In 2016, the Malaysian Marine Department (MMD) introduced an upgraded version of the AIS ATON, known as the AIS-based Remote Monitoring System (A-RMS). The A-RMS was designed to integrate with the existing AIS ATON and provide more comprehensive data on the lighthouses. The system included sensors to monitor environmental conditions such as wind speed, temperature, and humidity, as well as equipment performance, including battery life and generator status.

The A-RMS was also designed to be more user-friendly, with a web-based interface that allowed authorized users to access the system from any location with an internet connection. The system provided real-time data on lighthouse conditions, enabling quick response times in the event of equipment failures or other issues.

2.2 Comparison between SCADA and AIS ATON

There are advantages to both AIS ATON (Automatic Identification System for Aids to Navigation) and SCADA (Supervisory Control and Data Acquisition) systems for lighthouse monitoring. Here are some advantages of AIS ATON over SCADA:

Coverage: AIS ATON provides wider coverage than SCADA systems, as it utilizes a network of shore-based and vessel-based AIS receivers to provide real-time data on vessel traffic and navigation. This makes it easier to monitor vessels and their proximity to Aids to Navigation in real-time.

Cost: AIS ATON can be a cost-effective option for lighthouse monitoring, as it does not require extensive infrastructure or specialized hardware like SCADA systems. The network of AIS receivers is already in place for vessel traffic monitoring, so the additional cost for AIS ATON monitoring is relatively low.

Compatibility: AIS ATON is designed to work seamlessly with existing AIS and Vessel Traffic Management (VTM) systems, making it easy to integrate into existing monitoring systems without requiring major changes to infrastructure or hardware.

Real-time alerts: AIS ATON can provide real-time alerts to vessel traffic that is in proximity to the Aids to Navigation, providing immediate notification of any potential safety hazards or risks.

Remote monitoring: AIS ATON can be remotely monitored from a centralized location, allowing for 24/7 monitoring without the need for on-site personnel.

Data sharing: AIS ATON can easily share data with other organizations or agencies, allowing for collaborative monitoring efforts and increased safety across larger areas.

In summary, AIS ATON offers advantages over SCADA systems in terms of coverage, cost, compatibility, real-time alerts, remote monitoring, and data sharing. These advantages make AIS ATON a compelling option for organizations looking to monitor Aids to Navigation and vessel traffic in real-time while minimizing costs and infrastructure requirements.

2.3 Establishing a mercury-free lighting system for all lighthouses

Using mercury baths as a low-friction rotation mechanism is a common practice for lighthouses with large Fresnel lenses. However, recent incidents of acute mercury poisoning and abnormal behavior in lighthouse keepers have brought attention to the potential for chronic mercury poisoning in these workplaces.

Mercury is a toxic substance that can cause serious health problems, including damage to the nervous system, kidneys, and lungs. Chronic exposure to mercury can occur through inhalation, ingestion, or skin contact with the substance.

In lighthouses, the use of mercury baths in rotation mechanisms can expose workers to mercury vapors, which can lead to chronic poisoning over time. Symptoms of chronic mercury poisoning can include tremors, memory loss, and mood disorders.

To address this issue, lighthouse operators should consider replacing mercury baths with alternative rotation mechanisms that do not use mercury. This can help protect the health and safety of lighthouse workers and visitors and promote a more sustainable and environmentally friendly approach to lighthouse operations. Additionally, lighthouse operators should implement proper safety procedures and training for workers who may be exposed to mercury in other contexts, such as during lamp replacement or maintenance activities.

2.4 Slip Ring to replace mercury bath.

Using slip rings as a replacement for mercury baths as a low-friction rotation mechanism is a viable option for lighthouses with large Fresnel lenses. Slip rings can provide a low-friction rotational movement, without the need for a mercury bath.

Slip rings are devices that transmit electrical signals or power between a stationary and rotating structure. They consist of a conductive ring and brush assembly, which allows for a low-friction connection between the rotating and stationary parts.

In the context of lighthouses, slip rings can be used as a replacement for mercury baths in rotation mechanisms for large Fresnel lenses. This can help eliminate the potential for mercury exposure to workers and visitors and reduce the environmental impact of lighthouse operations.

When implementing slip rings, it is important to ensure they are properly installed and maintained to ensure their safe and reliable operation. Lighthouse operators should work with qualified professionals to install slip rings and conduct regular inspections and maintenance to ensure their continued operation.

In conclusion, using slip rings as a replacement for mercury baths is a safe and effective solution for lighthouses with large Fresnel lenses. This can help promote a more sustainable and environmentally friendly approach to lighthouse operations while protecting the health and safety of workers and visitors.

2.5 Conversion from incandescent to LED light.

Converting from incandescent to LED lights for Aids to Navigation (ATON) offers several advantages:

Energy Efficiency: LED lights consume significantly less energy compared to incandescent lights, resulting in lower operating costs and a reduced carbon footprint. This makes them a more environmentally friendly choice.

Longevity: LED lights have a much longer lifespan than incandescent lights, reducing the need for frequent replacement and maintenance. This can result in lower maintenance costs and decreased downtime.

Improved Visibility: LED lights produce a brighter and more focused beam of light, providing improved visibility for mariners. This helps to enhance safety and reduce the risk of accidents.

Enhanced Durability: LED lights are more resistant to damage from environmental factors such as moisture, vibration, and temperature changes. This makes them ideal for use in harsh marine environments.

Better Control: LED lights are easier to control and can be dimmed or brightened as needed. This allows for greater flexibility in managing the intensity and timing of light emissions.

Lower Heat Emissions: LED lights produce less heat compared to incandescent lights, reducing the risk of damage to the housing and the surrounding environment. This makes them safer and more reliable.

Overall, converting from incandescent to LED lights for ATON offers numerous benefits, including energy efficiency, longevity, improved visibility, enhanced durability, better control, and lower heat emissions. This makes them an attractive choice for marine organizations looking to improve the safety, reliability, and cost-effectiveness of their navigation systems.

2.5.1 Importance of LED Heat Management

Effective heat management is essential for LED lanterns used in lighthouses. LED lights produce heat during operation, and if not properly managed, the excess heat can damage the LED components and shorten the lifespan of the lantern.

Proper heat management for LED lanterns in lighthouses involves several measures. First, the lantern design should include heat sinks, which are components that absorb and dissipate heat away from the LED components. Heat sinks can be made from materials such as aluminium or copper, which have high thermal conductivity.

Secondly, the lantern should have adequate ventilation to allow heat to escape from the housing. This can be achieved using fans or natural convection. Proper ventilation helps prevent heat build-up, which can damage the LED components and reduce the efficiency and lifespan of the lantern.

Finally, the materials used in the lantern housing should be selected for their thermal properties. Materials with low thermal conductivity, such as plastic, can trap heat and lead to damage to the LED components. Materials with high thermal conductivity, such as metal, are better at dissipating heat and protecting the LED components.

Effective heat management is crucial for the longevity and performance of LED lanterns used in lighthouses. Proper design, ventilation, and material selection can help prevent heat build-up and extend the lifespan of the lantern. In addition, proper heat management can help reduce maintenance costs and ensure the reliability and safety of the lighthouse.

2.5.2 Lumen maintenance

Lumen maintenance is a term used to describe the ability of a light source, such as an LED, to maintain its initial light output over time. It refers to the rate of degradation in light output over the lifespan of the light source.

All light sources experience a decrease in light output over time, which is known as lumen depreciation. The rate of lumen depreciation depends on several factors, such as the quality of the light source, operating conditions, and the environment in which it is used.

Lumen maintenance is expressed as a percentage of the initial light output of the light source. For example, a light source with 90% lumen maintenance after 10,000 hours of use means that it has retained 90% of its initial light output after 10,000 hours of use.

Lumen maintenance is an important consideration for lighting applications, such as in lighthouses. A decrease in light output over time can affect the performance and safety of the lighthouse. Therefore, selecting light sources with high lumen maintenance can help ensure the reliability and longevity of the lighting system.

In addition, regular maintenance and cleaning of the lighting system can help prevent dirt and debris build-up, which can contribute to lumen depreciation. Proper maintenance and selection of high-quality light sources can help ensure the lumen maintenance and longevity of the lighting system used in lighthouses.

2.6 Conversion from Lead Acid Batteries to LiFePO4 batteries

There are several advantages of using Lithium Iron Phosphate (LiFePO4) batteries over lead-acid batteries for Aids to Navigation (ATON). Here are some of the main advantages:

Longer lifespan: LiFePO4 batteries have a longer lifespan than lead-acid batteries, with a typical lifespan of 2,000 to 3,000 cycles compared to 300 to 500 cycles for lead-acid batteries. This means that LiFePO4 batteries will last significantly longer before needing to be replaced, reducing the overall cost of ownership for ATONs.

Higher energy density: LiFePO4 batteries have a higher energy density than lead-acid batteries, meaning that they can store more energy in a smaller space. This is important for ATONs, as they often have limited space available for battery storage.

Lower weight: LiFePO4 batteries are lighter than lead-acid batteries, which is important for ATONs that may be installed in remote or hard-to-reach locations. The lighter weight makes installation and maintenance easier and less costly.

Faster charging: LiFePO4 batteries can be charged faster than lead-acid batteries, which is important for ATONs that may need to be recharged quickly in order to maintain their functionality.

Better performance in extreme temperatures: LiFePO4 batteries are more resistant to temperature fluctuations than lead-acid batteries. They can operate in a wider range of temperatures without significant degradation in performance, making them a more reliable choice for ATONs that may be exposed to extreme temperature variations.

Overall, LiFePO4 batteries offer several advantages over lead-acid batteries for Aids to Navigation, including longer lifespan, higher energy density, lower weight, faster charging, and better performance in extreme temperatures. These advantages make them a more reliable and cost-effective choice for ATONs.

3 CHALLENGES FACED DURING MODERNIZATION

Despite the benefits of modernizing AtoN infrastructure, several challenges were faced during the modernization process. One of the significant challenges is the high cost of implementing modern technologies. The installation of AIS ATON requires significant investment, and the cost of maintenance and upgrading can also be substantial.

Another challenge faced during modernization is the need for human resources with specialized skills and knowledge to operate and maintain the modern AtoN infrastructure. Training and capacity-building programs have been implemented to address this challenge, but it remains a significant hurdle to overcome.

3.1 Remote Monitoring for Self-Contained Lantern Challenge

It is true that not many lantern manufacturers provide access to their self-contained lanterns. This can make it challenging for organizations that require remote monitoring of their navigation aids, as the ability to access and integrate monitoring equipment with the lantern is essential for effective remote monitoring.

One reason for this lack of access may be that self-contained lanterns are often designed as sealed units, with no external access for safety and security reasons. This makes it difficult to integrate monitoring equipment with the lantern without compromising its integrity or exposing it to environmental factors such as moisture or dust.

Another reason for the lack of access may be related to intellectual property or proprietary technology. Some manufacturers may not want to share their design or technology with third-party monitoring equipment providers, which can limit the availability of compatible monitoring equipment.

Despite these challenges, there are still some lantern manufacturers that provide access to their self-contained lanterns. These manufacturers may offer specially designed access points or interfaces that allow for the integration of monitoring equipment while maintaining the integrity of the lantern. It is important for organizations seeking remote monitoring solutions to carefully research the available options and select a manufacturer that can provide the necessary access and compatibility for their specific needs.

3.2 Conversion from incandescent to LED light challenges.

While converting from incandescent to LED lights for Aids to Navigation (ATON) offers numerous advantages, there are also some challenges that need to be addressed:

Compatibility: LED lights require different power supplies and control systems than incandescent lights. This means that existing infrastructure and control systems may need to be updated or replaced to accommodate the new LED lights.

Cost: While LED lights have a longer lifespan and consume less energy, they are initially more expensive than incandescent lights. This can result in higher upfront costs for organizations looking to convert to LED lights.

Certification: LED lights need to meet specific certification requirements set by regulatory bodies such as the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). Ensuring that the new LED lights meet these requirements can be time-consuming and expensive.

Compatibility with legacy systems: Some legacy systems may not be compatible with LED lights. This means that additional upgrades may be necessary to ensure that the new LED lights work seamlessly with the existing system.

Installation: The installation of LED lights may require additional expertise and specialized equipment, which can increase installation costs and complexity.

Maintenance: While LED lights require less maintenance than incandescent lights, specialized training may be required for maintenance personnel to ensure proper upkeep of the LED lights.

In summary, converting from incandescent to LED lights for ATON offers numerous benefits, but it also poses challenges such as compatibility, cost, certification, compatibility with legacy systems, installation, and maintenance. These challenges must be carefully considered and addressed to ensure a smooth transition to LED lights that provides the desired benefits.

3.3 Conversion from Lead Acid Batteries to LiFePO4 batteries challenges

Replacing Lead Acid batteries with LiFePO4 batteries can present some challenges. Here are some of the main challenges to consider:

Cost: LiFePO4 batteries are more expensive upfront than lead-acid batteries, so there may be a higher initial investment required to switch to LiFePO4 batteries. However, the longer lifespan and lower maintenance costs may make up for this over time.

Compatibility: LiFePO4 batteries require a different charging profile than lead-acid batteries, so the charging system may need to be replaced or modified to properly charge LiFePO4 batteries. Additionally, the voltage requirements of LiFePO4 batteries may be different from those of lead-acid batteries, so any devices that are connected to the battery system may need to be updated or modified to accommodate the new batteries.

Installation: LiFePO4 batteries may require a different form factor or physical layout than lead-acid batteries, so the installation process may require additional modifications to the battery compartment or housing.

Safety: LiFePO4 batteries are generally considered safer than lead-acid batteries, but they still require proper handling and maintenance to prevent accidents or damage. Training and proper safety protocols may need to be implemented when switching to LiFePO4 batteries.

Availability: LiFePO4 batteries may not be as widely available as lead-acid batteries, which could make it more difficult to source replacement batteries or find service providers who are familiar with LiFePO4 technology.

Overall, switching from Lead Acid batteries to $LiFePO_4$ batteries requires careful consideration of the cost, compatibility, installation, safety, and availability factors. Proper planning and preparation can help mitigate any potential challenges and ensure a successful transition to the new battery technology.

4 IMPACT OF AIDS TO NAVIGATION MODERNIZATION ON THE MARITIME INDUSTRY

The modernization of aids to navigation (ATON) systems has had a significant impact on the maritime industry in several ways.

Firstly, modern ATON systems, such as LED-based lanterns, have improved the safety of maritime transportation. These systems provide brighter and more reliable lighting, which helps ships navigate safely in challenging conditions, such as fog and storms.

Secondly, the integration of technology, such as automatic identification systems (AIS) and remote monitoring systems, has improved the efficiency of ATON maintenance and monitoring. This has reduced the need for manual inspections and improved response times to ATON issues.

Thirdly, the modernization of ATON systems has resulted in significant cost savings for the maritime industry. LED-based lanterns have lower energy consumption and longer lifespans compared to traditional incandescent bulbs, reducing the need for frequent bulb replacements and maintenance.

Furthermore, the use of renewable energy sources, such as solar and wind power, and better batteries for ATON systems have reduced the reliance on fossil fuels and lowered operational costs.

Overall, the modernization of ATON systems has had a positive impact on the maritime industry, improving safety, efficiency, and cost-effectiveness. As technology continues to advance, it is expected that further improvements will be made to ATON systems, benefiting both the maritime industry and the environment.

5 CONCLUSION

In conclusion, the modernization of AtoN infrastructure in Malaysia has significantly enhanced safety and efficiency in maritime transportation. The integration of technologies such as AIS and GNSS has improved the accuracy and reliability of navigational information, resulting in safer and more efficient navigation for vessels. However, the modernization process has also faced several challenges, including the high cost of implementation and the need for specialized human resources. Nonetheless, the impact of modernization on the maritime industry in Malaysia has been significant, contributing to the country's economic growth and enhancing its reputation as a reliable destination for maritime transportation.

AUTHOR BIOGRAPHY

Hairizam Albukhari is the Director of Traffic Management and Aids to Navigation Division, Malaysia Marine Department . He studied at University Putra Malaysia majoring in Marine Science Degree in 1998. He began his career at Malaysia Marine Department as a Marine officer in 1998 and served in various capacities at Marine Department before assuming his current position in 2021. Mr. Hairizam has represented Malaysia, attending and participating in various IALA Committee Meeting since 2012. He has also credited as Train the Trainers (IALA model Course V-103/4). He has been appointed as Secretary of the Light Dues Board from 2012 to 2014.

As a Director of Traffic Management and Aids to Navigation Division, Mr. Hairizam is also the Management Representative of The Light Dues Board Peninsular Malaysia. The Light Dues Board managed the Light Dues Fund for the provision, maintenance and upgrading of aids to navigation in Peninsular Malaysia.He also been selected as a Malaysia Head of Delegation to Aids to Navigation Fund (ANF) Committee Meeting under the Cooperative Mechanism on safety of Navigation and Environmental Protection in the Straits of Malacca and Singapore.

S102.4 Dynamic assessment of safety in maneuvering through constricted navigational channels using an online operational system (048)

Simon Mortensen, Vice President Ports and Terminals at DHI. Denmark

ABSTRACT

Highly constricted time windows for allowing safe and efficient maneuvering of large ships in confined navigational channels are one of the largest growing sources of congestion in ports worldwide. With increasingly larger container vessel introduced to many shipping routes, this challenge is predicted to grow for years to come. For decades, several ports worldwide have started to utilize the benefits from online systems that predicts safe dynamic under keel clearance (UKC) transit windows hence providing increase flexibility an capacity over old fashioned static port rules.

In this paper we will present a significant recent improvement to a operational decision support system for the effective dynamic management of safe transit windows through constricted waterways. In addition to incorporating the effect of dynamic UKC, the physics-based operational system calculates dynamic safe transit windows incorporating the constraints of safety in maneuvering with the same level of accuracy as a top tier 3D full bridge simulator. The paper will provide examples of the operational use of the live system and present the underlying technical framework for how the system uses detailed vessel maneuvering response predictions for deriving practical dynamic thresholds for safe transit planning.

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(No paper submitted)

AUTHOR BIOGRAPHY

(No biography submitted)

S102.5 Corridor Management Execution - The RIS COMEX project (139)

Lukas Kessel, Federal Waterways and Shipping Agency, Germany

ABSTRACT

RIS COMEX is a CEF funded multi-Beneficiary project aiming at the definition, specification, implementation, and sustainable operation of Corridor RIS Services. 13 European countries had the vison to realize Corridor Management by harmonized Corridor RIS Services. The Services aim to improve safety, efficiency and reliability of inland navigation including positive effects on the environmental protection. The Partners linked and improved their existing RIS Services to give access to those services not only on a regional level but on national and international level in the European inland waterway network. “Corridor Management” defined three levels of services.

Level 1 is the basic level, with gives static and dynamic information about the infrastructure and fairway required for route-planning. Level 2 deals with the traffic information to enable reliable travelling times for voyage planning and traffic management. This level is subdivided. Level 2a is about the actual traffic situation and Level 2b will provide predictions of the traffic situation. Level 3 services will give support to the logistics partners. To reach the goals it is obvious that sharing of information and a common portal are an essential need. The presentation will show what has been done to reach this goal and going online with "EuRIS-Portal".

(No paper submitted)

AUTHOR BIOGRAPHY

Lukas Kussel graduated with a Master’s degree in electrical engineering and information technology from Technical University of Dortmund in 2020. Since then, he works on inland traffic technologies and digitalisation of inland waterway transport (IWT) in the Federal Waterways and Shipping Administration of Germany. His main emphasis is the development of harmonised, cross-border River Information Services (RIS) and multimodal transport in Europe. This includes collaboration in projects like RIS COMEX and DIWA. Besides he is co-responsible for requirements engineering in traffic technologies.

SESSION S3 – ATON TECHNOLOGIES

S3.1 Buoys and Synthetic Moorings for Deeper Water Environmentally Significant Areas (002)

Adrian Van Boven, M-NAV Solutions Inc./Inovaton Ltd, Co-founder, Proprietor and Director, Bonifacio Ridge, 1st Avenue, Bonifacio Global City, Taguig City, 1634, NCR, Philippines, adrian@m-nav.com

ABSTRACT

The Benham Bank Seamount (BBS) is a geological feature of the Philippine Rise (formally known as the Benham Rise), which is located approximately 150 nautical miles East of Central Luzon, Philippines. With a summit reaching 52 metres of water depth and covering an area of approximately 170 square kilometers, the seamount quickly falls away at its boundary to a depth approaching 3000 meters. The BBS is unique in the fact that it has a number of mesophotic coral species and supports dozens of commercially important fish species, while remaining relatively free from the pressures of commercial fishing. The Philippine Government recognized this ecological importance and in 2018, created a protection zone over the area and the Philippine Coast Guard were subsequently tasked with installing buoys to clearly delineate the BBS boundary. These buoys needed to remain operational through the extreme weather conditions that the area experiences whilst minimizing physical impacts on the coral ecosystem.

After a government procurement process in 2020, M-NAV Solutions were awarded the contract for the supply and installation of buoys for the BBS, and subsequently mobilized for installation in May 2021. Three (3) polyethylene buoys with environmentally friendly hybrid mooring systems (utilizing a mix of traditional chains and synthetic Ultra-High Molecular Weight Polyethylene tethers), AIS AtoN's and a Satellite monitoring system, were successfully installed. Their design was put to the test in September 2022, when Super Typhoon Noru (Karding) passed within 50 nautical miles of the buoy sites, with wind gusts exceeding 240km/hr. All the units remained operational and undamaged, and continue to perform as per specification. It was noted during the installation process that the BBS summit extended further than the available bathymetric data showed, which highlights the fact that additional surveys and research is needed to fully understand the geographical extents and total biomass of this unique ecosystem.

KEYWORDS: Philippine Rise, Benham Bank, Synthetic Buoy Mooring, Hybrid Buoy Mooring, Environmental Buoy Mooring, Satellite Monitoring.

1 INTRODUCTION

The Philippine Rise (formally known as the Benham Rise) is a submarine ridge in the East Philippine Sea [1] located 150 nautical miles East of Baler, Aurora Province on the Eastern Central part of Luzon, Philippines. The Philippine Rise is one of many bathymetric highs that exist in and around the Republic of the Philippines [2].

Located within the Philippine Rise is the Benham Bank, a geological seamount which slopes rapidly up from 3000 meters to its summit of approximately 52 meters, and is one of the largest seamounts in terms of area in the entire Pacific Basin [3]. The summit covers approximately 170 square kilometers, of which a large proportion sits between 55 and 100 meters of water depth. A lack of accurate bathymetric data exists for the Benham Bank Seamount (BBS); although several depth data sources are publicly available, much is contradictory in nature, which created a number of challenges that will be addressed later in this paper.

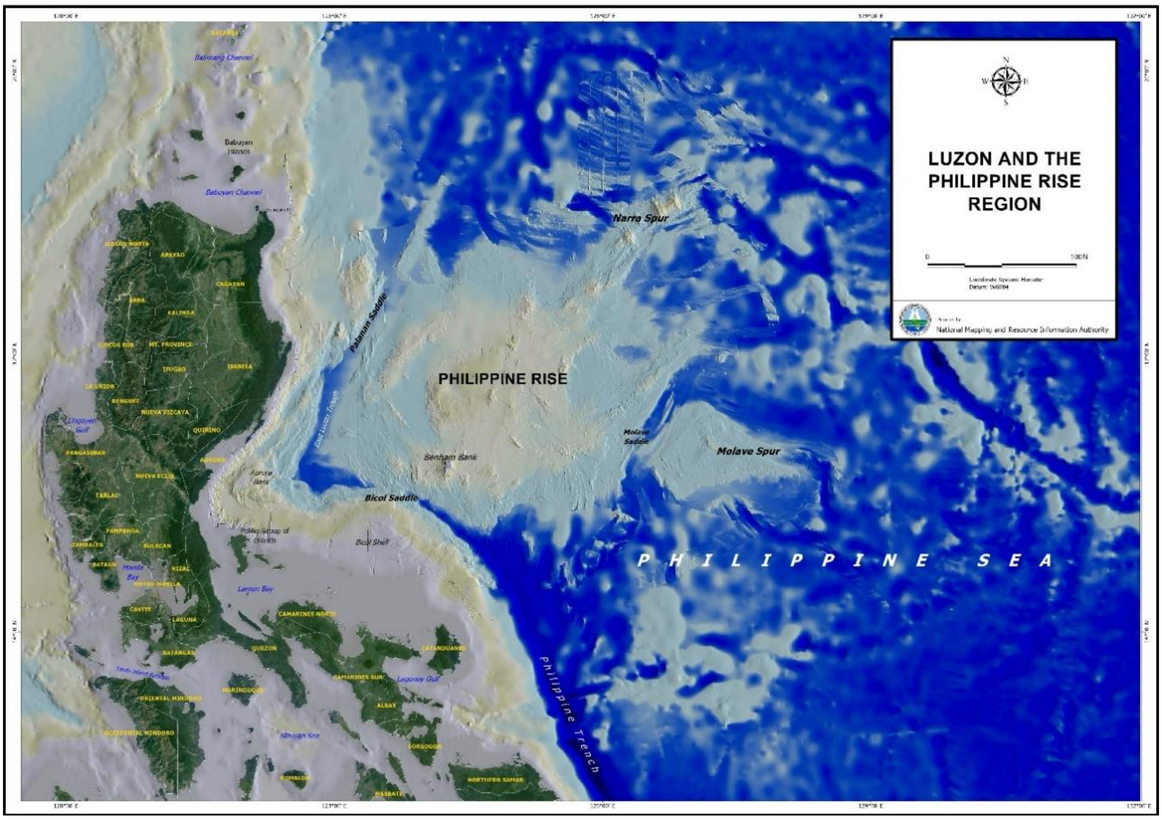


Figure 24: Location of the Philippine Rise and Benham Bank (NAMRIA).

Figure 2 and Figure 3 provide an example of some of the most accurate depth data publicly available for the BBS. Figure 3 is a smaller-scale snapshot of Figure 2 and highlights how rapidly depth falls away from the summit, in some cases, an 800-metre increase in water depth occurs within 1 nautical mile of distance travelled.

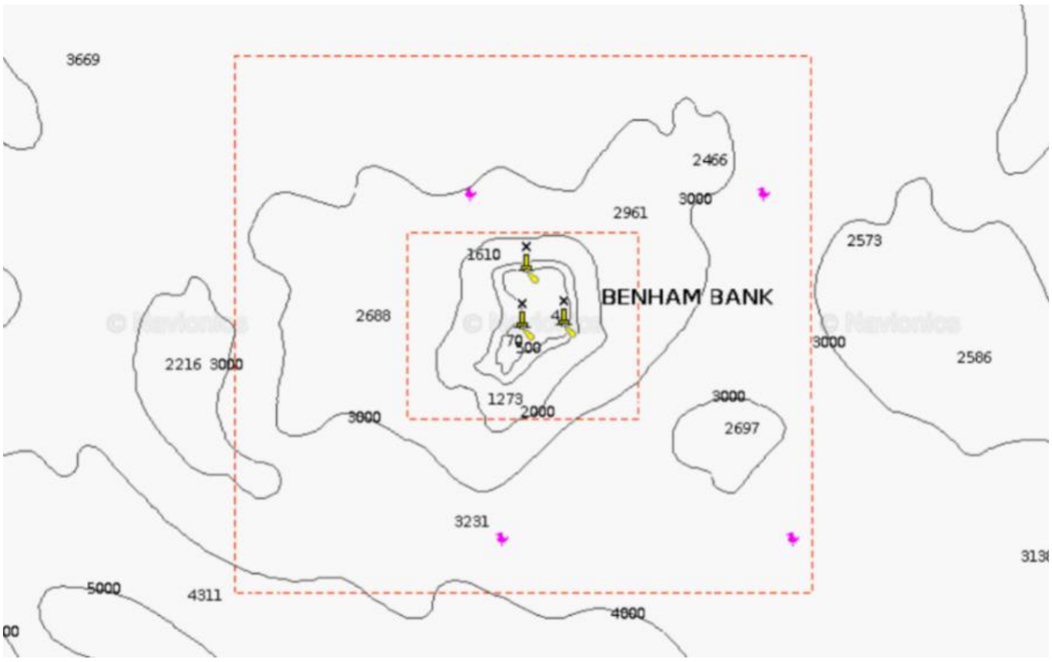


Figure 25: Benham Bank Bathymetric Data – Large Scale. (NAVIONICS - Basemap Version 20230201)

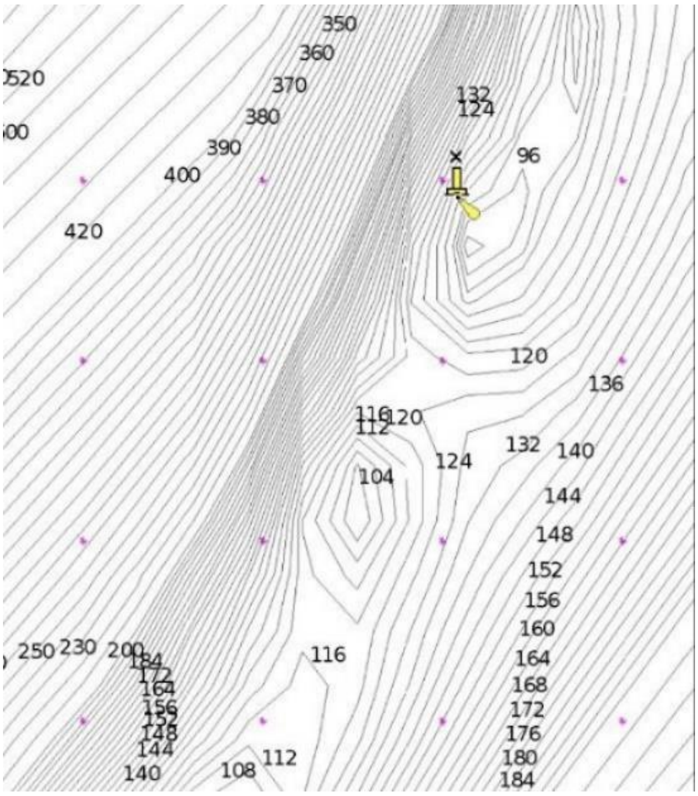


Figure 26: Benham Bank Bathymetric Data - Small Scale. (NAVIONICS - Basemap Version 20230201

Water currents at the BBS are significant and often exceed 2 knots [4], distributing significant levels of nitrogen-fixing phytoplankton over and across the summit [5], which provides the base nutrients for the range of marine biodiversity found there. These currents flow up and over the entire Philippine Rise and mix in with the western North Pacific Water or the North Equatorial Current waters, depending on seasonal variations [4].

The BBS is unique in terms of its coral species; it is one of a small number of locations around the world which have extensive mesophotic corals, that is, coral species which survive in comparatively lower light conditions down to 150 meters of water depth. In research carried out at the BBS in 2014, light received on the summit at 52 meters was only 12% of the light measured at the water's surface. However, extensive mesophotic coral formations, represented by more than 12 different species, were identified at between 50 and 60 meters of water depth, including extensive areas of tiered plate coral, some measuring several meters in height [6].

In addition, Nacorda et.al. [6] identified a number of soft sponges and 63 different fish species including commercially important food fish from the snapper, trevally and tuna families. Of particular importance was the fact that the majority of fish species identified were adult or large in size, and were in abundance. The BBS is also considered an important spawning and nursery ground for all the oceanic tuna species, including the highly endangered Pacific Bluefin tuna [7], which are a critical food species not only for the Philippines, but the entire Asia-Pacific region.

The research carried out by Nacorda et.al. [6], coupled with the fact that illegal commercial fishing continues to be a threat, especially for areas untouched by commercial fishing practices, was the impetus for the Philippine Rise being declared a Marine Resource Reserve under Proclamation No. 489 in 2018 by President Duterte. This protected area was named the Philippine Rise Marine Resource Reserve, measuring a total of 352,390 hectares and taking in the entire BBS [7]. As a result, the Philippine Coast Guard were tasked with clearly marking the BBS summit boundary with a number of buoys as the first step in safeguarding this unique ecosystem.

In 2020, the Philippine Coast Guard, via the Philippine Government Procurement System (PhilGEPS), put out an *INVITATION TO BID FOR THE SUPPLY, DELIVERY OF TEN (10) LIGHTED OCEAN BUOYS AND THE INSTALLATION OF THREE (3) OF SAID LIGHTED OCEAN BUOYS* for suitably qualified bidders.

Key Specifications stated in the bidding documents are summarized as follows:

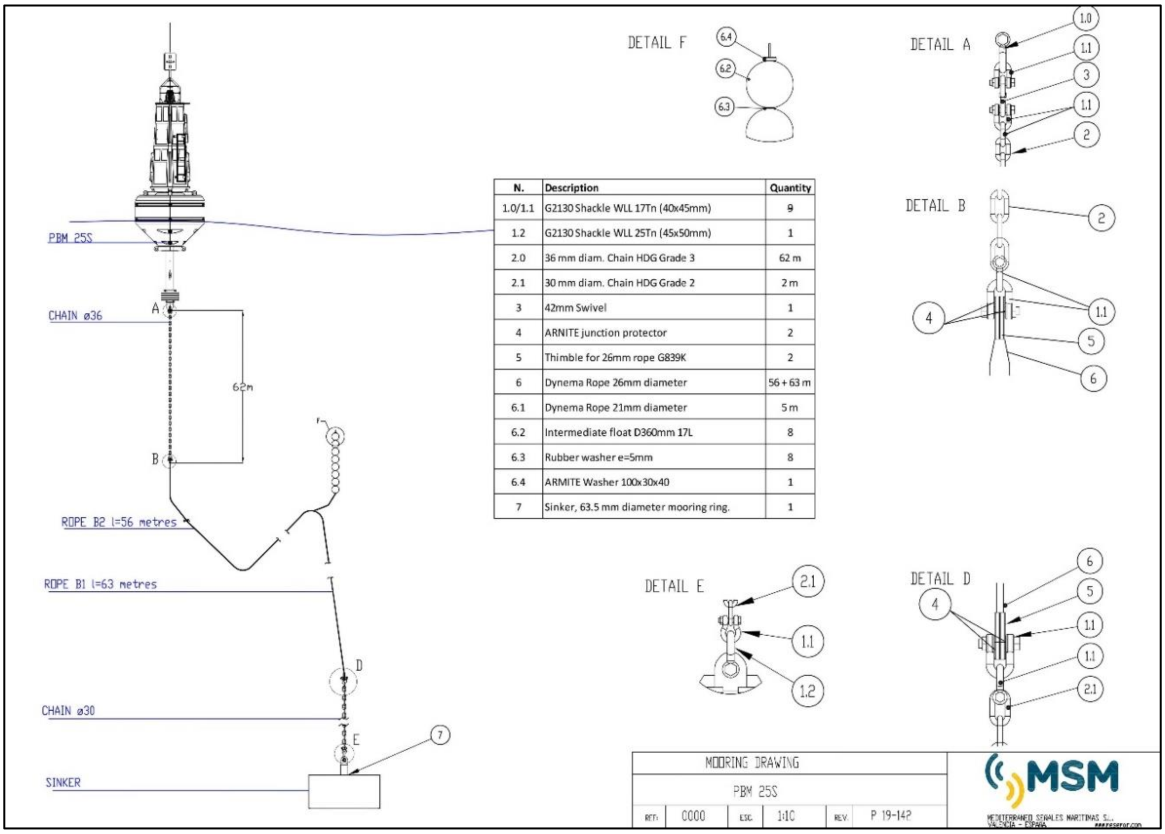
- Buoy: 2.5-3 meter diameter, 3.5-4 meter focal plane, polyethylene or polyurethane elastomer float, Combination of either/or polyethylene, steel, or stainless-steel superstructure, Special Mark.
- Mooring System: to be designed to suit the buoy, 75-95 meter water depth, must be designed to survive Sea State 8 conditions (maximum wave heights of 14 meters), no chain thrash zone (to protect corals), steel reinforced concrete sinker of 20 tonnes.
- Lantern: Self Contained, minimum 7 nautical miles, integrated AIS AtoN (Type 3), satellite monitoring.
- Manufacturer-hosted satellite monitoring plus 1 x server with monitoring software to be installed at Philippine Coast Guard (Cavite).

Another key condition stated in the bidding documents was that an inspection of the sea bed must be carried out at the installation site by the contractor prior to buoy deployment to ensure significant coral formations were not present (and therefore not damaged) during sinker installation. In addition, Philippine Coast Guard personnel were to be on-site at the time of installation to approve the location based on two specific criteria: that installation would not adversely affect any significant coral formation/s and that the location itself was acceptable in terms of representing the BBS boundary.

The bid process specified that all equipment to be offered had to be listed in the bid submission, and all product data sheets and relevant technical information included. M-NAV Solutions is the in-country (Philippines) partner for Mediterráneo Señales Marítimas (MSM), who manufactured and supplied all the Marine Aids to Navigation equipment for the Project. The bid specified the supply of a suitable and compliant mooring system, with the design work carried out by MSM (with input from M-NAV Solutions), and submitted as part of the bid. The design took into account the mooring system specifications contained in the bid, the buoy characteristics and the fact that an ecologically sound design was required. The buoy chosen for this project was the MSM PBM 25-S model and the following parameters were used for the mooring system design calculations:

- Draft (average): 85 meters.
- Tide range: 2.3 meters.
- Maximum wave height: 14 meters (corresponding to the maximum height for Sea State 8).
- Wave period: 20 seconds.
- Maximum tidal current: 0.3 m/s.
- Maximum wind speed: 200 km/h.

The calculation of the applied forces was based on the method outlined in Guideline 1066 – The Design of Floating Aid to Navigation Moorings [8] and processed using MSM SIMCAD Software to produce a suitable compliant design. The final design of the mooring system utilized an Ultra-High Molecular Weight Polyethylene (UHMWP) tether, rather than nylon (polyamide) which is more commonly used. Whilst UHMWP is considerably more expensive and may not have the stretch (and therefore the degree on energy absorption) that nylon has, it is noticeably stronger than nylon, more resistant to UV damage and abrasion and absorbs less water [9], [10]. The mooring design included 64 meters of chain connected to the buoy tail which in itself absorbs a great deal of energy, so a reduction in stretch on the synthetic tether was not considered an issue. Figure 4 outlines the design submitted in the bid and what was installed at site.



N.	Description	Quantity
1.0/1.1	G2130 Shackle WLL 17Tn (40x45mm)	9
1.2	G2130 Shackle WLL 25Tn (45x50mm)	1
2.0	36 mm diam. Chain HDG Grade 3	62 m
2.1	30 mm diam. Chain HDG Grade 2	2 m
3	42mm Swivel	1
4	ARNITE junction protector	2
5	Thimble for 26mm rope G839K	2
6	Dynema Rope 26mm diameter	56 + 63 m
6.1	Dynema Rope 21mm diameter	5 m
6.2	Intermediate float D360mm 17L	8
6.3	Rubber washer e=5mm	8
6.4	ARMITE Washer 100x30x40	1
7	Sinker, 63.5 mm diameter mooring ring.	1

Figure 27: Mooring System Design

M-NAV Solutions submitted a bid for the project, were determined to have been the lowest cost conforming bidder, and subsequently were awarded the project on December 31, 2020, with a Notice to Proceed received on February 3, 2021.

2 METHOD

The primary consideration for the successful installation of the buoys related to site weather conditions. Essentially, the only time installation could be carried out with any degree of certainty was between February and June, with the month of May providing the best overall weather for vessel stability. Low Pressure Systems and typhoons were of primary concern, however general wind and swell are also an issue at BBS as it is located in unprotected open ocean at a considerable distance from land. An installation date of May 2021 created a challenge, with only 90 days remaining until installation was due to commence. Buoys and equipment had to be ordered and manufactured, then shipped to the Philippines, all while the world was still in the grip of Covid-19 restrictions and sea freight in turmoil with a lack of capacity and long lead times.

To address this, purchasing decisions had to be made immediately once the Notice to Proceed was received to ensure a timely delivery schedule occurred. In addition to the AtoN equipment, other specialist equipment was required for installation. These are as follows:

- Blueye Robotics, **Blueye Pro Remote Operated Vehicle (ROV)**: to be used to carry out the visual seabed inspection for sinker deployment suitability and therefore obtain approval for the commencement of buoy installation by on-board Philippine Coast Guard personnel.

- Knudsen, **Chirp 3212 Portable EchoSounder**: to obtain accurate depth data to ensure site depths matched the mooring system depth design of between 75-95 meters.
- SeaCatch, **TR14 Air Operated Quick Release**: the bid specifications stated a sinker weight of 20 tonnes which meant that a safe and effective release system had to be in place for the installation of these units.

In practical terms, using Manila as the mobilization point would have been the easier option as all the personnel and facilities were located in the Metro Manila area, however there were two constraints. The first was due to the 20-tonne sinker weight and the fact that the BBS is offshore with the closest shelter 150 nautical miles away, with the most suitable vessel in terms of lift capacity, stability and speed located in Cebu. Second, the sailing distance to the BBS from Cebu was over 300 nautical miles shorter compared to sailing from Manila. This would save a significant amount of time and fuel cost; therefore, it was decided to mobilize from Cebu and sea freight the three buoys direct to Cebu City.

The company supplying the installation vessel also supplied a lay-down area adjacent to their wharf in Lapu-Lapu City, Cebu, where shipping containers could be unloaded, buoys assembled, inspections carried out and equipment subsequently loaded onto the vessel. The installation vessel details were as follows:

- Vessel Name: MV Morning Light
- Owner: Uni-Orient Pearl Ventures Inc.
- Registry: Philippines
- Official Number: 12-0002681
- Dimensions: 61.00m (LOA) x 15.5m (BREADTH) x 6.0m (DEPTH)
- GRT: 482.93
- Crane on Board: SKK 1506 Deck Crane (160 tons)

Aside from the actual vessel crew, an experienced crane operator and rigger were supplied and M-NAV Solutions had six persons onboard to carry out the buoy installation and final commissioning. Additionally, Philippine Coast Guard had four persons onboard from the Marine Safety Services Command (MSSC) to provide final approval for installation sites and document the installation process.

3 RESULTS

The installation timeline that occurred was as follows:

- AtoN Equipment Arrives to Lay-Down Area, Lapu-Lapu City: May 7, 2021
- Assemble Buoys and Program/Commission Lanterns & AIS: May 8, 2021
- Equipment Inspection by Philippine Coast Guard: May 10, 2021
- Vessel Loading: May 11, 2021
- Depart Lapu-Lapu City: May 12, 2021
- Arrive BBS: May 14, 2021
- Install Buoy No. 1: May 14, 2021
- Install Buoy No. 2: May 15, 2021
- Install Buoy No. 3: May 16, 2021
- Depart BBS: May 16, 2021
- Arrive Lapu-Lapu City: May 17, 2021

Prior to vessel mobilization, all goods had to be unloaded from the containers, assembled, and inspected by Philippine Coast Guard to ensure that the equipment supplied was as per the specifications outlined in the bid submission, and that all electrical equipment was operational. Once all the goods were approved and accepted, the installation vessel was loaded and sailed to site.

Figure 28: Inspection of Goods – Philippine Coast Guard, Lapu-Lapu City.

Installation of each of the buoys required a number of critical pre-installation activities. The first of these activities were depth assessments; these were required due to the lack of charted information available and the need to identify a site with a depth profile that suited the mooring design whilst keeping in mind that the actual BBS summit boundary had to be marked. Depth assessments were carried out using the deep-water depth sounder. This allowed for the on-site installation team and PCG personnel to check and confirm suitable depths in the nominated locations whilst also ensuring that the bathymetric profile was suitable for the placement of the sinker. It was noted that the bathymetric data that was available did not represent the data obtained at site, and that shallower areas (<70 meters) of the BBS in fact extended much further than the charts that were obtained prior to mobilization showed.

The second pre-installation activity was a rapid seabed assessment using the Remote Operated Vehicle (ROV) to confirm seabed conditions and to identify the presence of any significant coral formations. As coral assemblage in the mesophotic zone is extremely difficult to assess and survey, the ROV was used to allow the team to visually assess the amount of coral cover in each location. Each of the locations was found to be suitable, without any significant hard or soft coral formations. Generally, each location, and the area adjacent, was characterized by a uniform and homogenous benthic substrate consisting of a hard calcareous rocky substratum with some coverage of filamentous algae and isolated new strands of juvenile coral growth (see Figure 6).

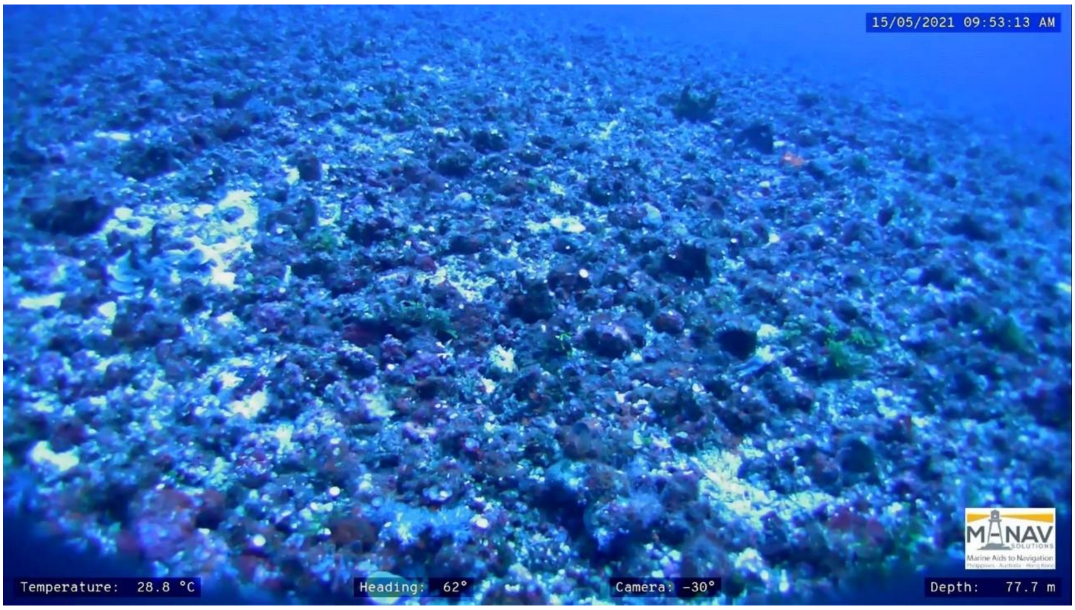


Figure 29: Seabed at 77 meters – Buoy No. 1.

No serious environmental impact was expected on these locations through the installation of the buoys. The footprint of the 20 tonne concrete sinkers is only 5.5 square meters, which is a fraction of entire area of the BBS and as such, any impact was negligible. The sinkers will have zero movement or displacement once installed and would not drag or create any further impact on the seabed. An important consideration was that the hybrid moorings were designed to ensure that the thrash zone of the mooring - the section of chain that normally lays on the seabed - was suspended in the water column, ensuring there was zero contact with the seabed. In a normal mooring system, where the thrash zone does lay on the seabed, the chain moves around the seabed as the buoy is moved by waves, wind and currents. This movement disrupts any living organisms in its path, and in the case of corals (particularly plate and soft corals) the chain will completely destroy them, leaving a permanent mooring scar.

In addition to denuding the area of marine life, the chain sweep causes a marked increase in suspended sediments in the immediate and surrounding areas, resulting in an increase in turbidity, which impairs photosynthesis and disrupts marine organism behaviors and physiological functioning. The hybrid mooring design used for the Philippine Rise buoys ensures this does not happen, and the placement of the sinker on the seabed will actually be habitat enhancing over time, due to eventual coral cover and the introduction of additional habitats for other marine life. The water depths of the three final installation locations were 77, 79 and 91 meters, all within the mooring depth design parameter of 75-95 meters. Figure 2 in the "Introduction" Section indicates the buoy positions on the BBS, highlighting the fact that the summit boundary is now marked.

Prior to the buoys being lifted from the vessel deck, the lanterns were tested again and the AIS AtoN units programmed with the final site co-ordinates using ProATON Software. The buoys were then placed into the water, followed by the sinker which was released using the air-operated quick release mechanism. AIS output of each buoy was checked and all information on the site, including seabed photos, were collated for the final installation report. MSM monitored the buoys and confirmed that the satellite monitoring was working from each buoy prior to site demobilization.

Figure 7: Lifting of a buoy from the Installation Vessel cargo hold.

Figure 8: Fully Installed Buoy.

4 CONCLUSION

Buoy installation was successful and twenty-three months post-installation to April 2023, the buoys remain operational and in position. Whilst twenty-three months of operations is insufficient in terms of how long a buoy should last, it must be made in the context that since installation, the buoys have been subjected to several tropical low-pressure systems and three typhoons passing in close proximity; the most extreme being Super Typhoon Noru (Karding) in September 2022. Super Typhoon Noru started off as a tropical storm and was not predicted to turn into a typhoon, however the system slowed as it approached Luzon and increasingly intensified. By September 25, the system had developed into a Super Typhoon with sustained winds approaching 200 km/hr and gusts exceeding 240km/hr.

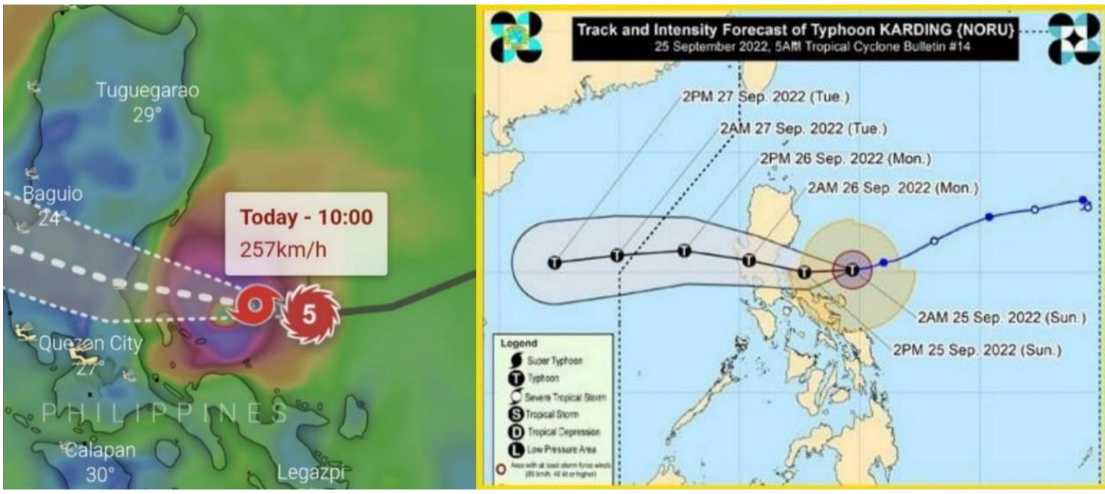


Figure 9: Super Typhoon Noru (Karding) Metrological Data (courtesy of Windy and PAGASA)

Although wind speeds exceeded the maximum wind design parameter of 200 km/hr, the buoys remained in their installation position and operational. There are no weather monitoring stations at the BBS, therefore the scale of the waves/swell that occurred as the typhoon approached and passed over is uncertain, however it would have been significant. This gives considerable weight to the fact that the mooring design principles utilized were sound, and the aim of having buoys installed at the Benham Bank which minimized environmental impacts on the coral whilst withstanding extreme weather events had been successful.

An interesting observation resulting from installation was the fact that once the team was on site, it was found that the bathymetric data that was publicly available was inaccurate. There were a number of instances where the charts showed that the seabed should have been sloping away to several hundred meters of depth, when in fact, the depth was measured to be steady at 60-70 meters only. This is further highlighted in Figure 10, where the Northern buoy (designated Buoy No. 3) is shown on the nautical charts as being in 460 meters of water, when in reality it is actually in 91 meters of water.

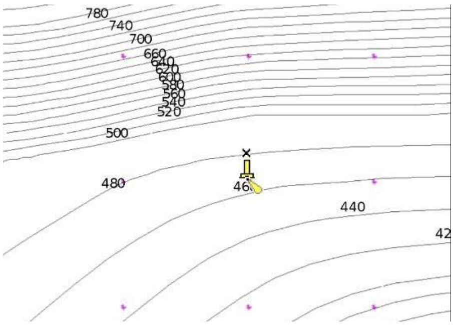


Figure 10: Buoy No. 3 Location Depth

This suggests that the summit of the BBS is significantly greater in area than is actually recorded, which would lead to an underestimation of the total biomass and the impact that this biomass holds in terms of nurturing and supporting the fish species in the surrounding geographical areas. This being the case, a more accurate and thorough survey of the area is warranted to better understand the extent of this unique and important ecosystem.

5 ACKNOWLEDGEMENTS

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AUTHOR BIOGRAPHY

Adrian’s career started off in agriculture in Australia, obtaining an Associate Diploma in Applied Science (Horticulture) then later, a Bachelor of Agricultural Science (Rural Technology). Moving to Papua New Guinea in 2009 to take on a large agricultural irrigation project in the Ramu Valley which was completed in 2012, Adrian then took on the role of General Manager, then Chief Operating Officer, for a marine construction company in PNG involved in AtoN installation and maintenance throughout the country.

After seeing further opportunities within the AtoN Industry, Adrian co-founded M-NAV Solutions in 2016, which now operates as separate entities out of the Philippines, Hong Kong and Australia. In 2021, Adrian co-founded Inovaton Limited to develop, design, and manufacture innovative products for the maritime safety and maritime surveillance industries. Adrian currently resides in the Philippines and remains very much hands-on with regards to all facets of M-NAV Solutions and Inovaton Limited business operations.

S3.2 Research on Intelligent Light Buoy under the Background of Intelligent Shipping (085)

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ABSTRACT

With the development of artificial intelligence technology, Maritime Autonomous Surface Ships (MASS) , etc., factors related to shipping have been deeply integrated with modern information technology, and a new form of modern shipping featuring intelligence has taken shape. It is of great significance to enhance the research of the intelligent lighted buoy to provide better navigation services for the development of intelligent shipping. This paper takes the intelligent development of lighted buoys as the main content of the research, deeply analyzes relevant advanced technologies and experiences such as the e-navigation testbeds under the background of intelligent shipping , and proposes the basic connotation, functional characteristics, and main technical requirements of intelligent lighted buoys, which provides reference for the development of intelligent navigation services and intelligent shipping.

KEYWORDS: artificial intelligence, intelligent shipping, intelligent lighted buoys, Maritime Autonomous Surface Ships (MASS)

1 INTRODUCTION

A lighted buoy is an aids to navigation that mainly function by its visual effects such as light, color, and shape. With the application of new technologies such as GPS, Beidou satellite positioning and navigation system and Automatic Identification System (AIS), the functions of lighted buoys have been continuously improved.In 2018, the 99th session of the Maritime Safety Committee(MSC 99) of the International Maritime Organization (IMO) included in its the provisional agenda for an output on "Regulatory scoping exercise for the use of maritime autonomous surface ships (MASS)" and developed the provisional definition of MASS for the purpose of the scoping exercise. China responded to the call of the IMO by issuing the Guidance on the Development of Intelligent Shipping jointly by the Ministry of Transport of the People's Republic of China and other six relevant departments, actively organizing and conducting intelligent navigation tests for autonomous container ships and cargo ships. Since the concept of e-navigation was put forward, many countries have carried out extensive research and practice on the concept, framework, technology, and implementation of e-navigation. Meanwhile, multi-functional lighted buoys were developed.

A representative case in China is Tianjin Port e-Navigation testbed with two multifunctional lighted buoys installed for the Tianjin Port Dual Channel Pilot Project. The project, which was incorporated in the e-navigation testbed of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), has played an active role in promoting the construction and development of the e-navigation pilot projects in China . The achievements made by the project was shared on the website of IALA.In addition, e-navigation projects at the Yangshan Port, Yangtze River Estuary, the Pearl River Estuary and other waters have also been gradually carried out. In these pilot projects, marine monitoring buoys were integrated with buoys for navigation safety to improve the monitoring capacity of the marine hydrological and meteorological environment in navigable waters, reduce the manufacturing and operation management costs of marine monitoring buoys, and improve navigation support efficiency. However, it is urgent to carry out research on intelligent lighted buoys to meet the increasing needs for the intelligent shipping and the intelligent navigation support services for MASS.

2 BASIC CONCEPT AND CHARACTERISTICS OF INTELLIGENT LIGHTED BUOY

2.1 Basic Concept of Intelligent Lighted Buoy

The intelligent lighted buoy is considered as an intelligent device for marine navigation, which fully integrates technologies such as the Internet of Things(IoT), mobile Internet, big data analysis, equipment manufacturing, engineering materials, and comprehensively adopts modern technology of navigation service, communication and information, computer network and intelligent control to provide intelligent, standardized, customized, and accurate comprehensive information services for the safe navigation of ships, to meet the needs for safe navigation of manned and unmanned ships in the era of intelligent shipping.

2.2 Functions and Characteristics of Intelligent Lighted Buoy

The main functions and characteristics of an intelligent lighted buoy is reflected in its ability to automatically perceive its own state, surrounding water environment, traffic flow and service objects, etc. At the same time, it has the characteristics of diversified information acquisition, intelligent analysis and processing, and autonomous command execution. The intelligent lighted buoy has the function of self-control and self-management. It can automatically identify and analyze the information based on remote control instructions or its own judgment, and then provide corresponding intelligent navigation services according to the needs of users.

2.2.1 Intelligent Perceiving Function

According to the characteristics and requirements of intelligent shipping, intelligent lighted buoy can be equipped with various sensors and communication devices to obtain various types of navigation information. The information obtained includes its real-time state, real-time surrounding water environment, real-time surrounding traffic flow information, etc. Real-time state of the lighted buoy includes its precise position, energy supply, operating state of each sensor, real-time posture, etc. This type of information is mainly used to assist in judging the displacement equipment performance of buoys, and whether there is a collision so as to conduct self-diagnosis, self-repair or send emergency information to the management personnel. The surrounding water environment is mainly perceived by the integrated equipment on the lighted buoy which can obtain the information on wind, wave, current, visibility, and water depth to provide decision-making reference to the management personnel. The real-time traffic flow is mainly perceived by carrying AIS, monitoring cameras, small radars, etc., to master the traffic situation in the surrounding waters in real time, and generate reports or emergency information based on different application scenarios, and provide them to the interested parties.

2.2.2 Intelligent service function

Compared to a traditional lighted buoy, the function of the intelligent lighted buoy would be expanded, which will promote the transformation of navigation service from a single visual service to a comprehensive navigation service featured diversity, differentiation, and customization. As a main part of the intelligent aids to navigation system, the intelligent lighted buoy has the function of deep learning. It can automatically conduct multi-source information collection, fusion and complex computation according to different seasons, weather and sea conditions, and take corresponding measures based on the results of data processing. In this way, the lighted buoy could achieve intelligent upgrading of its own services. At the same time, it is possible to automatically select and judge the type, classification, and frequency of information transmission. That is, the lighted buoy could automatically select information obtained for analysis and process them based on different application scenarios and specific traffic environments. Then the lighted buoy generate appropriate comprehensive navigation services based on different requirements. For example, when sensing an abnormal traffic flow, the lighted buoy could transform its navigation service from a passive mode to an active mode, and send the information of its own state as well as the warning about the traffic flow to ships in the vicinity, reminding them of the dangers to ensure safe navigation. In addition, the key nodes of the intelligent lighted buoy adopts redundant equipment and modular design, which can ensure the reliability of its service taking into account the possibility of its service development. This also allow the development and embedding of its system maintenance and new services.

2.2.3 Intelligent management function

The intelligent lighted buoy could achieve intelligent full-life-cycle management, including comprehensive monitoring of its own operating state, autonomous alarm, and fine management. They can conduct self-planning and self-scheduling of task priorities, energy consumption and operating time based on preset conditions such as the operating state and natural environment of the lighted buoy to generate a flexible, harmonious and optimized sequence for data analysis and processing. On the one hand, the state monitoring is accurate. The intelligent system monitors and manages the operating state of the aids to navigation . If the state is "normal", the task management unit is allowed to continue working. If the monitoring result is "abnormal", the function of intelligent fault diagnosis and reconstruction would be required. On the other hand, the fault diagnosis is accurate, which includes two functions: intelligent fault diagnosis and restoration management. The first step is to identify the type of the fault based on monitoring data. Then, the intelligent lighted buoy conducts self-isolation and self-restoration to simple faults. If the fault cannot be repaired by itself, a corresponding warning would be issued. If there is any change about its own position, the emergency response of the lighted buoy would be triggered. The buoy could send its position and emergency information to the management personnel and the ships in the vicinity, and take automatic response such as collision avoidance, etc.

3 TECHNICAL REQUIREMENTS FOR THE DESIGN OF THE INTELLIGENT LIGHTED BUOY

The intelligent lighted buoy in essence is an integrated equipment platform based on the lighted buoy. It is constructed by carrying various sensors and electronic modules. By the application of artificial intelligence technology and 5G network, the platform not only has the capability to perceive various types of marine information, but also has the function of independent information analysis, judgment, and processing, which contribute to a three-dimensional, intersecting, and efficient information network to provide comprehensive and standard marine information services.

3.1 Modularization design

Modularization design is to subdivide the system of the intelligent lighted buoy into several functional modules according to their specific functions including information perception, self-diagnosis, communication transmission, data processing and intelligent decision-making. As for the design of the functions of the intelligent lighted buoy, various modules can be plugged in and put into operation independently when switching on and off automatically. Standardized basic configurations, data interfaces, sensor mounting and communication interfaces are used on the intelligent lighted buoy to facilitate data exchange. Multiple system interfaces need to be designed for the intelligent lighted buoy, including:

Ship dynamic information interface: including access to ship position information and AIS to achieve integrated display on shore-based or electronic equipment.

Navigation environment information interface: including access to basic information of the buoy, geographic information data access, hydrological and meteorological data access, to achieve data collection, processing, display, and other functions.

Water communication information interface: including ground medium and short wave communication data access, communication data of VHF/VDES and other base stations access, and satellite communication data access such as Beidou and GPS, to increase communication transmission rate and ensure transmission stability.

3.2 Diversification of data acquisition

As an intelligent maritime navigation service equipment, it should has comprehensive sensing capabilities to obtain information on its own state, sea environment, traffic environment, users, relevant meteorological and hydrological forecasts, navigational warnings. Some of the data can be obtained in real-time through its own onboard sensors, and other data can be obtained and stored from the shore-based terminals through communication equipment. Data acquisition channels are diversified, including sensors carried by the lighted buoy itself, navigation service departments, maritime administrations, meteorological departments and shipping companies.

The intelligent lighted buoy could obtain real-time information on the state of its own (including position), working state of various functional modules of the buoy and the energy system, wind, wave and current conditions, water depth, visibility, as well as dynamic information of ships in its surroundings by the lighted buoy itself. This type of information can be obtained in real-time by carrying high-precision positioning devices, posture detectors, functional module management software, wind, wave and current detectors, bathymeters, cameras, small radars, and AIS.

Dynamic information on aids to navigation, regional AIS information about ships, nautical chart update information and hydrological information in the port area can be obtained from the navigation service department. Such information can be obtained and stored through 5G networks, VDES, Beidou short messages and microwave communication.

Ship report information, route plan information of ships entering into and departing from ports, berth information and navigational warnings (notices) can be obtained and stored through shore-based service interface or dedicated receiving devices from the maritime administrations.

Information such as weather forecast and early warning can be obtained from the meteorological department, and ship route planning information and cargo loading information can be obtained from the shipping company. Such information can be forwarded, obtained, and stored through a dedicated shore- based service interface.

3.3 Data processing intelligence

Intelligent data processing mainly includes intelligent processing of collected information and intelligent generation of maritime services. Due to the navigation safety, various types of information obtained must be accurate and reliable. At the same time, because of the coexistence of multiple driving modes on the sea, the requirements of navigation service are different, and different maritime services must be intelligently generated for different users.

Intelligent information collection and processing mainly refers to the intelligent extraction, conversion, and review of a large number of multi-source heterogeneous data collected and obtained. At the data extraction stage, a prefabricated strategy should be adopted to intelligently extract and store the source data set according to the data content, acquisition method, acquisition frequency. At the data conversion stage, source data is converted according to preprocessing rules such as repetitive processing, basic data collection, actual data supplementation and data association to form data in a standard format. At the data review stage, for those data that require manual review, a manual review interface would be generated. For those that do not require manual review, verification would be conducted according to data verification rules. The data that has passed the review would be stored in the target database. The data that has not passed the review would be stored in a temporary database, requiring manual error correction processing.

Intelligent maritime service generation mainly involves classification and grading of various types of data in the target database, encoding and encapsulating them into maritime service portfolios(MSP) information according to the MSP coding rules. At the same time, it can respond to instructions of application layer according to the requirements, conduct combined applications of various data portfolio, and generate corresponding navigation services for different users, including intelligent service content generation, transmission priority determination and independent frequency selection of core functions such as transmission links.

3.4 Data standardization

The data standardization of intelligent lighted buoys aims to build a data standardization method for based on the characteristics of a large number of multi-source heterogeneous data, establish data standard elements covering business, technology, and management, and provide support for the sharing, exchange, extraction, distribution, and heterogeneous integration of data resources. The construction of intelligent lighted buoys data standardization should not only comply with S-100 product data format, but also comply with the standard data requirements of MSP to ensure the consistency of obtaining intelligent shipping services for different navigation stage, port countries and coastal countries. The data standard elements of the business, technology, and management of the intelligent lighted buoy data standardization mainly include:

Business attribute data Standard: Technical requirements developed for basic business data such as the name, number, category, field, attribute, collection specification, etc., formulated based on the business requirements of the intelligent lighted buoy.

Technical attribute data standards: Standards and specifications developed for data management and technology development based on the technical requirements of the intelligent lighted buoy, including standards for data management, data exchange format, modular integrated applications, and development standards, development management specifications, and development testing specifications required for database development, as well as technical requirements for operating systems, system users, and system software installation and naming involved in development.

Management attribute data standards: Management standards developed for process management, including application, approval, change, sharing standards for data services, as well as roles, competent departments, creation dates, effective dates, and standard versions, developed based on the management requirements of the intelligent lighted buoy.

By constructing a standard model framework for the intelligent lighted buoy data, rapid and intelligent acquisition of built-in standards, intelligent tracking of processes such as addition, deletion, modification, and release of data standards, scenarios that meet users' customized management standards in combination with user permission management mechanisms could be achieved. The visualization of the entire life cycle of data standards from creation to extinction, and full role visualization could be achieved. Personnel at both the executive and decision-making levels can improve data standards.

3.5 Ubiquitous communication transmission

An intelligent lighted buoy communication network with multi-system ubiquitous connection could be constructed based on network data such as GMDSS, NAVTEX, Inmarsat, AIS, and VTS. Advanced technologies such as artificial intelligence, big data, and 5G are utilized to achieve intelligent processing of massive communication data. Cloud storage, analysis, and utilization of information resources are carried out to meet the intelligent perception and scientific prediction needs of multiple users. The intelligent lighted buoy could achieve the data transmission of multi-format shipping information, including text, images, audio, video. It could provide digital interfaces to achieve seamless connection with ship information systems, to provide regional and refined, customized, and automated information services, such as recommended routes based on real-time traffic flow information, route planning, intelligent collision avoidance, and traffic organization.

On the one hand, the digital construction of traditional buoy system enables the buoy collect basic information of its own in real time. The collected information is transmitted through public networks such as GSM and CDMA, as well as Beidou satellite navigation systems, digital radio stations, VHF, communication satellites, and other means. After comprehensive analysis, judgment, and fusion of information between the monitoring center and AIS, ECDIS, and DGNSS, the digital aids to navigation information is released to the ship. On the other hand, by comprehensively applying systems such as AIS, VTS, GNSS, VDES, as well as geographic information systems (GIS), remote sensing (RS), digital communication technology and virtual simulation, a comprehensive platform for data, network, and application is established, integrating buoy information resource. The platform could conduct telemetry and remote control, emergency deployment, real-time scheduling, networked coordination, systematic management, and standardized services for aids to navigation, forming a new integrated navigation service system based on network and information technology which would promote the interconnection and information sharing in maritime information services.

4 CONCLUSION

Based on the navigation requirements of intelligent ships, this paper proposes the functional characteristics and main technical requirements of the intelligent lighted buoy, providing ideas and solutions for the transformation and upgrading of traditional lighted buoy and construction and development of the intelligent lighted buoy.

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AUTHOR BIOGRAPHY

Gao Hanzeng is a senior engineer in the field of AtoN management. He is the director of Tianjin Science and Technology Center of AtoN and Hydrography of Northern Navigation Service Center of CHINA MSA. He has been working in navigation field for 26 years and has participated in 2 national projects including the Project of *Key Technologies of Ship Intelligent Navigation and Control Based on Ship-Shore Cooperation*. He has won 4 awards at the provincial and ministerial level, among which, the achievement of *"Development and Application of Maritime Service Information Platform with Complete Data Fusion"* won the first prize of the China Institute of Navigation for Science and Technology Progress. He has been in charge of drafting5 strategic plans including *the Development Strategy of the Northern Navigation Service Center (2021-2035)* and 2industrial standards, including *Radio Beacon-Differential Loran System Broadcasting Data Format*. He compiled one official publication and published 12 academic papers. Under his guidance, 7 proposals including *Progress on the Study of RBN-based Differential Loran-C Technologies* have been submitted to the committees of the IALA.

S3.3 The Implementation of Modular Plastic Buoys in Canada (144)

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ABSTRACT

Plastic buoys have been used by the Canadian Coast Guard (CCG) for over 40 years with very good operational success. However, their eventual disposal and recycling has become increasingly problematic. The overwhelming majority of the plastic buoys in use by the CCG are of a one-piece or "monocoque" design and less than a meter in diameter. Once these buoys begin to colour fade, they must be replaced or if any part of the buoy shell is compromised the buoy is often unrepairable and must be scrapped.

In this context, the CCG is addressing this issue on 3 main fronts: 1) Launching a plastic buoy recycling trial/feasibility study. The emphasis will be on 100% material recovery using innovative/non-traditional recycling technologies. 2) Investigating plastic buoy design concepts to reduce reliance on certain materials (foam buoyancy materials and types of plastic) and to introduce modularity concepts for ease of handling and recycling, and life extension. Material analysis will be performed to enhance the colour retention, using steel for structural purposes and avoiding less desirable materials such as concrete. Reuse of material, such as the radar reflector will be optimized. 3) Introducing the concept of a circular economy, focusing on reusing plastic to manufacture new buoys with the aim of 100 % material recovery (old/broken plastic buoys being used to build new plastic buoy floats) and eradicate the need for disposal via landfill or waste-to-energy technology.

This paper outlines what the CCG has done to overcome this problem and the resulting initiative to design its own modular buoys to reduce overall waste and to reduce lifecycle costs. The CCG wishes to share the results of its work with other national authorities to stimulate the dialogue and debate, as many other authorities may have similar concerns and interests with regards to plastic waste from buoys.

KEYWORDS: Modular Plastic Buoy, Circular Economy, Canadian Coast Guard, Sustainable Development

1 INTRODUCTION

Buoys come in various sizes, shapes, and materials. Their placement and maintenance are essential, since they often provide the only guidance to mariners for channel locations, shoals, reefs, and other hazards. If a light is extinguished, the buoy is damaged by collisions, or the buoy breaks loose from its moorings, it is replaced by the Canadian Coast Guard (CCG) as is the practice of the various Aids to Navigation Authorities around the world to ensure the safe navigability of their waterways.

For the longest time buoys were made primarily from steel and, over the many decades, these steel buoys have proven to be very reliable and durable. Steel buoys, however, are not without their drawbacks as they require plenty of maintenance to be seaworthy. Steel buoys are painted in various colours and after a few years at sea, the paint colour fades due to prolonged exposure to sunlight and other environmental factors resulting in the need for the buoy to be sandblasted and repainted (Figure 1). Other issues such as rust due to the corrosive nature of salt water, often result in the degradation of the steel structure which, if not addressed in time, can deteriorate the buoy and lead to its eventual failure at sea. The retrieval of the steel buoy, transportation back to the base, and its sandblasting, repair and repainting has become increasingly resource intensive with no relief in sight.

Figure 30: Rusty Red steel buoy

The CCG owns and manages around 12,000 short-range floating aids of which 8,500 are plastic buoys (75 % of all buoys are plastic). These plastic buoys started appearing on the market about 40 years ago as a result of the ability to roto-mould polyethylene plastic to produce a one-piece watertight plastic enclosure or shell (Figure 2).

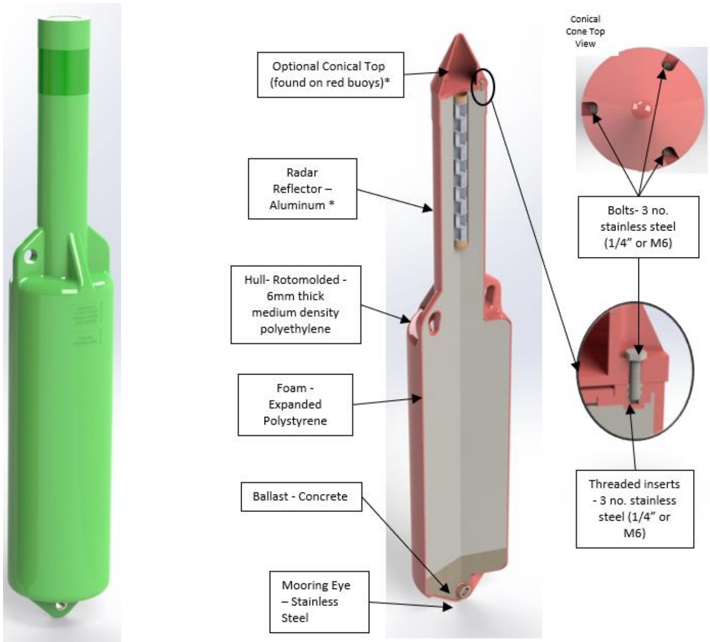

Figure 31: Monocoque Ottawa River Type (ORT) Plastic Buoy

While the thin polyethylene skinned plastic buoy shells look simple (Left picture of Figure 2), they are actually much more complex; they are filled with concrete at the base which acts as ballast, low-density polystyrene foam for buoyancy in the event of a breach, and other metal parts such as a radar reflector, mooring eye and inserts for fasteners (Right of Figure 2). These plastic buoys have some significant advantages over steel; they are lower in cost, don't rust, are easier to transport and are almost maintenance free compared to their steel counterparts.

2 THE PROBLEM

Although these plastic buoys have proven to be very cost-effective for the CCG over the years, they are not without their drawbacks, most of which are related to environmental impacts. In many cases breached buoys at sea have leached out much of their internal polystyrene foam which is not desirable. The main disadvantage is due to its one-piece or monocoque design which results in a lot of waste as well as complexity at disposal. After approximately 10-12 years these plastic buoys begin to colour fade and must be replaced. Moreover, if any part of the buoy shell is compromised, the buoy can be unrepairable and must be scrapped. Over the decades, CCG bases across the country have stockpiled large quantities of "end of life" plastic buoys (Figure 3) as there is no established process for their disposal or recycling.

Research into the recycling of industry of plastics in North America has revealed that only 9 % of plastic is actually recycled leaving the other 91 % to be burned as fuel or landfilled[1]. An internal survey conducted by the CCG of the plastic recyclers in Canada has yielded the following.

- There is a general lack of available local plastic recyclers in certain parts of Canada;
- Typically, recyclers only want plastics that have been separated into bins prior to pick up. Figure 4 shows a dissected buoy with its various internal components. This mix of component pieces in these buoys reduces the options for recycling. Quite a few of these components must be landfilled as there isn't a viable recycling process.;
- It is the responsibility of the CCG to transport these buoys to the recycling facility; *and*
- The recycling facility gets the plastic for free

This paper describes the CCG studies and initiatives undertaken to resolve these issues which have resulted in the modular buoy prototype.

Figure 32: End of life plastic buoy stockpiles in St. John's (NL), Dartmouth (NS), and Prescott (ON)

Figure 33: The dissection of current monocoque plastic buoys

3 PLASTIC RECYCLING INITIATIVE

In 2021-2022 the CCG launched a plastic buoy recycling trial with the target to accomplish 100 % diversion of material from landfill. The initiative was conducted over four months with a total of 137 buoys (five different models) sent for processing. CCG engaged a vendor to deconstruct the buoys and perform material separation to assess each material streams' recyclability. Materials that were suitable feedstock were sent to vendors for processing. Any material that could not be recycled or reused was sent to landfill. Figure 5 shows an example of the different materials found within a buoy, and Table 1 shows the results of this plastic recycling initiative where 95.7% (or 31.51 tonnes of material which was mainly plastic) was successfully recycled.

Figure 34. Example of the different waste streams from a buoy.

Table 4. Final Disposal Mass and Percentage

Final Disposal	Total (kg)	% of Materials
Recycled / Reused	31,510	95.7
Landfill	1,415	4.3
Totals	32,925	100.0

Lessons learned from the initiative include: 1) Manual disassembly and material separation was the only option (very labour intensive, storage space required). 2) Processing buoys in Winter (below freezing) temperatures posed challenges for material separation due to ice formation within internal components. 3) 10-15 % of buoys were waterlogged, sometimes with upwards of 100 % weight gain due to water absorption. 4) The cost of recycling ranges from 36 % to 96% of the purchase cost depending on the buoy model, level of contaminants and water infiltration.

The following materials could not be recycled due to contamination or their composition:

- “Wet/waterlogged” polystyrene material;
- Reflective stickers which left glue residue on metal strips;
- Metal hardware that was embedded and moulded into the plastic;
- Concrete that was embedded in the plastic or foam;
- Biological fouling, such as Zebra mussels; *and*
- Shavings, sweepings and cuttings from the separation and deconstruction process.

4 THE IN-HOUSE SOLUTION

Faced with these challenges, the CCG’s Maritime and Civil Infrastructure (MCI) engineering team put forward an innovative approach to this problem by introducing modularity to the buoy design and developed prototypes of the designed buoys.

The first buoy that the CCG chose to redesign was the “Ottawa River Type” (ORT) buoy since it accounts for most of the CCG’s plastic buoy inventory. The CCG owns more than 4,000 of this type of buoy which is a small spar buoy used extensively in rivers and lakes, and in some coastal areas.

The objective was to create a buoy with a lower environmental impact (maximising recyclable components) while maintaining the advantages and the functionality of current plastic buoys. The hybrid buoy (Figure 6) marries the strength and longevity of steel with the weight and low maintenance of plastic to make a longer lasting, cost effective, and more eco-friendly buoy. The design consists of a painted steel frame, four hollow plastic floats (two main hulls and two towers), a reusable radar reflector (retrieved from the current plastic buoy stockpiles), a steel lantern adapter plate, and a set of stainless-steel bolts/screws. The steel frame has two lifting eyes, and one mooring lug and is designed to hold up to three 5 kg steel plates for additional ballast weight on the buoy system if required.

This buoy was designed in-house by the CCG and incorporated several design and technological improvements based on the lessons learned over the years. As iterations of the buoy models were developed using Computer Aided Design (CAD), they were subjected to an in-house stability analysis to evaluate performance in various bodies of water (lake, river, fresh and sea water, etc.). A finite element analysis (FEA) was performed on the steel structure to achieve a safety factor of 5 for the lifting and mooring lugs. After a few design iterations and consultations with the CCG’s stakeholders, the engineering team was able to come up with a design that optimized both the buoy’s structural strength (mooring and retrieval) and its stability when deployed. Note that the new modular buoy exceeds all operational requirements such as air draft, colour, visibility, marking, material handling, etc.

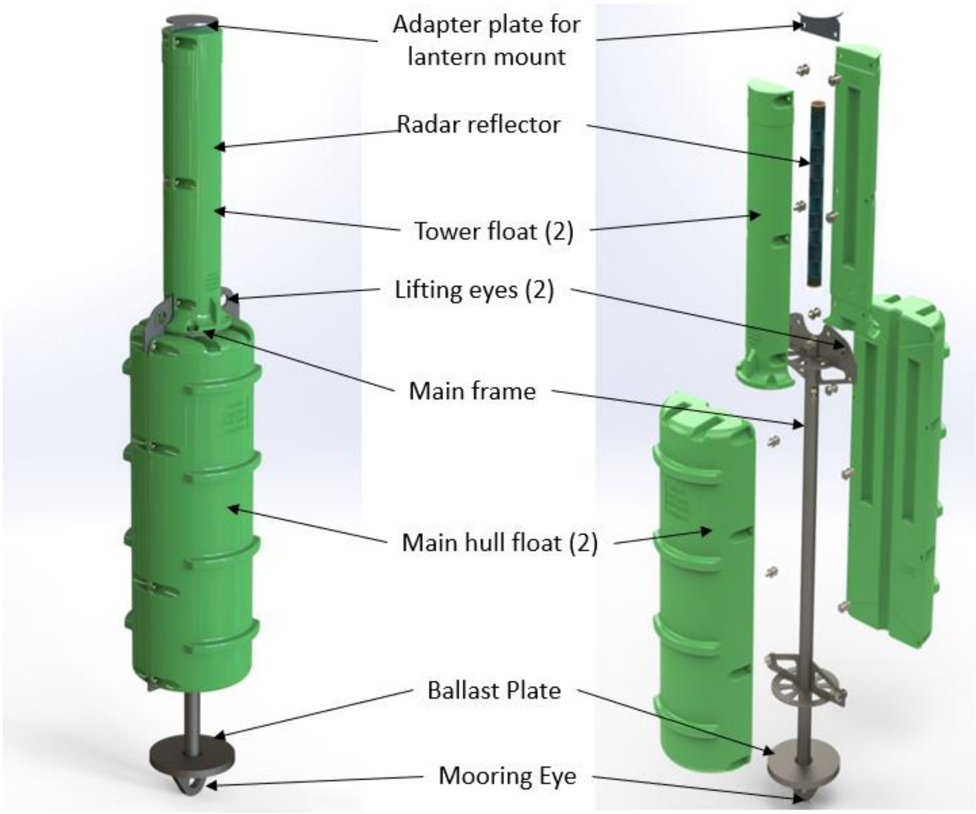

Figure 35: New Modular Hybrid ORT Buoy Design

5 THE MODULAR BENEFITS

Although modular buoys have been around for many years and made by various buoy manufacturers, their sizes were usually confined to diameters of over 1 meter. Since the largest number of plastic buoys in the CCG that are scrapped annually are smaller than 1 meter in diameter, it was desirable to introduce a modular approach for these buoys as well. The benefits of a such a design are as follows:

- Buoy parts are easily replaced in the event of damage or colour fading;
- Part replacement is a fraction of the price compared to total buoy replacement;
- Disposal costs for smaller parts with no filler/foam inside is significantly less;
- Reduces overall buoy waste by making buoy parts replaceable whilst also removing undesirable materials from the buoy;
- Smaller replacement parts are easier and cheaper to transport;
- Overall life cycle costs are significantly reduced (from purchase to disposal);
- Buoy inventories are reduced because of availability of replacement parts; *and*
- Instead of relying on the plastic structure of a 'one-piece' buoy design while handling the buoy, the buoy safety (deployment and retrieval) has significantly improved due to the modular buoy's incorporation of a structural steel frame which can also be used for handling.

6 THE MODULAR DESIGN BONUS

A modular design has one other big advantage not yet mentioned and that is the ability to use the format to make other types of buoys. The engineering team at the CCG realised early on that the steel frame used to attach components could also be used to make a smaller "Marker" style buoy by utilizing the same main hull float sections only. Images of both buoys using the same steel frame are shown in Figure 7. This bonus of being able to generate two different buoys with one design was fortunate and shows that the modular format is indeed a good one to embrace. Additionally, “conical” and “can” topmarks can be mounted on the buoy adapter plate.

The prototype modular ORT’s are now in testing with buoys deployed across the country for sea trials. If sea trials are successful, the CCG will begin to mass-produce these buoys and move on to the next buoy to modularize.

Figure 36: Two buoy models in one design (left and middle) and topmark feature (right)

7 CIRCULAR ECONOMY AND END OF LIFE OF MODULAR PLASTIC FLOATS

Not only has the CCG embraced the modular solution for its buoys; it has taken the challenge to a new level. The CCG engaged a plastic research facility to analyse several plastic buoys no longer in use, to reuse the pre-moulded polyethylene plastic. The analysis considered many factors and determined that a large percentage of older polyethylene plastic can be cleaned, reground, pulverized and then reused in the manufacture of new float sections for the modular buoys as shown in Figure 8. This attempt to recycle and reuse older buoys will ultimately reduce plastic waste and eliminate the spent buoys’ diversion to the landfill.

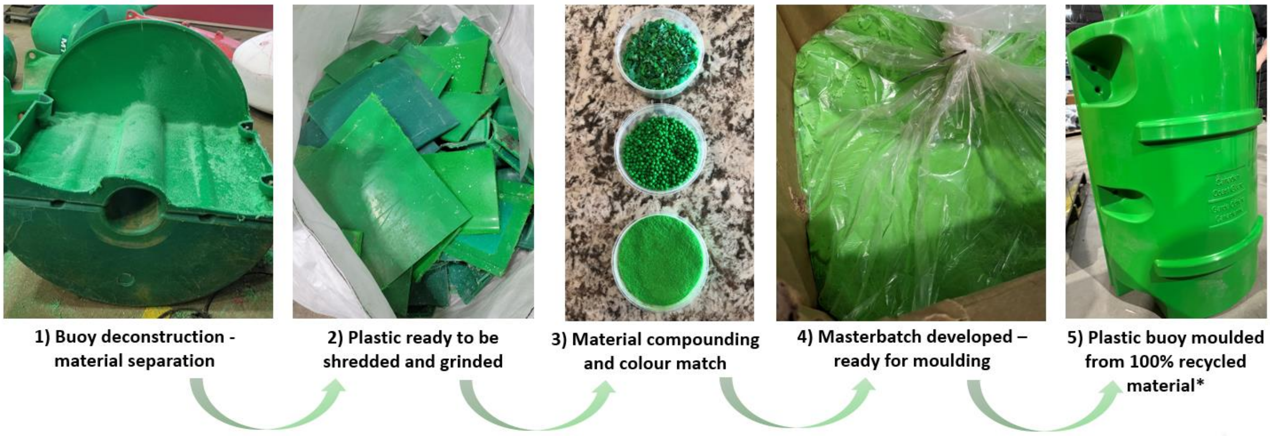

Figure 37: Circular Economy

8 CONCLUSION

By designing its own plastic buoy, the CCG now better understands the plastic buoy life cycle management process, which will help when engaging with private industries. As a result the CCG is able to direct the fabrication states, the asset handling, the cost over the life cycle, the waste management and recycling at end of life. The CCG will then be able to obtain a product that better meets operational requirements.

The CCG has successfully used plastic buoys for years. However, analysis found that this was not the most environmentally friendly option. The new modular buoy design has an improved life cycle, lower costs and a more optimal reuse of materials. Earth Day (April 22nd) reminds us all of our responsibility to promote both better and greener practices for our planet, and how government policies should be aligned with this objective. The project introduced in this paper, highlighted new ways for the CCG to be proactive in the sustainable development of plastic buoys by 1) establishing the right methodology to dispose plastic buoys that reach their end of life, 2) introducing new modular plastic buoy designs for which components can be easily repaired, replaced, recycled or reused, and 3) developing a sustainable circular economy in which the raw material to fabricate new modular buoys will be composed of end of life plastic buoys.

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AUTHOR BIOGRAPHY

Pierre-Luc Delage is a Professional Engineer who holds a Bachelor of Civil Engineering and a Master of Applied Science in Hydraulics Engineering. He began his career in the private sector in 2006 and joined the Canadian Coast Guard in 2010. In 2015, Pierre-Luc was appointed as the Technical Authority for the Four-Season Buoy project. Working with his team, he designed three spar-shaped steel buoys capable of withstanding the harsh ice conditions of Winter on the St. Lawrence River while providing mariners a stable light signal during the Summer months. Pierre-Luc and his team carried out additional research to determine the ideal coating and electrical systems to ensure long-term functionality, which enabled the buoy system to be deployed for up to four years without requiring fleet services. In recognition of his exemplary contribution to this project, Pierre-Luc received the ***Prix d'Excellence Innovation*** in 2019, which is the most prestigious award at Fisheries and Oceans Canada.

Since January 2021, Pierre-Luc has been serving as the Acting Manager of Maritime and Civil Infrastructure (Integrated Technical Services) at the Canadian Coast Guard. He leads a team of engineers who work on various Aids to Navigation (AtoN) projects. This includes designs for mooring hardware and anchors, and enhancing efficiency of marine lights. Additionally, Pierre-Luc and his team are responsible for drafting technical specifications and standards for AtoN equipment such as Coating Standards for AtoN. Presently, his team is focused on sustainable development such as designing modular plastic buoys and establishing a circular plastic economy.

S3.4 Optimization of the service life of plastic buoys: Assessment of the aging of colors and materials, especially with regard to work safety (068)

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ABSTRACT

Plastic buoys are used in large numbers around the world. Due to their meanwhile good colour stability as well as the omission of corrosion protection and steel construction measures, they can optimize the overall system costs for the provision of floating aids to navigation. This concerns both the reduction of shore-side maintenance efforts and the reduction of ship costs.

Despite all the advantages of plastic buoys, the base material plastic ages in contrast to steel due to various influencing factors. This manifests itself in a deterioration of the colour properties and in a generally invisible reduction of the mechanical strength of the plastic parts of the buoy.

Sufficient buoy strength is essential to ensure work safety requirements, important terms here are safe working load, breaking load, embrittlement, etc.

Economic considerations usually specify a certain service life for plastic buoys, which in practice is limited by the aging of the plastic. The end of the service life is reached in particular when the strength characteristics have left specified ranges. In this case, plastic buoys must be replaced. Therefore it is necessary to detect any deviations from specified values as soon as possible.

Even if during the procurement of plastic buoys

- the plastic material was carefully specified,
- a safe buoy design was chosen,
- all requirements have been verified and
- quality controls were carried out during production:

Monitoring of the buoy properties is necessary during the service life!

KEYWORDS: plastic buoys, occupational safety, colours, ageing

1 INTRODUCTION

Plastic buoys of various designs are used in large numbers around the world. They are available in a wide variety of sizes and shapes, from small one-piece buoys to very large modular buoys, most of them are made of polyethylene (PE). They can optimise the overall system costs for the provision of floating aids to navigation by:

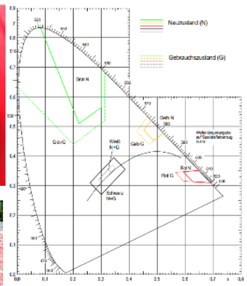
- The omission of corrosion protection and steel construction measures
- The reduction of ship costs

But:

- They are more expensive to buy than steel buoys.
- They have typically a shorter design life than steel buoys.

Economic calculations usually specify a minimum service life for plastic buoys. In any case, regarding sustainability they should be used as long as possible!

But: Ageing of the plastic and other components limits the service life.

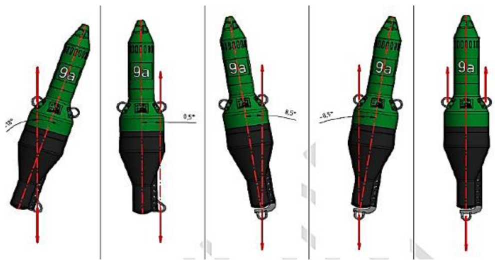


In contrast to steel buoys, which require regular maintenance for corrosion protection, plastic buoys can and must be operated maintenance-free over a long time (up to 15 years or more). This can be done until certain properties and parameters reach specified limits due to ageing. Only then a new procurement and recycling should take place for:

- Increasing the overall cost efficiency
- Ensuring sustainability
- Environmental protection / minimization of carbon dioxide emissions

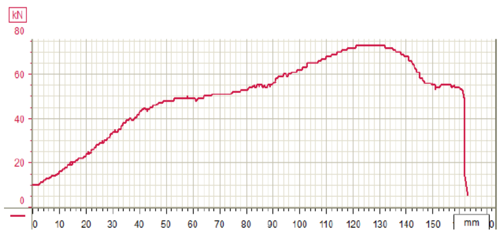
Therefore, all components of plastic buoys need a durable design.
For some components, such as mooring eyes or the lettering, the requirements are higher than for steel buoys (which are regularly maintained...).

2 PROCUREMENT REQUIREMENTS



To maximize the service life of plastic buoys, both the design and the manufacturing quality must be carried out accordingly. The following measures are essential:

- When drawing up the tender documents for the procurement, appropriate requirements have to be worked out.
- Particularly important are the careful selection and specification of the plastic material as well as a safe buoy design (according to the operational environment: Sheltered, exposed, ice, etc.)

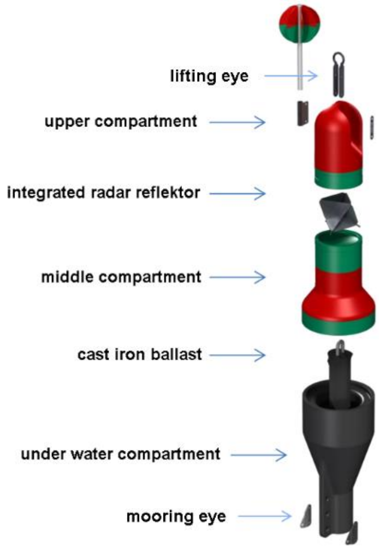


- It is important to check the fulfilment of the requirements, for example by execution of destructive tensile tests to prove the buoy strength.
- Quality controls during production ensure compliance with the requirements in series production.

3 AGEING OF OF PLASTIC BUOYS

However, even a well-designed and carefully manufactured plastic buoy ages. The ageing reduces the service life and has an impact on the following important properties:

- Occupational safety
- Navigational availability
- Economy

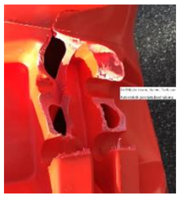


Plastic buoys are made of several different components and materials. As part of the operation and maintenance concept, measurement- and evaluation procedures are needed to monitor the ageing processes. In the following, the ageing processes of individual components of a plastic buoy are examined. The resulting effects/hazards are investigated. Advice is given on how to slow down ageing or minimize its effects.

3.1 The most important thing: Occupational safety

The greatest danger regarding the occupational safety arises when the buoy cannot (or can no longer) withstand the applied forces between mooring- and lifting eyes. This can lead to uncontrolled movements of buoy parts. The buoy tender crew is endangered by this. Hazards may occur with:

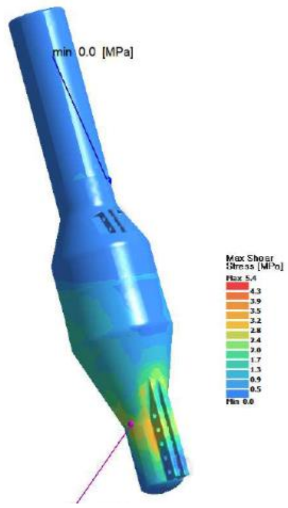
- Sudden cracking of the plastic material or weldings between plastic parts
- Tearing out of the lifting eye or the mooring eye out of the plastic body
- Breaking of the lifting eye or the mooring eye
- Breaking or loosening of the screw connections



In order to minimize the risk to staff during the handling of plastic buoys the following parameters are important:

- Permissible operating load
- Breaking load

3.2 Loads



The permissible operating load must be carefully determined based on real operating conditions:

- For example 2000 kg

The breaking load must be calculated with a sufficient safety factor. The safety factor should take a sufficient reserve for aging and wear into account:

- For example factor 3, which means 6000 kg

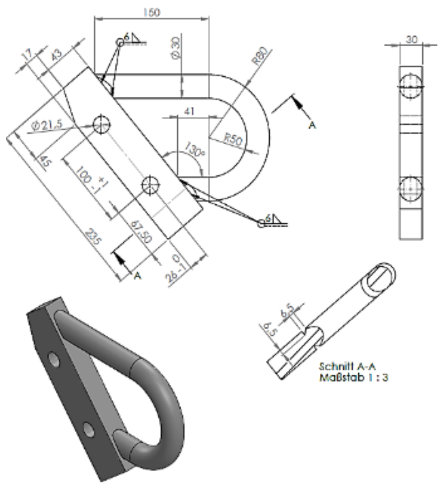
The strength of the buoy depends mainly on the plastic, its weldings and the metal parts.

When designing the buoy, each component of the load chain must be designed accordingly. Any deviations from the specified values must be detected by a continuous monitoring.

3.3 Visible wear of metal parts

The following tests can be carried out during the cleaning process and the chain check:

- Buoy body: Visual inspection for damage
- Visual inspection of metal parts for wear and rust
- Measurement of minimum material thicknesses
- Visual inspection of screw connections

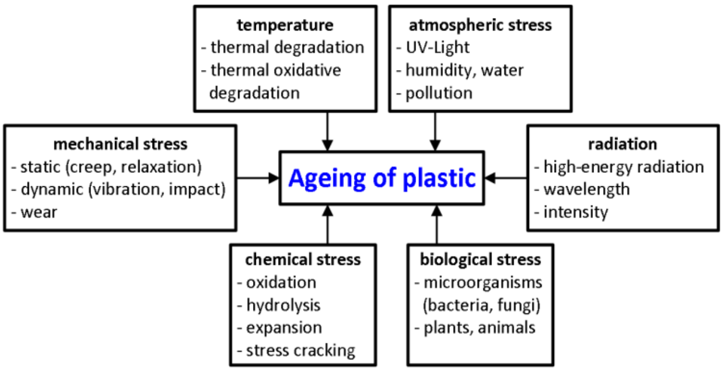


If necessary, worn parts must be replaced. A good design includes sufficient wear reserves, which significantly extends the service life of individual parts. Example:

- To ensure the breaking load of a mooring eye, a diameter of 20 mm is statically required.
- In order to have a sufficient wear reserve, a diameter of 30 mm was chosen.
- A similar procedure can be used for the chain.

3.4 Ageing of the plastic – Visible and non visible effects

Ageing is the totality of chemical and physical changes in the material that occur over time. Different environmental influences lead to ageing. Certain additives can slow down aging, but they cannot stop it. The ageing of the plastic essentially affects 2 things:



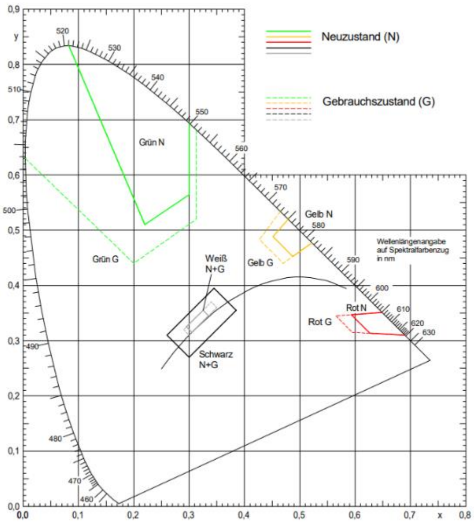
- The colours fade: Visible effect
- The mechanical properties of the plastic degrade: non visible effect

The aforementioned effects have different impacts, which will be explained in the following.

3.4.1 Ageing of the plastic – Colour fading and its effects

Colours should be within the ranges of IALA Recommendation R0108 Surface Colours used as Visual Signals on Marine Aids to Navigation. The colours fade towards white, the nautical availability suffers. The question of when a colour has faded so much that it can no longer achieve the required nautical availability is not easy to answer. Ideas on how to deal with this are described in IALA Guideline G1134 Surface Colours used as visual signals on AtoN. It contents colour specifications, measurement-, monitoring- and weathering methods. The degree of ageing can be determined by:

- Comparison with samples
- Measurement



However, the decision on when a plastic buoy needs to be replaced due to colour fading is usually made by the local nautical responsible person, e.g. a buoy tender captain.

3.4.2 Ageing of the plastic - Prevention of colour fading

What can be done in advance to ensure that the colour will remain within the acceptable colour range for at least the required lifetime or even beyond?

- It is important to know as precisely as possible how the colour will age.

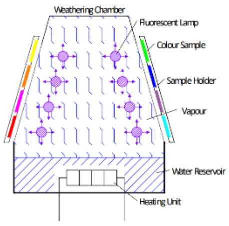
For the prediction results of weathering tests can be used. A distinction must be made between real-time weathering and accelerated weathering.

Real-time weathering can be done in-situ or in an outdoor test field. It is time-consuming and partly expensive (in-situ).

Accelerated weathering can be done according to different standards and procedures (exposure to UV + heat + moisture or Xenon arc lamps).

Correlation factors between accelerated weathering time and real-time can help to predict the aging.

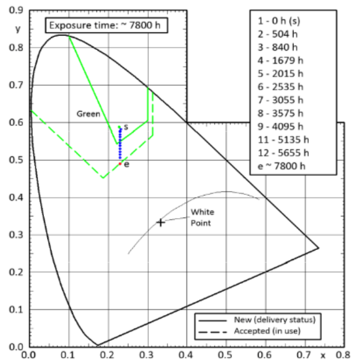
During the tender process, the competent authority can request the results of weathering tests and select the right materials for a long colour stability.



3.4.3 Ageing of the plastic - Prevention of colour fading: Example

For a plastic buoy a minimum service life of 12 years was required. Based on many years of experience, the following correlation factor for a well known polyethylene compound was found:

- 12 years of operation on the German North and Baltic Sea coast correspond to nearly 5000 h of accelerated weathering with a Xenon arc lamp according to standard DIN EN ISO 16474-3.



Based on accelerated weathering tests the tender required a proof, that the colour of the plastic offered will be within the permissible colour range after at least 5000 hours of accelerated weathering (minimum requirement).

If it can be proven that the plastic will remain in the permissible colour range for more than 5000 hours, the product was rated correspondingly higher in the bid evaluation for the criterion quality / durability (point system).

According to this procedure, it can be assumed that the buoy will achieve the required service life of 12 years or more regarding the colour.

3.4.4 Occupational safety: Non visible ageing of the mechanical properties of plastic

While colour fading is visible and measureable, ageing of the plastic regarding its mechanical properties is more or less invisible. Plastic buoys, where the forces between the lifting- and the mooring eyes are also transmitted through the plastic body, can cause a risk to occupational safety due to plastic ageing.

- The question arises: How long can a plastic buoy be used safely?

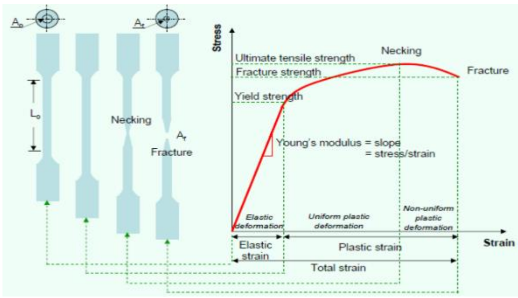
Regarding this, the German Waterways and Shipping Administration has carried out many years of research.

From the measurement and monitoring of some important parameters of the plastic, statements about the strength of the buoy body have been derived.

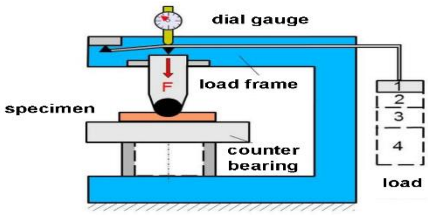
3.4.5 Occupational safety – Non visible ageing: Measurements of the mechanical properties of plastic

The mechanical properties of plastics can be assessed by test procedures according to relevant standards, such as:

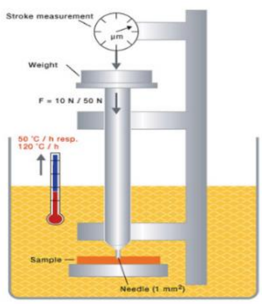
- Tensile test until the specimen breaks (DIN 527-2)
  - Maximum tensile strength / $Rm\ [MPa]$
  - Elongation at break / ε [%]



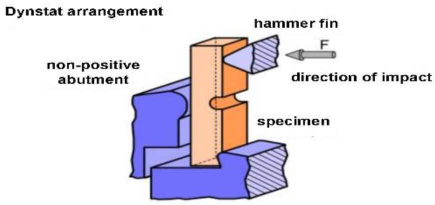
- Hardness test: Resistance that the test specimen offers to the penetration of another, harder body (DIN EN ISO 2039-1)
  - Ball indentation hardness / $H\ [N/mm2]$



- Heat deflection temperature: Test to determine the ability of a test specimen to maintain its shape under a specified loading condition until a specified temperature is reached (DIN EN ISO 306).
  - Vicat softening temperature / VST [°C]



* Heat deflection temperature: Test to determine the ability of a test specimen to maintain its shape under a specified loading condition until a specified temperature is reached (DIN EN ISO 306).
    * Vicat softening temperature / VST [°C]



In order to obtain a comprehensive result that is as close to reality as possible, the following was investigated:

* Test of plastic buoys from different manufacturers
* Tests on plastic buoys made of rotationally moulded PE
* Tests on plastic buoys made of extruded PE

The tests were carried out as follows:

* Tests on new buoys and buoys that have been used for years (0 / 6 / 12 years)
* Tests at different temperatures to simulate warm and cold environmental conditions (-30°C, -10°C, 25°C)
* Test on samples of different colours

3.4.6 Occupational safety – Non visible ageing: Measurements results of the mechanical properties

General findings:

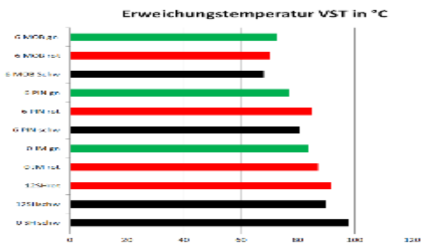
* Extruded plastic has generally stronger mechanical properties than rotationally moulded material (this depends on the processing method).
* Plastics from different manufacturers have different mechanical properties due to different additives and fillers.
* The mechanical properties also vary depending on the colour.

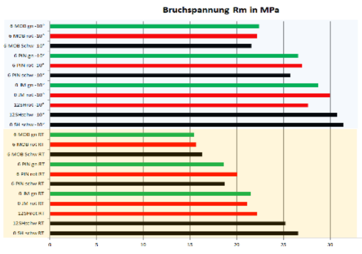
Results regarding the ageing of the plastic:

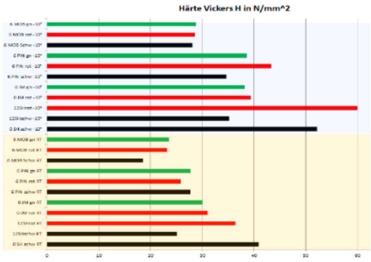
* Small degradations were found in rotationally moulded material.
* The changes were in the expected directions:
    * Decreased tensile strength and elongation
    * Decreased toughness = increasing brittleness

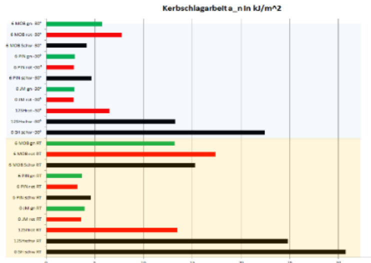
3.5 Conclusion:

- The change in measured mechanical properties does not indicate "dangerous ageing" of buoys that are up to 12 years old.
- For a long-term safe operation of plastic buoys, regular tests and measurements should be carried out with regard to the ageing of the mechanical properties.
- This should be part of the operation and maintenance concept.



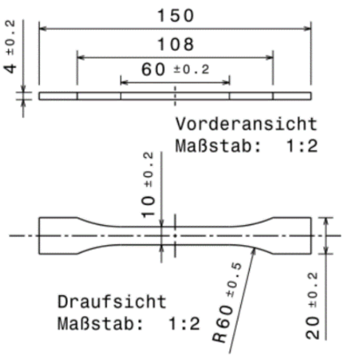


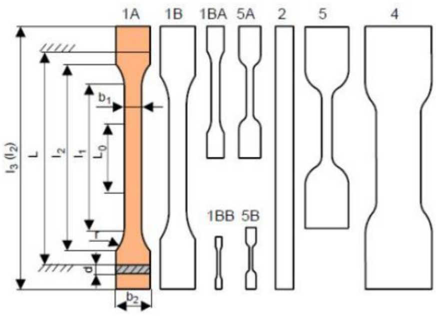




4 NON VISIBLE AGEING: MEASUREMENT CONCEPT FOR THE MECHANICAL PROPERTIES

- Standardized test specimens must be made of the same plastic as the plastic buoys.
- All colours should be considered.
- Their number must be large enough to provide enough test specimens for the whole investigation period (several years).
- In order to determine the initial data of the new material, the measurements described above are carried out promptly.
- The other samples are subjected to natural ageing, e.g. in a free-weathering rack.
- The measurements should be repeated at regular intervals, e.g. every 2 to 4 years.
- If strongly fluctuating deviations become apparent over the years, the intervals should be shortened accordingly.
- For a clear overview and assessment of the ageing process, the measurement results should be prepared in a suitable diagram including the associated limit values.





AUTHOR BIOGRAPHY

54 years old, married, one child, education as radio electronics technician, studying telecommunication engineering, worked as development engineer and product manager, since 2003 working at Federal Waterways and Shipping Administration, Germany. Member of the IALA ENG Committee since 2014, Vice Chair of Working Group 2.

S3.5 The assessment of buoy dynamics as part of a new buoy design (096)

Rob Dorey, Director of Operations, Trinity House, Harwich UK

ABSTRACT

Trinity House have for many years operated high focal plane buoys with a tail tube (Type 1), and smaller skirted (Type 2) buoys. Both of these designs have evolved over 60 years or so from gas powered lights to solar powered modern radio and visual AtoN. Such changes have impacted on how the weight within and on the buoy is distributed. This has posed some questions, such as:

- What impact has this had on the dynamic motion of the buoy?
- How does this impact on the effectiveness of AtoN performance?
- How could this be assessed?
- Is there a more suitable design that can be adopted for the future?

In considering these questions, this presentation will look at a number of phases in the buoy's development to achieve a stable and common platform for future AtoN and support equipment. A structured approach is discussed which includes a before and after performance data capture, computer modelling and wave tank testing, all of which inform the design.

(No paper submitted)

AUTHOR BIOGRAPHY

Commodore Rob Dorey joined Trinity House as the Director of Operations in October 2015. In this role he is responsible for the operational functions of the Lighthouse Authority, delivered through the Engineering, Marine, Commercial and Planning departments. His teams constantly striving to deliver innovative and cost effective solutions which maintain an effective Aids To Navigation service for the safety of the mariner and shipping, the prevention of pollution and facilitating the safe flow of trade through our waters. As an Elder brother he is a Trustee of the Corporation of Trinity House Maritime Charity, taking a part in overseeing the allocation of funding to a range of charities which meet the objectives of maritime benevolence, safety and education – a role which dates back some 500 years. He came to Trinity House from the Royal Fleet Auxiliary where he qualified as a Master Mariner in 1990 and was promoted to Captain in 2004 and then Commodore and Head of the RFA Service in 2013.

During that time he has served around the world including conflicts in the Falklands, the Gulf and the Former Republic of Yugoslavia. He is a qualified RN Specialist Navigator and has completed staff appointments with the RFA, Royal Navy and in the Ministry of Defence. He commanded a number of ships with his last seagoing appointment conducting counter piracy operations off Somali with embarked Royal Marine, medical and aviation detachments. He is a keen advocate of innovation, the application of technology and business focussed personal professional development. He is a Fellow of the Institute of Marine Engineering Science and Technology, where he was President in 2018. It is with continuous learning in mind where Rob became instrumental in establishing Trinity House as an accredited IALA World Wide Academy training organisation, providing IALA model courses to support the successful delivery of AtoN Services. Rob relocated from Dorset to Essex on taking up the Harwich based post with Trinity House and when not at work, he enjoys boats, motorbikes and walking the dog.

SESSIONS 4 AND 104 – LIGHT AND OPTICS

S4.1 The new generation of lighthouse intensity measurement equipment (129)

Dr Alwyn Williams, Principal Visual Signalling Engineer, General Lighthouse Authorities of the UK and Ireland, GRAD, Harwich, United Kingdom
alwyn.williams@gla-rad.org

ABSTRACT

For many decades, the General Lighthouse Authorities of the UK and Ireland Research and Development (GRAD) has pioneered the techniques for measuring the light intensity of an operational lighthouse in the field. This, largely unique, facility has enabled the performance of lighthouses fitted with a variety of light sources and optics to be determined, providing the ability to optimize the balance between meeting the navigation requirement and capital cost. In the last couple of years, the light measurement facility has been upgraded with custom-built photometric measurement equipment based on a silicon photomultiplier, leading to a step increase in measurement performance and accuracy. This paper provides a brief history of field light measurements undertaken by the General Lighthouse Authorities before discussing how the new equipment has improved the facility. Examples of measurements taken with the new system are provided to demonstrate its capabilities.

KEYWORDS: Light Measurement, Metrology, Lighthouse, Performance, Verification

En este documento, se describen los requisitos de formato para la 20ª Conferencia de la IALA. Revise este documento para obtener información sobre el formato del texto, los títulos de las tablas, las referencias y el método para incluir la información de indexación. Las actas de la conferencia se publicarán en formato electrónico. El trabajo completo en archivo MS Word se redactará de conformidad con estas instrucciones. En una etapa posterior, se convertirá a formato de documento portátil (PDF).

Un resumen de no más de 250 palabras debe aparecer en la parte superior de la primera página, después del título del trabajo en una sección titulada "RESUMEN" (sin número de sección), después de los nombres de los autores.

PALABRAS CLAVE: Medición de luz, metrología, faro, rendimiento, verificación

RESUME DE L'ARTICLE

Dans cet article, les exigences de formatage pour la 20e Conférence de l'AISM sont décrites. Veuillez consulter ce document pour en savoir plus sur la mise en forme du texte, les légendes des tableaux, les références et la méthode pour inclure les informations d'indexation. Les actes de la conférence seront publiés sous forme électronique. Le document complet dans le fichier MS Word doit être rédigé conformément à ces instructions. À un stade ultérieur, il sera converti en format de document portable (PDF).

Un résumé n'excédant pas 250 mots doit apparaître en haut de la première page, après le titre de l'article dans une section intitulée "RÉSUMÉ" (sans numéro de section), après les noms des auteurs.

MOTS CLÉS : Mesure de la lumière, métrologie, phare, performance, vérification

1 INTRODUCTION

For many decades, the General Lighthouse Authorities of the UK and Ireland (GLA) Research and Development (GRAD) has been measuring the light intensity from lighthouses in order to confirm their performance against that published in the Admiralty Light of Lights [1]. In addition to this verification purpose, the process, known as “field measurements”, allows the GLA to test the performance of the lamp-optic system in the case of a new light source that is untested in the lighthouse of interest. Whilst this can be calculated by theory using the techniques in IALA Recommendation R0205, only a measurement can provide a definitive answer as to the suitability of a light source in a lighthouse optic. In this paper, we shall cover a brief history of the process, how it is carried out today, and what the possibilities may be in the future.

2 BACKGROUND

The GRAD Field Measurement System (FMS) has been in almost continuous development for over 50 years, with records of measurements going back to at least the early 1970's, and possibly earlier. The method of measuring the intensity of light with a given lamp-optic combination was previously carried out in a custom light range. This provided a relatively comfortable environment that made it straightforward to measure the intensity of the light.

The light ranges had to be physically large, not only because the optics themselves were large, but also because the photometer that senses the light intensity needs to be a certain distance to provide a meaningful measurement. The light ranges were often made with two buildings either side of light measurement path, with the light beam being shone between them. The optic system was often placed on a goniometer, which allowed it to be rotated and tilted to get the distribution of intensity at different viewing angles.

GRAD still operates two light ranges in Harwich to this day, and they are often used to measure the light intensity and distribution of modern aid-to-navigation lights.

It was recognised early on that whilst light ranges were very useful in measuring the intensity of light beams from aids-to-navigation, they cannot replicate the conditions on the lighthouse nor can they be used for the largest optics used in the lighthouse service due to their sheer size and availability.

Because of this, it was decided to create a mobile light range that would enable engineers to carry out a measurement of the lighthouse light-optic system while it is in place. A number of challenges had to be overcome, some of which we are still dealing with today.

3 MEASURING LIGHTS IN THE FIELD

The basic principle used in measuring lighthouse light intensity is very similar to that used in the light ranges. The light to be measured is compared to a light of a known intensity - a calibrated reference light. With all else being equal, ratio of the photometer response between the two measurements will be the same as the ratio of the two light intensities. In other words, if the response from the photometer when measuring the light under test is double that of the reference light, then the intensity of the light under test is double that of the reference light. This method is known as the substitution method, and allows for accurate measurements of the device under test and is used in many areas in the metrology industry.

A calibrated reference light is also used to compare against the light intensity from the lighthouse, and sits near the beam in the direction of the measurement apparatus (Figure 1).

In a laboratory, it is relatively straightforward to keep the measurement conditions in a consistent state to enable low uncertainties and accurate results. However, in the field, the conditions are almost constantly changing, and thus the measurement procedure must be adopted to such environments. GRAD uses the reference during each and every measurement to account for the variations in the atmospheric conditions that might occur during the measurement period.

Figure 38 – One of GRAD’s field measurement calibration lights mounted on a remote-controlled pan/tilt head, with the whole assembly clamped to Donaghadee Lighthouse (Northern Ireland) balcony handrail.

Once the measurements have been captured, they are analysed to calculate the effective intensity and the intensity at the beam peak. The software allows the user to identify flashes to analyse, and compare them to the reference light intensity (Figure 2). The results of the analysis, and any additional observations, are presented in a report to the client so that they can understand the performance of their lighthouse.

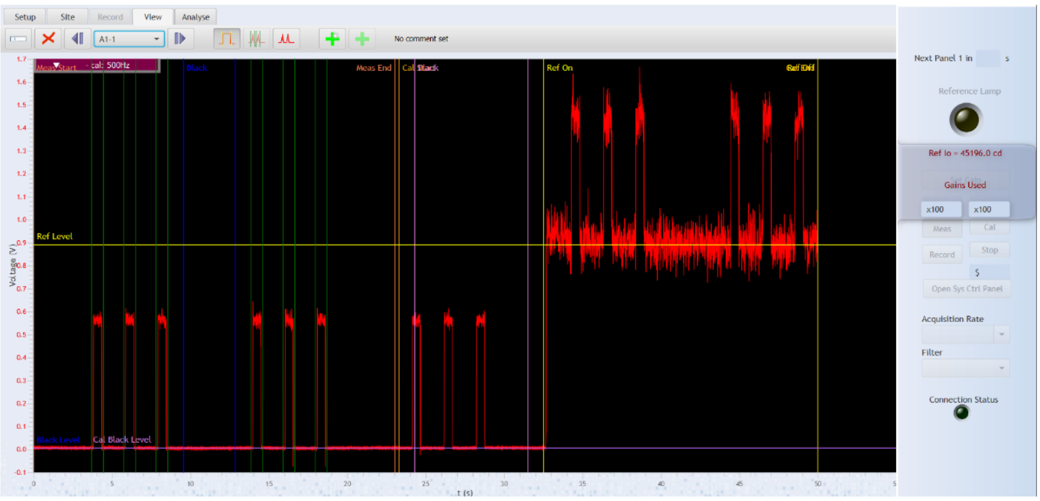


Figure 39 – Measurement analysis software showing the flashes to be analysed on the left, and the reference light intensity captured on the right.

4 UPDATED EQUIPMENT

In this section, we will consider the newer equipment that GRAD has implemented in our FMS.

4.1 Silicon Photomultiplier Sensor

The use of a photomultiplier in field measurements is not new. In fact, the GLA have been using such devices for many decades. However, traditional tube photomultipliers are fragile, require dangerously high voltages (around 1 kV or more) and specialist controlling equipment [2].

Silicon Photomultipliers (SiPM) are solid-state devices that are far more robust than the tube-based versions, and do not require a high voltage to operate [3]. The one utilised in the new FMS requires only a 5 V power supply and outputs an analogue voltage relative to the amount of light incident on the sensor [4]. One of the issues with a SiPM is the increase in dark current – the noise that is generated by the sensor, even when no light falling on it. For this reason, the SiPM incorporates a Peltier-cooling device in order to keep the sensor at a sub-ambient temperature and thus keeps the noise to an acceptably low level.

Figure 40 – The green enclosure of the new SiPM mounted on a tripod during a field light measurement at Saint Abbs Lighthouse, Scotland.

In order to use the SiPM in the field, some additional signal conditioning and physical protection is required, as well as a means to connect the sensor to the Pritchard-mirror telescope that GRAD uses. To achieve this, the SiPM fits inside a fetching custom-made luminous green 3D-printed enclosure, and the entire assembly is mounted on a tripod pointing towards the light of interest (Figure 3).

The SiPM system has been very successful, and it is so sensitive that more often than not, several neutral density filters are required to reduce the light intensity to a level that will not overload the sensor, even when measuring from several kilometers away! The sensor has now become the de facto measurement device for field measurements, with other sensors being used far more rarely now.

4.2 Portable Spectroradiometer

Until relatively recently, GRAD did not have the means to measure the spectral content of a lighthouse light in the field. However, the purchase of a portable spectroradiometer has been a great addition to the tools available in order to confirm the performance of the AtoN.

In the past, the effect of any filters used at a lighthouse had to be determined once the measurement team were back in the laboratory. The type of filter material would be determined, and with a suitable sample of the material along with a previous measurement of the light source, both the transmittance and the colour would be estimated. This result would then be used to determine the nominal range and colour of sectors at the lighthouse of interest.

Whilst this process can give a good indication of performance, it can be improved by using a spectroradiometer measurement carried out on-site. GRAD purchased a SpectraScan® PR-655 for this purpose in autumn 2019, although experiments on finding the best means of using it on-site were curtailed by the COVID pandemic.

Figure 2 demonstrates the spectroradiometer in use at Rathlin West Lighthouse (Northern Ireland) in autumn 2022. Whilst it took some time to understand how to use the device in practice, it provided a good amount of information about the colour and transmittance of the filter material. Further work will be carried out by GRAD over the next few measurement campaigns to ensure that the instrument is used in its most optimal way.

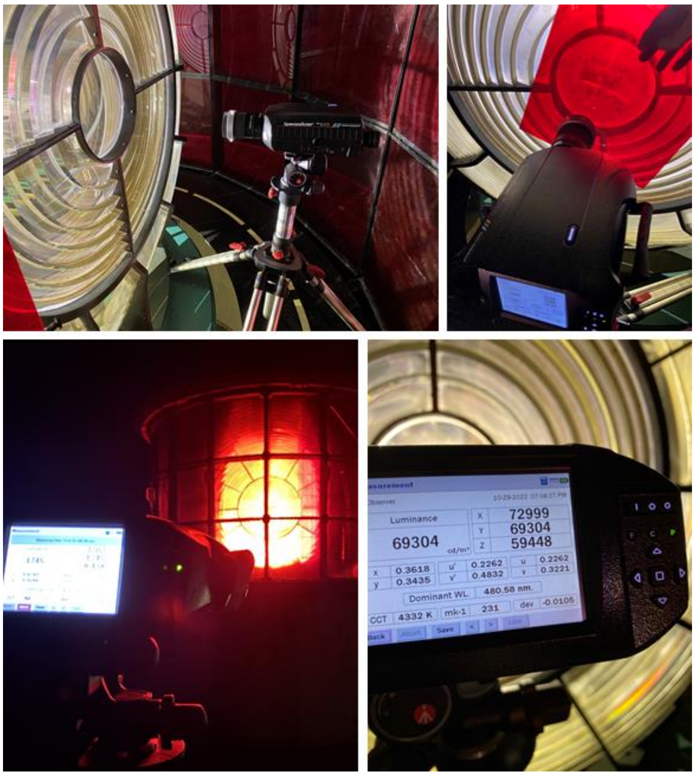


Figure 41 – Portable spectroradiometer in use. Top-left: measuring the white light through the optic. Top-right: holding some filter material to measure colour and transmittance. Bottom-left: measuring the colour outside the lighthouse. Bottom-right: typical measurement screen.

4.3 Data Capture Hardware

For many years, the measurement systems in both the light ranges and in the field have used the Agilent U2352A USB Modular Multifunction Data Acquisition device to carry out the conversion and control of analogue signals to a digital format. However, these devices are becoming more difficult to obtain, and rely on an old application-programming interface (API). The physical interfacing to the device is also very difficult, using a rather complicated connection system.

Figure 42 – The new field measurement data capture and communications unit.

It was decided that a brand-new data capture board would be designed specifically for the purpose of light measurement by GRAD. This new system was specified, procured and finally delivered in 2022. This new board allows the entire measurement system, including any remote controls, to be done through a single USB connection and a simplified, modern 64-bit API.

The new board provides some room for future expansion, which allows GRAD to use new sensors should they become available. In addition, the intention is to use the new board for the light ranges in Harwich. This would make software maintenance of the entire facility much simpler since it is all based on the modern hardware and underlying software.

4.4 Luminance Distribution Measurement

GRAD has noticed a growing trend of integrated lanterns being installed inside the lighthouse lantern room. There are reliability benefits in this approach, since it limits any weather effects on the light. However, most lantern rooms have astragals between the glazing panels, causing a reduction in the light in certain directions. Whilst this has always been the case, the light emission area from an integrated lantern is small compared to the output of traditional optics. Due to this, the impact of any astragals on the performance of the light is greater. It is possible to calculate the effect and mitigate against it. However, one aspect that is not sufficiently understood or have data available is the distribution of luminance across the face of the lantern in any given direction.

In order to collect this data, GRAD has produced a luminance capture system in their outdoor light range. This system is essentially a calibrated camera at a fixed location that will capture a 2D luminance distribution of the light emitted from the device under test.

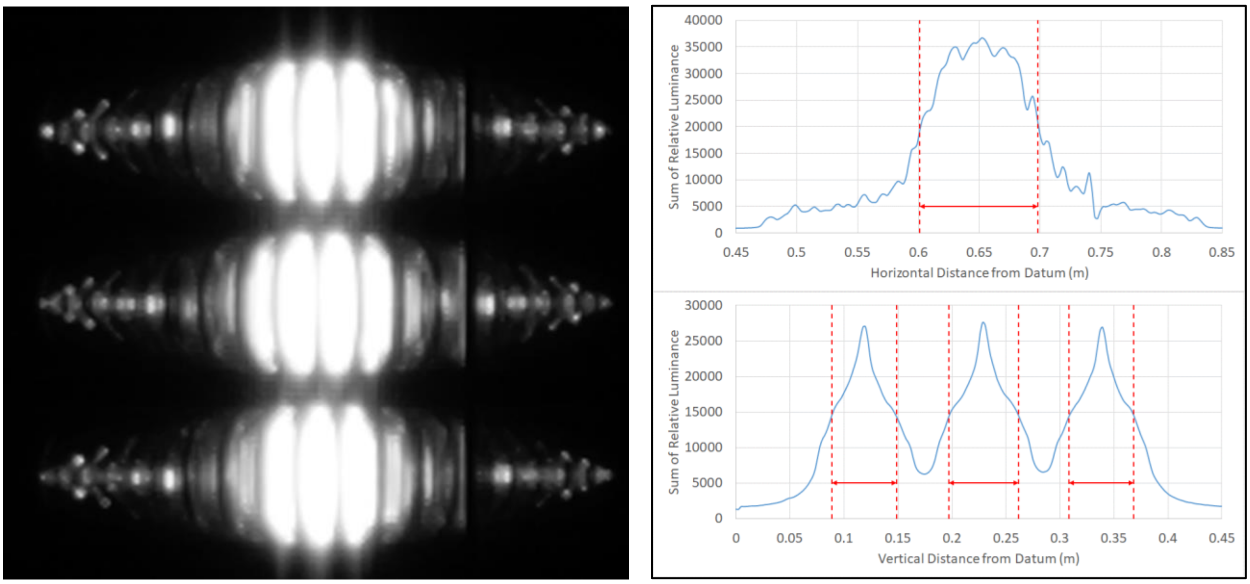


Figure 43 – The luminance distribution of a three-tier lantern (left) and rudimentary analysis of it (right).

As shown in Figure 6, the new measurement system will be able to map the luminance distribution of a lantern, which will help engineers to understand any potential obscuration due to astragals, handrails or any other obstruction between the lantern and the outside.

At the time of writing, the equipment is in the process of being commissioned and tested. In order to provide a meaningful set of data to the user, one area that is being considered is the method of reporting the measurement. A rudimentary report of the horizontal and vertical distribution of the luminance is demonstrated in Figure 6, and whilst this provides some useful information, a better method of presenting the results is needed. This will be explored further by GRAD, with the intention for it to become a standard feature of their light measurement reports.

5 FUTURE DEVELOPMENTS

There are four areas that GRAD is looking to improve the FMS, and these are briefly discussed in this section.

5.1 Reference Light Stabilisation

In the past, and to this day to some extent, the reference lights used by GRAD were based on filament lamp technology. However, the use of LEDs as reference lights are becoming more prevalent due to the lack of availability of traditional incandescent lamps. Indeed, CIE recently released Technical Report 251 on the use of LEDs as reference lights [5].

Temperature stability is an area that LEDs can be considered as being inferior to traditional lamps because their output is directly related to the semiconductor junction temperature (Figure 7), and therefore the ambient temperature through the heatsink device. Their use in the outside environment means that the LED-based reference light is subject to temperature variations, which affects the measurement uncertainty.

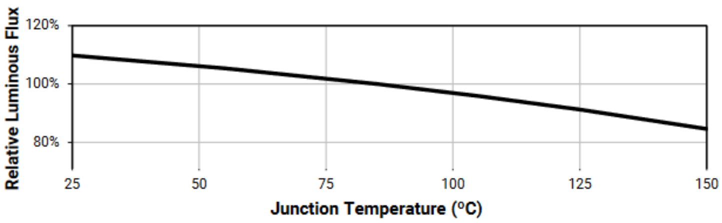


Figure 44 – Variation of LED luminous output with temperature. Modified from [6].

To overcome this, the intention is to produce a custom-built field reference light that is temperature controlled to ensure that the light intensity is sufficiently stable to allow for further reduction in the measurement uncertainty. The specification of such a device in the early stages, with a view to getting a prototype built in the next two years.

5.2 Scintillation

Scintillation is the observed variation in light intensity due to rapid and random fluctuations in the atmospheric conditions [7]. This is often seen as distant lights twinkling as the refractive index of air continuously changes, bending the light in many directions. The change in the refractive index is due to variations in air density caused by heating and cooling by the surrounding environment. The effect is greatest over water when there is a large difference between water temperature and the air temperature. The way it affects light rays is shown in Figure 8. An example of how it manifests itself is shown in Figure 2 earlier – the higher the light intensity, the higher the scintillation noise amplitude is. This differs from amplifier or sensor noise, which tends to be the same amplitude regardless of the input signal level.

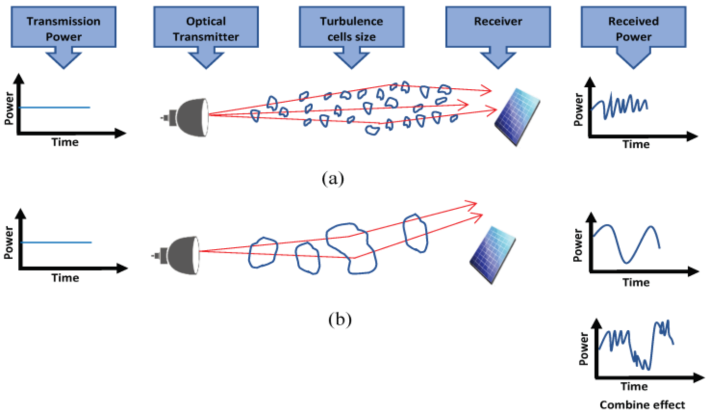


Figure 45 – Effect of atmospheric scintillation on the received optical signal. After [7].

The effect is entirely random, and is not easily removed in data post-processing. So, how can this be overcome? One answer is to increase the aperture of telescope used to collect the measured light. By increasing the aperture, more of the light beam from the source is captured, even if it has deviated from the true straight path. This is known as aperture averaging, and is a physical solution to the problem of scintillation.

Increasing the aperture obviously means that the optical system of the photodetector would need to increase in size, which for a portable system is problematic. The compromise between measurement uncertainty and a practical measurement system needs to be balanced, and this can only be determined by experimentation.

GRAD will be taking the opportunity to understand, and potentially reduce, the effect of scintillation on the measurement results, leading to a reduction in measurement uncertainty.

5.3 Beam Vertical Profile Measurements

From the very beginning, GRAD and its predecessors have been measuring the vertical profile of light beams. The main reason for this is to check the focus of the light and to determine the true intensity of the light beam.

Ideally, a measurement will be conducted at a height in line between the lighthouse light and the horizon. However, this is very difficult to achieve given the very limited number of feasible measurement locations available around a typical lighthouse. Therefore, the light beam is refracted using fixed-size prisms by a known vertical displacement, and the light intensity is recorded. Thick black curtains are normally used around the prisms to prevent the measurement being contaminated by unwanted light (see Figure 7).

Once these measurements have been made, it is possible to see the vertical distribution of the light beam, and the elevation of the measurement site relative to the optic plane. This result is used to calculate a correction value for other measurements that determine the nominal range of the light, and to make sure that the light beam is pointing in the right direction.

Different light sources tend to create different vertical distributions, so if two different light sources need to be tested, then the entire vertical beam profile measurements need to be repeated for each one. This adds considerable amount of time to the measurement.

In addition, the use of LED light sources have meant that the vertical beam profile has tended to be rather narrow, and the coarse steps with the fixed-size prisms have caused the beam peak to be missed.

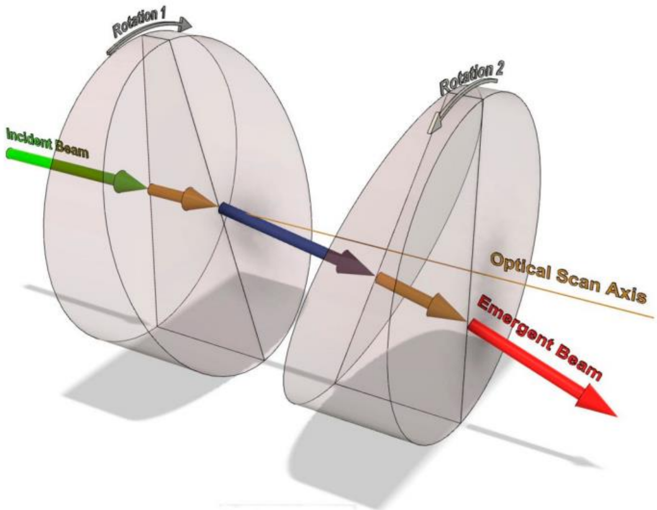


Figure 46 – Left: use of prisms to measure the light beam vertical divergence. Right: schematic of a Risley Prism arrangement and the effect on the light beam propagating through it. After [8].

To assist with overcoming these issues, GRAD will be investigating the use of Risley prisms to allow for a continuously variable refraction of the light beam. A Risley prism comprises of a pair of prisms aligned so that the light beam can be steered in any direction based on the relative orientation of the prisms [9]. By using a counter-rotating arrangement of the prisms, the light will be refracted in one plane, but not another – ideal for the measurement of vertical divergence. If the system is electronically controlled, then a measurement of the vertical profile will take a matter of minutes rather than a couple of hours.

There are a number of challenges in implementing such a system, most notably relating to keeping the physical size and weight to a minimum whilst ensuring a robust and reliable system. The intention is to develop a prototype to see how well such a system could work in the field, and if it proves successful, then a fully developed system will be implemented and used by GRAD.

5.4 Measurement Uncertainty Modelling

Since 2020, GRAD has been undertaking a complete review of their measurement uncertainty models used at their facilities. This includes the light ranges based in Harwich, as well as the field measurement equipment.

This is not a trivial task, and requires a deep understanding of the measurement process to develop the mathematical models. Once a measurement model has been created, the impact of each variable on the uncertainty of the measured quantity can be assessed and determined. This will eventually lead to a better estimation of the uncertainty of the measurement process and identify areas that can be improved.

It has already been a rather challenging task, with many aspects of the measurement procedure coming under scrutiny. For example, the telescope used in the field measurement as assumed to have a near perfect response across its aperture. However, further analysis prompted by this work showed that this was not the case. Indeed, under some circumstances, a change in size of the aperture did not make any difference. By understanding the limitations of the equipment and the impact they have on the measurement uncertainty, one is able to improve the measurement process and the service that GRAD provides.

The analysis of measurement uncertainty is a complex area that takes time and effort to understand. CIE, BIPM and other institutions publish documents to provide very useful guidance on this area [10]–[14]. Nevertheless, for the lay engineer, the subject matter can be considered impenetrable as soon as the model becomes larger than the simplest of models. GRAD is intending to make available their measurement uncertainty documents available to IALA members with the hope of providing an engineer's guide to the subject. Eventually, this should form the basis of a guideline to support the new IALA Recommendation R0203 on Terms of Measurement in the new IALA work plan.

6 CONCLUSION

GRAD is continuing its tradition of using new technology and techniques to improve their light intensity measurement capability. This paper demonstrates how far GRAD have been pushing their ability to measure lighthouse performance in real conditions, and the challenges that come with that. GRAD will continue to improve their measurement systems, and where necessary, update IALA members on progress.

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AUTHOR BIOGRAPHY

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S4.2 Development of the technology of AtoN in Korea for the 4th industrial revolution (191)

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ABSTRACT

As the 4th industrial revolution occurs, the paradigm of the future maritime environment is changing. In the Republic of Korea, in response to this trend, we are strengthening the overall capacity of Aid to Navigation (AtoN) by promoting a smartification strategy. In this regard, in the field of AtoN in the Republic of Korea, the smart AtoN, customized virtual digital AtoN service technology, and photometry technology using drones are being developed.

This is a study on the establishment of a maritime transportation infrastructure that provides new services to users with smart AtoN that are integrated with technologies such as big data and AI by collecting, integrating, and analysing maritime information. This is a study on the improvement the efficiency of the measurement process of photometric measurement technology based on image processing technology that uses drones to measure the luminance of medium/large lanterns installed in lighthouses. This is a study on provided services such as information on digital passageways and danger zones with customized virtual digital AtoN service technology that provides virtual AtoN according to the operating conditions of each ship.

As such, in this paper, we would like to introduce the smart AtoN technology being researched in the Republic of Korea.

KEYWORDS: AtoN technology, The fourth industrial revolution, Maritime safe technology, Infrastructure development

1 INTRODUCTION

With the emergence of the 4th industrial revolution, technological development is progressing briskly, with various technologies are being applied in a complex way to develop new technologies or to build systems. In the maritime sector, technological development is taking place with autonomous ship technology using technologies such as artificial intelligence, IoT, and advanced sensors, so that ships can recognize and control the situation on their own to operate safely and economically.[1] In addition, for maritime safety, various studies are being conducted, such as for AtoN intensity and equipment design, AtoN planning and service, and radio navigation service.

AtoN is navigational aid facility that informs a sailing vessel about the position/direction of the vessel and the location of obstacles by means of light/figures, etc., and provides fixed information at a physically fixed location at all times. With the development of technology, many changes are progressing in the operation of vessels on the sea. In particular, the development of electronic navigation equipment has developed as a means of improving work efficiency and reliability in various fields, ranging from safe navigation, marine environment, and maritime logistics. AtoN induce safe navigation with traditional visual expressions such as characteristics of figures for daytime and light for night-time. However, visual perception is limited due to natural environmental factors. To overcome this problem, three studies are being conducted in the Republic of Korea.

First, by analysing the problems of existing AtoN and the needs in the field, we are developing a multi-purpose platform-based smart AtoN facility that can respond to various maritime environments. The goal is to develop a stable high-capacity power supply system and to secure an efficient maintenance support system. Additionally, we are developing an integrated platform for information collection and operation to provide various services. We are developing an optimal communication system between the vessels, the land network environments, and the smart AtoN. As such, by applying a new service based on smart AtoN, we aim to actualise AtoN advancements that are suitable for the future maritime environment.

Second, in the case of a lantern, as one of the equipment for used for AtoN, the standards such as brightness and chromaticity must be satisfied before installation or use.[2][3] Therefore, before installation or use, it is necessary to have an inspection to ensure that the lamp used has meet the criteria. In addition, since there is a problem of performance that deteriorates over time, the inspection should be performed periodically. Small-size lanterns are easy to be attached and detached, so they can be inspected indoors (dark rooms). However, medium-size and large-size lanterns that are difficult to be attached and detached must be measured directly on the spot. In particular, medium-size and large-size lanterns located in areas where it is difficult for people to access would be difficult to be measured on land, so they need to be inspected using measurement lines. The use of measurement lines may lead to cost problems, safety problems, and measurement errors. To solve this problem, we are developing a measurement system using drones (unmanned aerial devices).

Third, with the development of maritime ICT and the introduction of e-Navigation and autonomous vessels, the types and scope of maritime communication networks are expanding. Although the need for digital AtoN services is increasing, digital AtoN service is only at the level of virtual AtoN service using Automatic Identification System(AIS).[4] Therefore, it is necessary to develop a digital AtoN service to systematically and continuously provide digital AtoN information. In the Republic of Korea, customized virtual digital AtoN services are being developed to help prevent marine accidents, by providing electronic information on AtoN and inducing safe navigation.

2 THE ADVANCEMENT OF SMART AIDS TO NAVIGATION FACILITIES

In addition to the existing AtoN technology and its role, smart AtoN facility that enables the collection and mutual sharing of digital marine information converged with ICT technology must be developed. To make the existing AtoN smart, it is necessary to find solutions for on-site difficulties in power management, multi-communication support, on-site self-diagnosis, and response to new services.

The contents and schedule of smart AtoN research are displayed on Figure 1. This research is a 5-year project from 2021 to 2025. Currently, in this 2023, the 3rd year task is being carried out. The basic design was carried out in the 1st year. In the 2nd and 3rd years, the research is being conducted on the implementation of smart AtoN and the verification of the basic function. Later in the 4th and 5th years, we plan to implement and optimize the system integration and linkage for the advancement of smart AtoN.

	1st Year	2nd Year	3rd Year	4th Year	5th Year
Target by Year	Basic design	Implementation & basic function testing		On-site advancement and optimization	
Final goal	Advancement of smart aids to navigation facilities				
	Integrated platform implementation			AtoN prototype demonstration	
Annual goal	Element technology analysis and system basic design for smart AtoN advancement stage	Element technology analysis for smart AtoN marking advancement and system basic design stage	Structural and platform implementation for smart AtoN advancement stage	System integration and linkage for smart AtoN enhancement implementation and advancement stage	Integrated system working performance for smart AtoN advancement evaluation and optimization stage
Technical item					
Next-generation power supply and management technology for AtoN	Deriving AtoN power system specifications and design of eco-friendly energy collection/power management/battery system structures	AtoN power management and battery system module design and development of eco-friendly energy collection technology	Implementation of eco-friendly energy collection technology for AtoN power management and implementation of battery system modules	Verification and performance enhancement of the integrated power system for AtoN	Optimization and verification of the entire system of smart AtoN
Multi-purpose and scalable platform design technology	Analysis of requirements and system specifications for multi-purpose platform design	Management system and intelligent fault diagnosis technology design for multi-purpose platform operation	Implementation of integrated system for multi-purpose platform operation and verification of intelligent fault diagnosis technology	Verification of multi-purpose platform system integration and empirical-based advancement in the actual sea area	Establishment of an integrated system through actual sea area connection and demonstration of multi-purpose platform
Next-generation AtoN (medium-to-large light buoy, etc.) design technology	Analysis of AtoN installation status and related technical needs in the actual sea area	Detailed design of AtoN inspection and facility linkage technology	Implementation of integrated system for multi-purpose platform operation and verification of intelligent fault diagnosis technology	Test of actual sea area linkage of AtoN inspection and facility linkage technology	Stabilization of actual sea area verification base for navigation aid inspection and facility linkage technology
Development of optimum communication device for smart AtoN	Basic analysis for maritime safety, vessel, information security, and future communication network linkage	Technical design for maritime safety, vessel, information security, and future communication network link	Implementation of marine safety, vessel communication, information security, and future communication technology specification	Demonstration of marine safety, vessel, communication, information security, and the future communication technology structure advancement	Optimization, based on marine safety, vessels, and communication demonstration Information security and future communication connection operation plan presented
Development and demonstration of optimum communication network for smart AtoN	Basic design of optimum communication system for smart AtoN and network environment study	Optimum communication system structure design for smart AtoN and actual sea network environment analysis	Optimum implementation and verification of communication system base station/terminal function for smart AtoN	Production of optimum communication system terminal module for smart AtoN and establishment of real sea area network	Optimization of actual sea area network through demonstration of optimal communication system for smart navigation aids

Figure 1: Development Plan (2021-2025)

As shown in Figure 2, currently, we have designed two models of medium-size light buoys that can apply next-generation power supply and management technology for AtoN and multi-purpose platform design technology that is easy to be expanded. In addition, the stability for the two designs was evaluated through hydrodynamic analysis such as metacenter (resilience), draught, and dynamic motion analysis. Later, the proposals for the two designs will be evaluated once more to compare the stability with the existing standard light buoy.

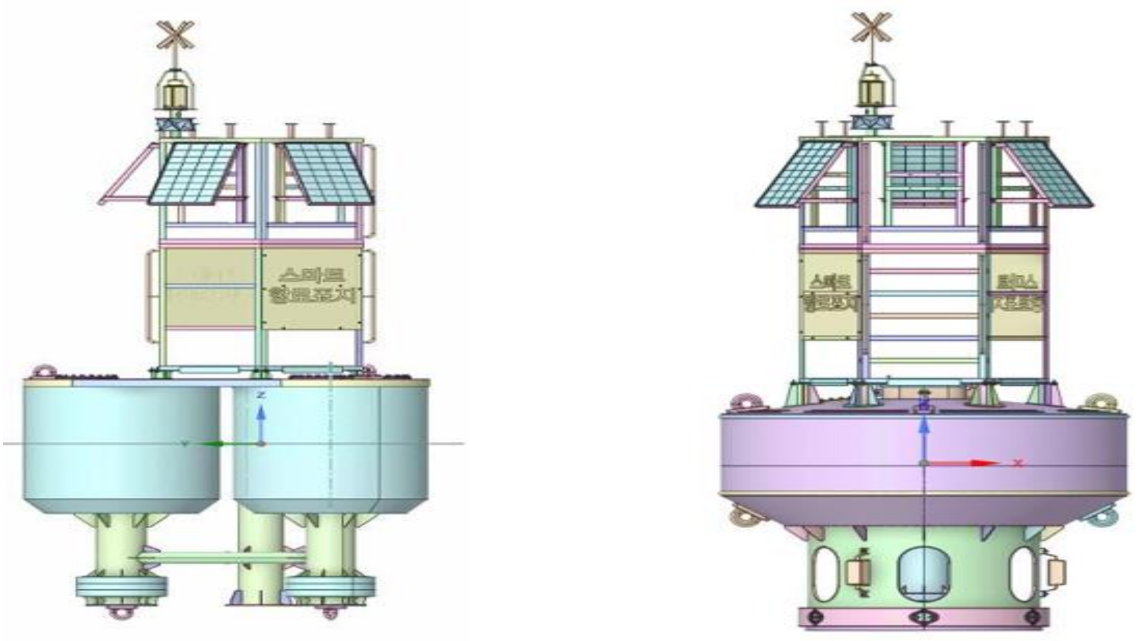

Figure 2: Light Buoy (Medium Class)

3 DEVELOPMENT OF THE DRONE-BASED ATON PHOTOMETRY EQUIPMENT

This research is a three-year project from 2022 to 2024, and currently the 2nd year task is being carried out. The goal of this study is to utilize the existing measurement lines as shown in Figure 3, that is to improve the inspection system to an inspection system utilizing drones. Therefore, drones that area equipped with inspection equipment and a program that can analyse luminance are being developed.

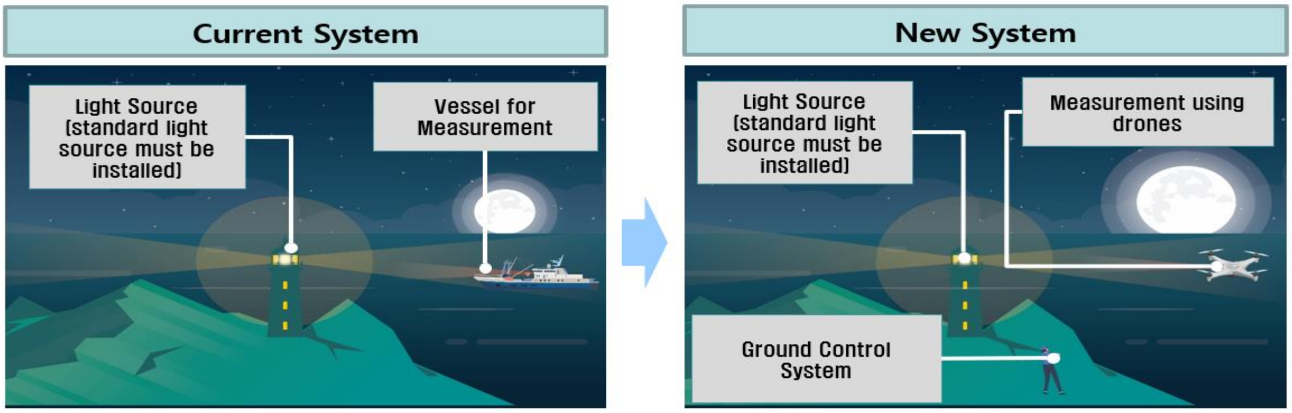

Figure 3: System Configuration

The luminance analysis algorithm has been designed based on the research conducted up to this date, and a simulator has also been developed based on the designed algorithm. The luminance analysis algorithm is as shown in Figure 4.

The current algorithm uses still images (raw file) as input data. Dark current correction, uniformity correction, and linearity correction are performed on the input still images to remove the noise from the digital camera used. The Y value corresponding to luminance can be obtained from the corrected data through XYZ conversion.

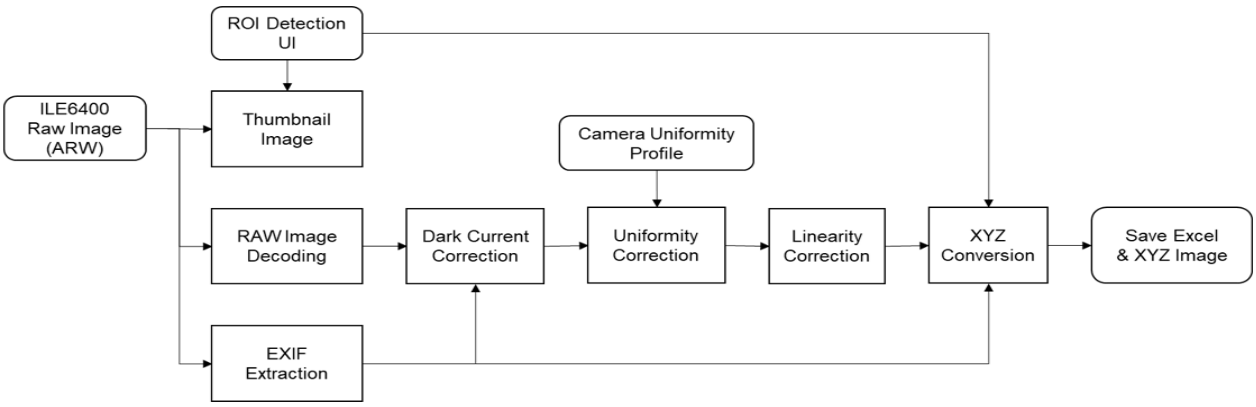

Figure 4: Luminance Analysis Algorithm

The performance of the luminance analysis algorithm was compared with the results measured at the same position and angle with Minolta CS-1000 as plane luminance meter equipment. As a result, it was confirmed that there was an average error of 2.58% for luminance of 24 natural colours, and an average error of 0.74% for the grey colour. In the case of white colour, it was measured at a level similar to that of a specialty plane luminance meter. With this, it is judged that there is no problem in measuring the luminance value of the white lantern.

Based on the algorithm, a simulator has been created. The screen of the simulator is as shown in Figure 5. If you select the area you want to analyse in the still image, then the maximum value, minimum value, and average value of the area would be derived. Currently, we are designing an algorithm that can be analysed based on video, in consideration of the characteristics of a rotating lantern. Efforts are also being made to reduce the analysis errors.

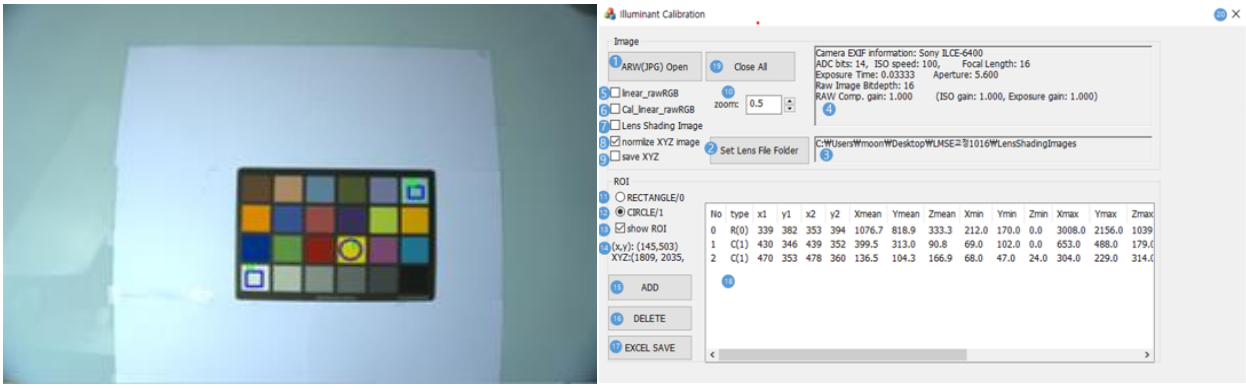

Figure 5: Luminance Analysis Simulator

In addition, drones equipped with cameras that can analyze luminance are being manufactured. It includes a system that automatically flies to the destination, shoots photos or videos, and returns, using the ground control system for convenient operation from the user's point of view. Currently, the ground control system and drone aircraft have been manufactured. The design and production are in progress to mount camera equipment used for inspection.

4 DEVELOPMENT OF CUSTOMIZED VIRTUAL DIGITAL ATON SERVICES

Virtual AtoN is a mark that does not exist physically, but it is used to display the AtoN on a navigation system through virtual signal transmission. Its scope is defined as any digital item or group of things that can be handled or manipulated by computers, regardless of the type or format, to inform sailors about safe routes, precautions, dangerous sea areas, etc.

In this research, the basic algorithm for service provision is designed, and the prototype is implemented to evaluate the effectiveness of the services, such as provision of variable passage routes according to vessel specifications, dynamic passage changes due to accidents and construction in ports, etc. Furthermore, a virtual AtoN management system that can be used as an alternative means in case of failure or trouble is being developed.

Figure 6: Customized Virtual Digital AtoN Service Program

The prototype produced through this research offers three kinds of services.

The first service is the digital passageway service. This is a function that provides digital information to autonomous vessels and all vessels in general about the space that can be navigated. This function allows temporary marking on deep-sea routes that are physically difficult to install. The information provided in the form of branch on the existing general passageways is shown as spatially perceptible digital information.

The second service is the variable passageway service. In the event of a temporary change in operating factors due to a vessel accident in the passageway or deterioration of the marine environment, etc., a virtual navigational aid within the passageway is generated to induce the safe navigation of the operating vessels. Additionally, a virtual AtoN for separation of passageways is created and provided in consideration of the specifications of the incoming and outgoing vessels.

The third service is the guidance service for dangerous passageway areas. This is a function to prevent vessel accidents by creating virtual AtoN for vessels operating in areas with a lot of crossings and in areas where accidents frequently occur.

The customized digital AtoN prototype system with the above functions was designed in the form of a server that generates digital AtoN information and a terminal that displays information on an electronic chart-based screen.

5 CONCLUSION

In this paper, three projects that Republic of Korea is promoting for the technological development of the future marine environment were introduced. By analysing the problems of AtoN and the needs in the field, we are developing a multi-purpose platform-based smart AtoN facility that can respond to various maritime environments. Additionally, research on photometric inspection system using drones is being done to improve the medium-size and large-size lantern photometric inspection system for AtoN equipment. Finally, a customized virtual digital AtoN service is being developed to provide safe navigation for sailors, and plans are being prepared for the service delivery.

As such, the Republic Korea is continuing to do research on smart and new technologies, in line with the era of the 4th industrial revolution.

6 ACKNOWLEDGEMENTS

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S4.3 Small Size Detector for Beacon Lights (038)

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ABSTRACT

Beacon lights are important visual AtoN. As time flows, the luminous intensity and range, color of Beacon lights would change. In this case, bringing the lights to detectors is necessary. However, the detectors are large and expensive, comprehensive for most on-spot staff, so, generally AtoN sector would not equipped with such detectors. The other way, also the most generally used in China, was taking the lights to professional institute, which is costly and time-consuming. Then, research on small size detector for Beacon lights provides a possible solution to conveniently exam the lights' luminous intensity and range, color.

This detector would combine hardware and software, following IALA's R0108, R0202, etc., is designed to measure the Beacon lights luminous intensity and range, color by putting lights into the dark chamber and in a short time, displaying the outcome on the detector's screen. The aim of this research is to help AtoN authorities or users to save time and money of detecting Beacon lights after it used by certain period.

(No paper submitted)

AUTHOR BIOGRAPHY

JunBo Wang has been joined in Aids to Navigation Section for 27 years from 1996, while graduated with Engineering bachelor degree. Now he is senior engineer, as well General Secretary and Deputy Director of NingBo AtoN, whose jurisdiction covers NingBo-ZhouShan port, which ranks Global Top1 throughout for 12 years.

Ranxuan Ke is PhD on Management Science and Prof. with long term research on Technology application on AtoN. She was offered Lever-1 AtoN manager certificate from IALA in Aug. 2015 and after that, engaged in ARM committee. Later from 2020, she also participates in ENG committee.

S4.4 Research on new multifunctional intelligent navigation aids (022)

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ABSTRACT

Racon and AIS are commonly used in navigation engineering. The department using aids to navigation often needs to use navigation light, AIS, Beidou telemetry terminal and Racon at the same time. These four kinds of equipment are independent products, which have complex structure, unstable signal and difficult maintenance. In order to adapt to the development of Aids to navigation in the direction of multi-function and intelligence, aiming at the problems of Aids to navigation with single function, isolation of a variety of equipment and insufficient energy supply. loading the AIS, Racon and Beidou module on the navigation light, it can sense the nearby large ships, adjust the light intensity adaptively, and form the interconnection of multi-source data of intelligent navigation light. This paper introduces the research and application of a new multifunctional intelligent navigation aids. Through the analysis and comparison of the current situation of the existing equipment, relevant suggestions are put forward for the application of intelligent navigation aids. The integrated new multifunctional intelligent navigation aids can greatly reduce energy consumption, prolong the life of navigation lights, reduce light pollution, meet the needs of all kinds of ships in navigation, and also provide a research direction for new forms of navigation aids in the future.

KEYWORDS: Aid to navigation, Racon, AI, BeiDou, Integration, Suggestions

1 INTRODUCTION

Radar responders and AIS navigation aids are commonly used radio navigation aids. When the radar responder interacts with the radar on the ship, it forms an auxiliary navigation aid system. AIS navigation aids, which work together with shore based facilities and onboard equipment, have the functions of identifying ships, helping to track targets, simplifying and promoting information exchange, and are a new type of digital navigation aid system.

The navigation mark using department needs to simultaneously apply four types of equipment, namely, navigation mark light, AIS navigation mark, Beidou telemetry terminal, and Leikang, at a single mark position. In actual use, these devices come from different manufacturers and are independent products. Each device has a power cable, transmitting antenna, and signal interface, and using them simultaneously can complicate the structure of the installation platform. The information transmission of each equipment is self-contained, which is not only inconvenient for maintenance and management, but also makes navigators have to face the information interfaces of various equipment, reducing the efficiency of navigation assistance services. Therefore, integrating the functions of radar transponders and AIS navigation aids while integrating them into the Beidou module to form integrated integrated equipment. The author believes that simplifying navigation aids, strengthening shipping supervision, and providing support for intelligent maritime and navigation construction will also become a need for the development of navigation aids technology in the future.

2 CURRENT SITUATION OF DOMESTIC EQUIPMENT

2.1 Radar responder

The working principle of a radar responder is as follows: After the signal transmitted by the interrogation radar is received by the RACON antenna, it is sent to the receiver for signal processing. Then, the transmitter transmits a group of coded and modulated response signals to the interrogation radar, with the same frequency as the interrogation radar. After this signal is received by the interrogation radar, the specific coded signal of the beacon is displayed on its screen corresponding to the azimuth distance of the beacon ［1］。 Currently, the main product models of radar responders in China are shown in Table 1.

Table 1 Main models of HY Racon

Order number	Model	Wave band
1	HY-II-X	X-band radar responder
2	HY-II-X/S	X/S dual band radar responder
3	HY-II-F	X-band split type radar responder
4	HY-II-Y	X-band telemetry and telecontrol radar responder

X-band frequency in the table: 9300~9500 MHz; S-band frequency: 2900~3100MHz. X-band horizontal polarization; S-band vertical and horizontal polarization; Side lobe suppression: Advanced SLS; Acceptance sensitivity: - 50dBm; The size of HY radar responder is 270mm in diameter, 450mm in height, and weighs about 7kg.

2.2 AIS

Automatic Identification System (AIS) is a kind of ship navigation equipment, which is composed of AIS navigation aids, AIS shipway, AIS shore station, electronic chart, airborne AIS, AIS base station, etc ［2］。 The AIS system relationship is shown in Figure 1.

AIS navigation aids can be divided into virtual navigation aids generated by AIS shore station transmission signals and AIS physical navigation aids generated by physical AIS navigation aids transmission signals ［3］。 AIS physical navigation aids are actually installed with AIS transponders on a physical navigation aid. These AIS navigation aids also have the function of navigation aid telemetry, enabling timely understanding of the working status of the navigation aid in the sea area center ［4］。 At the same time, AIS navigation mark telemetry and telecontrol system can monitor the working current, working voltage, switch status, and other functions of the navigation aids equipment in real time, facilitating the management and maintenance of the navigation aids management department.

Figure 47: AIS system diagram

Currently, there are many manufacturers producing AIS physical navigation aids in China, with mature technologies. Taking an AIS navigation mark communication management terminal as an example, the main technical indicators are shown in Table 2.

Table 2 Main technical indexes of AIS terminal

Order number	Project	Target
1	Working mode	Mode 3 (RATDMA)
2	working frequency	161.975MHz、162.025MHz
3	Frequency error	±0.5kHz
4	Transmit power	6W
5	Acceptance sensitivity	≤-110dBm
6	Power supply adaptation range	9—36V DC
7	Average power consumption	Continuous operation mode 1W
8	working temperature	-20℃～+60℃
9	size	500mm high × Width 175mm × 60mm thick
10	weight	≤1.5 ㎏

2.3 Beidou navigation system

The basic components of Beidou system include: space segment, ground control segment, and user segment. Currently, Beidou telemetry and telecontrol terminals produced by domestic manufacturers send real-time operating parameters and position parameters of the beacon lighters to the beacon management center through Beidou short messages. The product shell is made of PVC material and is fully sealed to adapt to harsh weather conditions at sea.

The Beidou terminal uses Beidou communication satellite data communication, which has the characteristics of long communication distance ,low electromagnetic interference from the environment ,high positioning accuracy and reliability.

2.4 Light

A light is a type of traffic light installed on certain navigational aids, which emits a specified light color and flash frequency (frequency can be 0) at night, reaching a specified illumination angle and visibility distance, and guiding ships traveling at night.

3 CURRENT SITUATION OF FOREIGN EQUIPMENT

3.1 EU radar responder equipment

Several models of radar responder equipment commonly used in EU countries include HEKLEO-SX, ITR04EX, and SeaWatch 300.

Among the three devices, HEKLEO-SX frequency range: X-band frequency:9300~9500 MHz; S-band frequency: 2900~3100MHz. X-band horizontal polarization; S-band vertical and horizontal polarization; Acceptance sensitivity: X-band: - 40dBm, S-band: - 35dBm; The size of the radar responder is 280mm in diameter, 740mm in height, and weighs about 9kg. Integral polyethylene cover.

ITR04EX frequency range: X-band frequency: 9300~9500MHz; S-band frequency:2900~3100MHz. X-band horizontal polarization; S-band vertical and horizontal polarization; Sidelobe suppression: X and S bands are independent; Acceptance sensitivity: - 72dBm; Radar responder size 246 × two hundred and seventy × 734mm, weighing about 30kg. The housing is made of 316 stainless steel and an impact resistant composite antenna.

SeaWatch 300 frequency range: X-band frequency: 9300~9500MHz. Acceptance sensitivity: X-band: - 40dBm, S-band: - 35dBm; The size of the radar responder is 379 X 268 X 856 mm, weighs about 16 kg, and is equipped with a handle of 18.3 kg; Antenna split type, light shell movement 4.5kg

3.2 British radar responder equipment

PHalcon 2000 frequency range: X-band frequency: 9300~9500MHz; S-band frequency: 2900~3100MHz. X-band horizontal polarization; S-band vertical and horizontal polarization; Side lobe suppression: X and S; Acceptance sensitivity: - 40dBm; The radar responder has a diameter of 350mm, a height of 705mm, and a weight of about 20kg

3.3 US radar responder equipment

SeaBeacon 2 System 6 frequency range: X-band frequency: 9300~9500MHz; S-band frequency: 2900~3100MHz. X-band horizontal polarization; S-band vertical and horizontal polarization; Side lobe suppression: X and S; Acceptance sensitivity: - 50dBm; The radar responder has a diameter of about 353mm and a height of 807mm (dimensions vary with different configurations), and weighs about 13.6kg.

4 COMPARATIVE STUDY OF DOMESTIC AND FOREIGN EQUIPMENT

Currently, due to unified international standards, the technical indicators of domestic and foreign radar responder equipment are basically the same. Compared with foreign products, domestic equipment has the following problems:

1） The radome of foreign products is made of molds, and the seat is made of aluminum alloy or stainless steel. Domestically produced radomes and seats are made of fiberglass reinforced plastic, which is relatively rough in processing and not aesthetically pleasing in appearance ［5］

2） The sealing design of the equipment is not standardized enough, resulting insealing strip failure

3） The sealing at the inner interface of the cable is coated with silicone, which is not beautiful enough

4） The closing screw is too close to the seat, and the wrench operation space is too small, which can easily damage the seat

5） The shielding method uses a metal film attached to the inner wall of the seat, which has poor workmanship and affects aesthetics

6） The circuit design process needs to be updated

7） The domestic radar responder has a short range and weak signal strength

8） The display clarity of domestic radar signals is low

9） Foreign products have fault alarm and radar blanking functions, power interface with grounding, and data interface for setting and communication. Domestic products do not have the above functions temporarily.

5 RECOMMENDATIONS FOR THE APPLICATION OF E AIDS TO NAVIGATION

The radar responder can automatically send an answer signal to the "inquiry" signal sent by the ship's radar, and the signal carries a specific navigation mark identification code [6]。 AIS Aids to Navigation and Beidou

Telemetry Terminals can transmit various information such as Aids to Navigation status and Aids to Navigation position.

The new integrated multifunctional E navigation mark product can adopt a comprehensive equipment design method, combining the structure, data information management, and control of the four functional equipment, making the four equipment become a single device. In terms of management and control, unify the management of working state detection, signal acquisition, and signal transmission; Structurally, the design uses a rack and a housing to assemble all equipment components, eliminating the need for repetitive external cables and multiple housing installations. Realize the sharing of data and information between modules on the premise of ensuring the independent and reliable operation of each functional module.

The integrated E navigation mark can be set up with a computer master control unit to uniformly manage the working status settings and changes of each functional part, uniformly manage external contacts, and ensure that the work of the four functional parts is independent; Adopt a cable input and internal multi-channel distribution management. Ensure that all functional parts work normally and that power supply does not affect each other; Unified collection and storage of information, centralized storage of data from various functional parts, and transmission through AIS or Beidou according to instructions ［7］。 The integrated function diagram is shown in Figure 2.

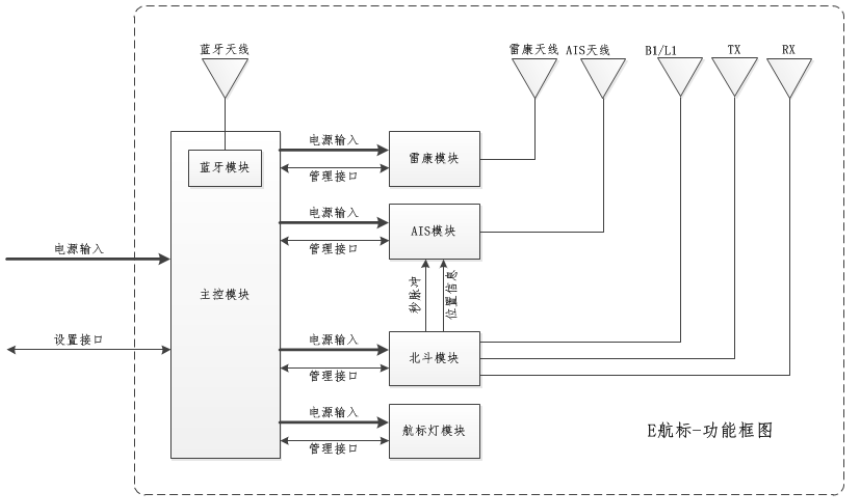

Figure 2 Function block diagram of integrated E-navigation

The advantages of integrated E navigation aids compared to existing products are reflected in: 1. The radar responder, AIS navigation aids, Beidou telemetry and remote control equipment and antennas are integrated in the same enclosure; 2. No interference between devices; 3. No external antenna wiring measures are required to eliminate potential wiring problems; 4. Single or dual power options provide additional redundancy ; 5. Loading AIS, radar responder, and Beidou module onto the navigation light can sense large ships nearby, adaptively adjust the light intensity, and form the interconnection of multi-source data for intelligent navigation lights, while also saving energy consumption.

6 CONCLUSION

Beidou, AIS navigation aids, radar responders, and beacon lights have all been promoted and used, and the products are relatively mature. Therefore, radar responders based on AIS and Beidou satellite navigation systems are technically feasible. Integrate electronic navigation aids with several functions,One chassis, unified control, sending multiple navigational aids information, can be convenient for user management, convenient for navigators to use. It will be popular with users in the market. The design of a new multifunctional intelligent navigation mark breaks the limitations of the original function dispersion, providing new ways and ideas for the development and research of new navigation mark technologies in the future.

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AUTHOR BIOGRAPHY

Wei Jiang has a master’s degree in Engineering information. Since 2009 she has been in engineering, designing and researching of aids to navigation. She has been engaged in the design and aids to navigation engineering System in CCCC Shanghai Waterway Engineering Design and Consulting Co., Ltd for 14 years. The project she participated in has won the medal of China's national design. She also participated in the preparation of many Chinese national standards.

S4.5 LED light sources in historic headlight and beacon lenses – feedback and follow-up (181)

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ABSTRACT

Before the emergence of LED light sources in French marine aids to navigation (AtoN), two light source technologies were used: halogen lamps (HLD) and metal halide lamps (HM). In 2005 and 2009, two calls for tenders allowed the development of the first generation of LED light sources for the optics of French AtoN: they were called monoDELs, DELV1 and DELV2. Their deployment has made it possible to stop the use of HLD lamps, to improve the service life (10 years against 6 months) and to divide by three the power consumption. But not to replace the HM lamps.

From 15 years of feedback we can say about LED that:

- They are suitable for the majority of applications and simple to implement;
- They are economical and reliable (energy consumption and service life);
- Systems are repairable quickly;
- They enable the preservation of historic Fresnel lenses.

Today, they equip the majority of lights with a range higher than ten miles. For lower range industrial lanterns are mainly used. However, some reservations:

- They need special manufacturing and long and complex development;
- Some of them are less suitable for sector lights;
- Some electronic components quickly become obsolete;
- Repairability could be improved.

In France, after 10 years of service, it is now necessary to replace them. Taking all that in account, a new call of tender had been launched. It has been won by MSM, an IALA industrial member. Work began in early 2023 and is expected to result in the manufacturing of more than 1,000 light sources expected next year.

KEYWORDS: Light sources – LED – Historical lenses – Feedback

RESUMEN DEL ARTICULO

Antes de la aparición de las fuentes de luz LED en las ayudas a la navegación francesas, se utilizaban dos tecnologías de fuentes de luz: lámparas halógenas (HLD) y lámparas de halogenuros metálicos (HM). En 2005 y 2009, dos licitaciones permitieron el desarrollo de la primera generación de fuentes de luz LED para la óptica de ayudas a la navegación: monoDELs, DELV1 y DELV2. Su implantación ha permitido dejar de utilizar fuentes de luz HLD, mejorar la vida útil (10 años frente a 6 meses), dividir por tres el consumo eléctrico, pero sin poder sustituir las lámparas HM.

Con 15 años de comentarios:

- Son adecuados para la mayoría de las aplicaciones y son simples de implementar;
- Son económicos y confiables (consumo de energía y vida útil);
- Los sistemas se pueden reparar rápidamente;
- Permiten la conservación de lentes Fresnel históricas.

Hoy en día, equipan la mayoría de los AtoN con un rango nominal superior 10 M. El resto está equipado con equipamiento industriales.

Algunas advertencias:

- Requieren fabricación especial y desarrollo largo y complejo;
- Algunos de ellos son menos adecuados para luces de sector;
- Algunos componentes electrónicos se vuelven obsoletos rápidamente;
- La reparabilidad podría mejorarse.

Después de 10 años de servicio, ahora es necesario reemplazarlos. Estos comentarios se incorporaron a una nueva licitación ganada por MSM, un miembro industrial de IALA. El trabajo comenzó a principios de 2023 y debería dar lugar a la fabricación de más de 1.000 fuentes de luz a partir de 2024.

PALABRAS CLAVE: Fuentes de luz – LED – Lentes históricas – Comentarios

RESUME DE L'ARTICLE

Avant l'émergence des sources lumineuses à DEL dans les aides à la navigation françaises, deux technologies de sources lumineuses étaient utilisées : les lampes halogènes longues durées (HLD) et les lampes aux halogénures métalliques (HM).

En 2005 et 2009, deux marchés ont permis de developper les premières génération de sources lumineuses à DEL destinées aux optiques des aides à la navigation: les monodel, les bidel, les DELV1 et DELV2.

Leur déploiement a permis d'arrêter l'utilisation des lampes HLD, d'améliorer la durée de vie (10 ans contre 6 mois), diviser par trois la consommation électrique, sans pouvoir remplacer les lampes HM.

Avec un retour d'expérience de 15 ans :

- Elles sont adaptées à la majorité des applications et simples à mettre en oeuvre ;
- Sont économiques et fiables (consommation électrique et durée de vie) ;
- Sont dépannables rapidement ;
- Permettent de conserver les lentilles de Fresnel historiques.

Aujourd'hui, elles équipent la majorité des feux de portées supérieurs à dix miles. Le reste est équipé de fanaux industriels.

Quelques réserves :

- Fabrication spéciale et mise au point longue et complexe ;
- Moins bonne adaptation de certaines sources lumineuses dans les feux à secteurs ;
- Obsolescence des composants électroniques ;
- Réparabilité à améliorer.

Ces remarques ont été intégré à un nouveau cahier des charges pour un marché de renouvellement remporté par la société MSM, member industriel de l'AISM

Le travail de mise au point a commencé début 2023, pour aboutir à la fabrication de plus de 1000 sources lumineuses à partir de 2024.

MOTS CLÉS : Sources lumineuses – DEL – Lentilles historiques – Retour d'expérience

1 INTRODUCTION

France has a large number of Fresnel lenses still used in aids to navigation (AtoN). Unalterable, historic, large and made of polished glass, they retain their unrivalled optical qualities, allowing light to be concentrated and seeing far away, even in bad weather. It is therefore important to preserve them.

The way in which light is produced has evolved over time towards ever greater efficiency. Today, the use of LEDs is the modern way of producing light. More reliable, more efficient, more economical, this is the technology chosen by France for the lamps used in most of the Fresnel lenses of its AtoN.

The use of LEDs in historical optics requires specific technical adaptations and special manufacturing.The objective of this article is to present the feedback from France on the use of LED light sources in existing Fresnel lenses since 2005.This feedback was used to draw up the specifications for the renewal of the range planned for 2023 - 2024.

2 HISTORICAL REMINDERS AND CONTEXT

Prior to the introduction of LED light sources in marine AtoN, two light source technologies were used: long-life halogen lamps (HLD) and metal halide lamps (HM).

- Long-life halogen lamps (HLD), manufactured especially for lighthouses and beacons, with a light output of 20 lm/W and a lifetime of 6 months, were particularly intended for use in rhythmic lights. About 800 such light sources were installed and are not yet used today.
- Metal halide (MH) lamps, more commonly manufactured and available from several suppliers, with a light output of 110 lm/W and a life of 2-3 years, are still in use today and are only used for rotating lights. The technological impossibility of putting them back into service when they are hot prohibits their use on rhythmic lights. About a hundred sources are concerned.

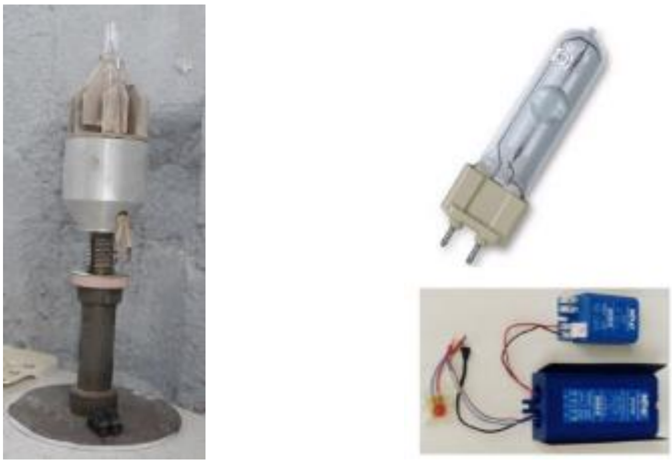

Figure 1: HLD (left) and MH (right) light sources

Based on an idea from the French administration of lighthouses and beacons, a first tender was signed in 2005 to manufacture the first generation of LED sources for short-range AtoN: the monoDELs.

Figure 2: MonoLED Light Source

This development has been a success. It allowed all the small filament light sources to be replaced by more modern and less expensive LED light sources. Based on this success, it was decided to develop more powerful LED sources to replace the remaining halogen sources.

In 2009, a new call for tenders resulted in the development of a second generation of sources for medium and high range AtoN: DELV1 and DELV2.

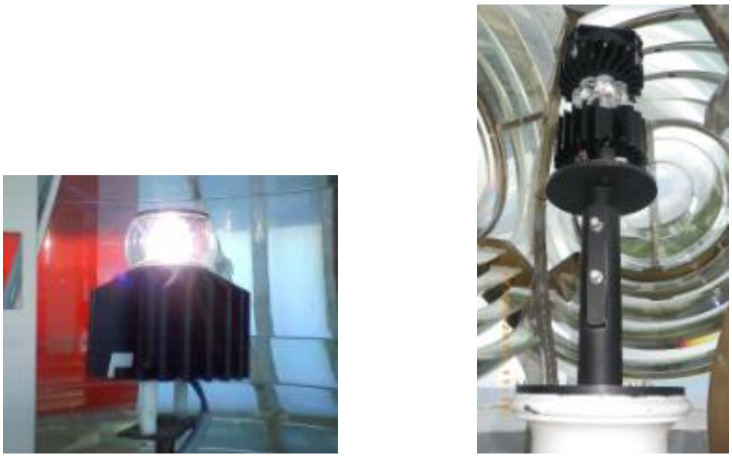

Figure 3: LED 1 (left) and DELV2 (right) light sources

The 3 types of lights sources supplied, monoDEL, DELV1 and DELV2, has made it possible to:

- Eliminate the use of HLD lamps (except for some sector lights);
- Improve productivity
  - With a twenty-fold increase in lifetime (10 years compared to 6 months for HLDs);
  - A threefold reduction in electricity consumption, with high light output (60 lm/W);
- But still insufficient to consider replacing HM lamps.

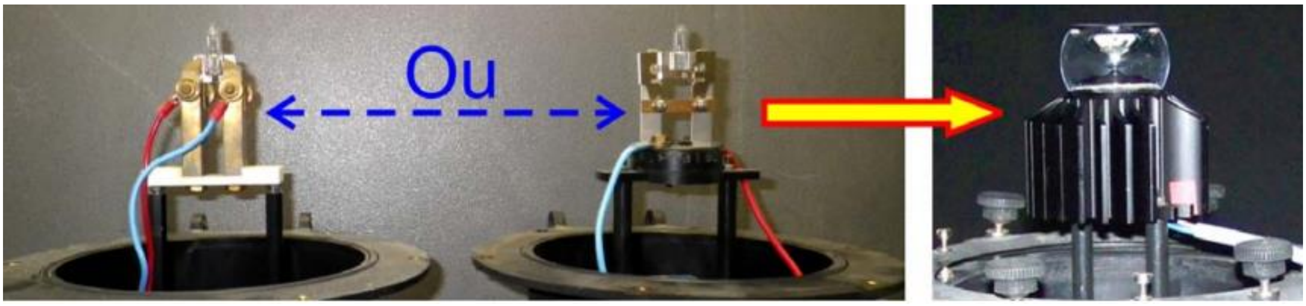

Figure 4: Replacing HLD sources with an LED light source

In 2019, the first failures of the DELV1 and DELV2 and the cessation of production of the LED electronic components used in the light sources led Cerema to develop a technical solution to recondition the DELV1. The DELV2 proved to be too complex to recondition.

This repair kit was very useful to repair the few faulty light sources (mainly due to lightning) and to give some time to consider their replacement.

3 OPERATING BALANCE SHEET

Today, initial feedback allows us to draw several lessons on the use of LED light source technology in AtoNs:

- They are suitable for most applications and are simple to implement;
- They improve the service provided to the navigator: better colour perception;
- They are economical compared to HLD lamps: power consumption divided by three and life span of ten years;
- They are considered reliable, given the low failure rate observed so far;
- A repair kit is useful.

These qualities have enabled these light sources to find their place in the French AtoN. Today, an assessment of the use of light sources in France shows their practical utility.

- Of the 3500 AtoN lights
- 1 000 are self-contained lanterns, used for ranges of less than 4 M ;
- 1 100 are controlled compact lights for ranges between 4 M and 11 M ;
- 1 300 are traditional lights equipped with LED light sources for ranges between 2 M and 20 M ;
- 100 are industrial lights equipped with HM light sources for rotating beam lights, for ranges between 20 M and 30 M.

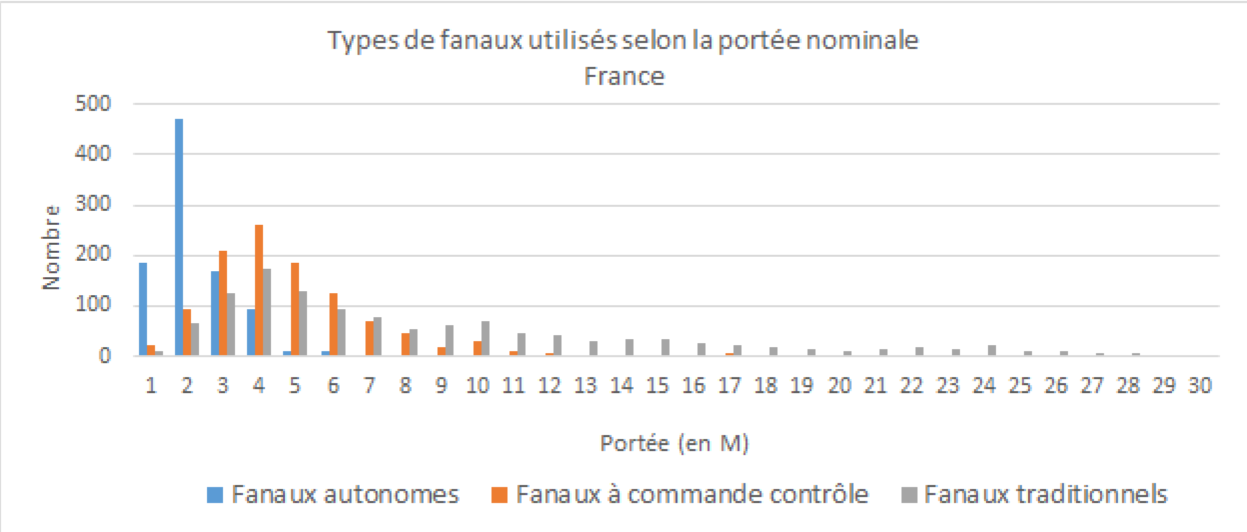

Figure 4: Beacons used in France according to the nominal range

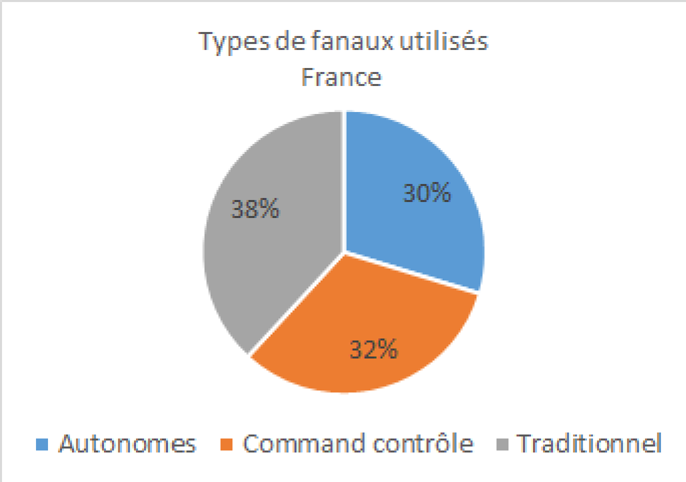

Figure 5: Distribution of beacons used in France

There are, however, some caveats:

- Specially manufactured light sources can be time consuming and complex to develop;
- Unlike DELV1, DELV2 cannot be used with sector lights;
- Until recently, it was still difficult to replace MH light sources;
- After a few years, it becomes difficult to find spare parts: the dependence on the manufacturer of the LED component used is very strong;
- Maintainability had not been sufficiently thought through from the outset: gluing and geometric precision for the assembly of LEDs and optics require skills (Cerema has been reconditioning V1 LEDs since 2019);
- The scalability of the light sources is very limited.

4 RENEWAL OF LED LIGHT SOURCES

The DELV1 and DELV2 light sources were developed in 2014. According to feedback, the lifetime of the offshore electronics is estimated to be 10-12 years before the first failures. It is therefore time to consider their renewal.

4.1 Feedback to take into account

Based on the experience of deploying LEDV1 and LED V2, there are a number of technical requirements to consider:

- DELV1s work well in sector lights. But they do not have the power to reach the longest ranges. A reinforced DELV1 is needed to fill this gap;
- New light sources should be easier to maintain: for example, plug-in electrical contacts and no glued parts;
- It is more interesting to order a volume of spare parts than complete replacement light sources;

4.2 A new need to be studied: the replacement of MH light sources

Manufacturers in the lighting sector are beginning to stop producing the less cost-effective MH sources. Inexpensive, reliable, with good efficiencies, commercially available, they have been the preferred technical solution for rotating optics lamps until now.

In this context, it is necessary to start thinking about the development of LED light sources capable of replacing MH lamps.
However, successfully replacing these light sources remains a challenge. The majority of MH light sources used in France for rotating lights have a power of 250 W and an efficiency of 110 lm/W, and it is difficult to achieve this performance with LEDs.

4.3 Technological developments

The latest evaluations carried out in Cerema's laboratories show technical improvements:

- An increase in luminous efficacy (lm/W) of 1.5 for white LED components since 2014;
- A very significant increase in luminance, by a factor of 1.7, with smaller and very bright emission surfaces;
- This new performance is likely to facilitate optical design.

To assess the new technological limits brought by these new components, Cerema pushed the exploratory work up to the proof of concept (POC).

For white, this method has been able to concretely demonstrate the feasibility of doubling the optical performance requirements since 2014.

4.4 Specification and tender for design/build

The need identified by Cerema does not exist on shelf.

The choice was made to have these light sources manufactured through a call for tenders. The goal is to achieve the design, production, supply and delivery of three models of LED light sources called Polaris.

- Polaris 1, essentially taking up the characteristics of the DELV1 for the lowest powers;
- Polaris 2, using the same design features as the DELV1 but twice as powerful to operate in the largest sector lights;
- Polaris 3, intended for the replacement of metal halide light sources.

The specifications were drawn up on the basis of feedback from Cerema over more than 15 years. IALA Industrial Member MSM won the tender and design work began in early 2023. Development is expected to be completed before the end of the year.

5 CONCLUSION

The use of LED light sources, of special manufacture, in the AtoNs historical optics is a modern solution, controlled, efficient, reliable, at a lower cost, and which works very well in most cases. With feedback, and the increase in LED performance, the concept can be further improved (troubleshooting, scalability), and extended to applications that were not yet capable of the technology (high-power sector lights, rotating beam lights).

Based on this observation, France undertook, at the end of 2022, to renew its LED light sources, by drafting renewed specifications and publishing a design/production call for tenders. MSM IALA Industrial Member Company has won the tender and design work is underway.

AUTHOR BIOGRAPHY

Yves-Marie Blanchard, 51, is an engineer and deputy head of the Aids to Navigation group. He graduated from the Ecole Nationale des Travaux Publics de l'Etat in the field of river and coastal development. As a civil servant, he can work in fields as varied as transport, the environment, civil engineering and the coastline, in the service of the French State and the national community. He also holds a degree in mathematics.

In a position of responsibility at Cetmef, then at Cerema, in the field of lighthouses and beacons since 2010, he is specialised in visual aids to maritime and river navigation. He was recognised as a specialist by the Ministry of Transport and the Sea in 2017 and confirmed in 2022. As a national technical referent, he represents France in the IALA ENG committee - sub-group "light and vision". In his field of expertise, he also participates in the development and implementation of the French national maritime signalling policy.

In his management functions, he supervises a team specialised in fixed and floating aids to navigation, lights and vision, power systems, electronics, mechanics, heritage and culture. He also maintains an expert activity, particularly in the field of visual aids to navigation. One of his areas of interest is the use of LED light sources in historic Fresnel lenses.

S104.1 Research on beacon lights control method in restricted waters based on differential flashing (024)

Assoc. Professor Jinhai Chen, Navigation College, Jimei University, China

ABSTRACT

The indication function of the present beacon lights are probably weakened due to the complex light source background, such as neon lights, harbor operation lights, and ship lights. In this work, we present a novel flashing control scenario which changes the traditionally synchronous flashing to differential flashing, improving the indication function of beacon lights. This scenario is based on the precise timing and synchronous flashing. The same batch of beacon lights can achieve time synchronization through accurate timing and the flashing error of beacon lights can be reduced. The same batch of beacon lights can achieve long time synchronous flashing based on the synchronous flashing according to setting the synchronous cycle.

The differential flashing control switch is added in the microprocessor to realize the inspection and control of differential flashing every minute and achieve more accurate differential flashing. In complex lighting background, the indication function of the beacons is probably greatly limited. Modifying the synchronous flashing to differential flashing of beacons can realize the scene that nearby beacons flash one after another, which outlines the navigation channels clearer at night and improves the ability to ensure the safety of night navigation. The solution can improve the overall effectiveness of the light visibility at night, which is quite suitable for application in restricted waters such as bridge channel and important equipment such as offshore wind farm.

(No paper submitted)

AUTHOR BIOGRAPHY

Dr. Jinhai CHEN is the Deputy Director of National-local Joint Engineering Research Center for Marine Navigation Aids Services. He has worked 20 years in Navigation College, Jimei University. His background is Maritime Transportation GIS. In July 2015, He has completed his PhD from State Key Laboratory of Resources and Environmental information Systems, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences. He was awarded a scholarship under the Education Department of Fujian Province, CHINA. to pursue his study for one year in the French Naval Academy Research Institute, as a visiting scholar. His current research interests focus on the Coexisting of Offshore Windfarms and International Shipping in the Taiwan Strait. His contributions in China Ocean Energy lies in Maritime Spatial Plan by combining ships tracks with Site Selection for Offshore Wind Farms in the Taiwan Strait. During the 9th session of the IMO Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), he joined the Experts Group on Ships' Routeing.

S104.2 Flash Simulator for determining suitable characters and synchronization patterns for AtoN lights (169)

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ABSTRACT

The paper gives an overview of the AtoN lights flashing simulator software developed by the Estonian Transport Administration.

KEYWORDS: AtoN lights, flash characters, flashing simulator, AtoN software

1 INTRODUCTION

Trying to comprehend how lights of AtoNs, or sets of AtoNs like leading lights or buoys marking a channel, work together and which combinations of flashes would give the best conspicuity and usability requires quite a good imagination. Alternatively, a piece of squared paper, as seen on Figure 1 below, and a bit less but still a considerable amount of imagination can be used.

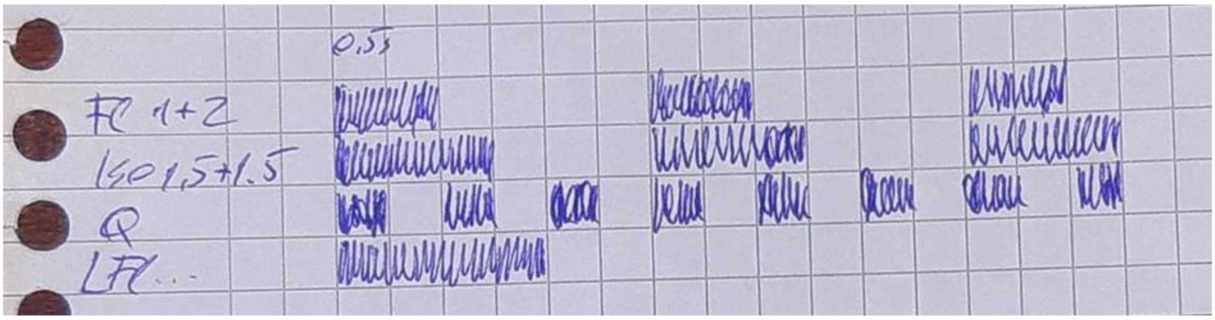

Figure 1: Using squared paper for visualizing flashing characters of AtoN lights

To make things easier my colleagues and I searched for some kind of simple simulator software we hoped already existed somewhere on the Internet. Unfortunately, we did not find any and so we decided to develop something more expressive and powerful than squared paper, but still simple enough, on our own. We worked out the concept of the simulator and procured the building of the software.

The flash simulator can be used for testing and demonstrating:

- flashing characters for leading lights to obtain the longest possible time when both lights are on for them to be most useful for the users;
- flashing characters for leading lights that can be synchronized, i.e. have the same or exactly multiplied length of flashing period;
- different options for synchronizing lights of lateral marks in channels – flashing simultaneously, sequentially (“runway lights”), or in groups to draw attention to particular sections of channel, etc.

2 THE FLASH SIMULATOR

Work with the Simulator takes place in two windows: the Viewing window and the Settings window.

In the Viewing window, the lights are inserted and displayed and can be dragged around, e.g. for adjusting with the locations of AtoNs in a possible background image, as seen in the screen capture below (Figure 2).

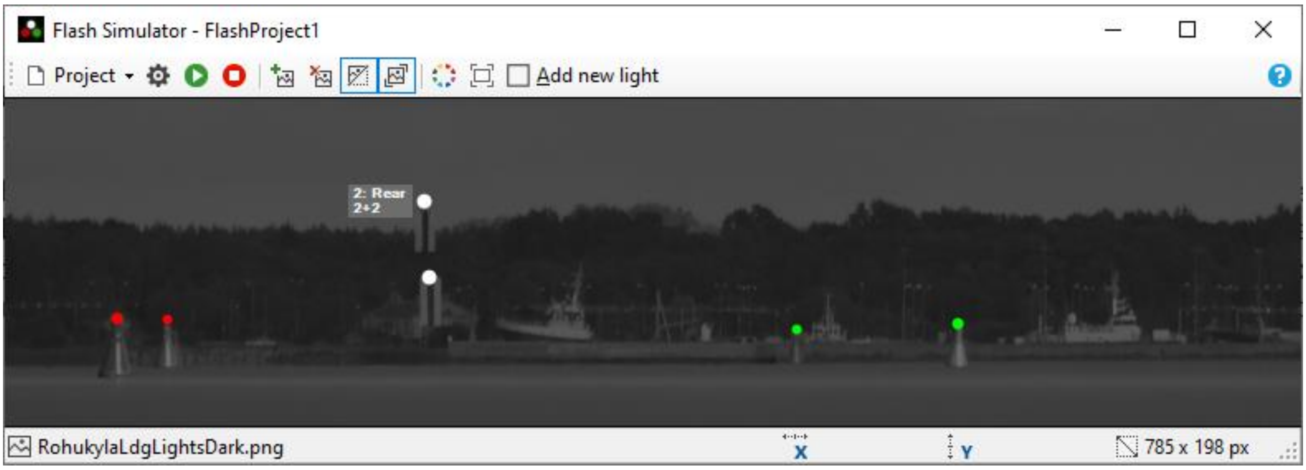

Figure 2: Viewing window with the lights of AtoNs positioned according to the background image

The projects can be saved (in the form of a csv-file) and the saved projects can be reopened from this window.

The Viewing window also has the buttons to start and stop flashing of the lights, change the colour of the background, add, remove, hide and fit the background image, switch to the full screen mode, and the check box for adding new lights to the screen one by one.

The lights in the Viewing window can be viewed against a plain one-coloured background or alternatively a background image can be used. For a background image, using a picture taken in daylight and manipulated to look like twilight (as in Figure 2 above) could be a good compromise between the struggle to find a suitable picture, realism, and the struggle to locate the AtoNs to pin the lights to a real night time image.

Instructions for using the Simulator are available behind a button in the upper right corner of the Viewing window. Last but not least, the Settings window can be opened with a button on the toolbar of the Viewing window.

In the Settings window, parameters of the lights can be set up – colour, size on the screen reflecting the relative brightness of lights (according to their intensity and distance), flashing character, and grouping with the other lights for synchronization.

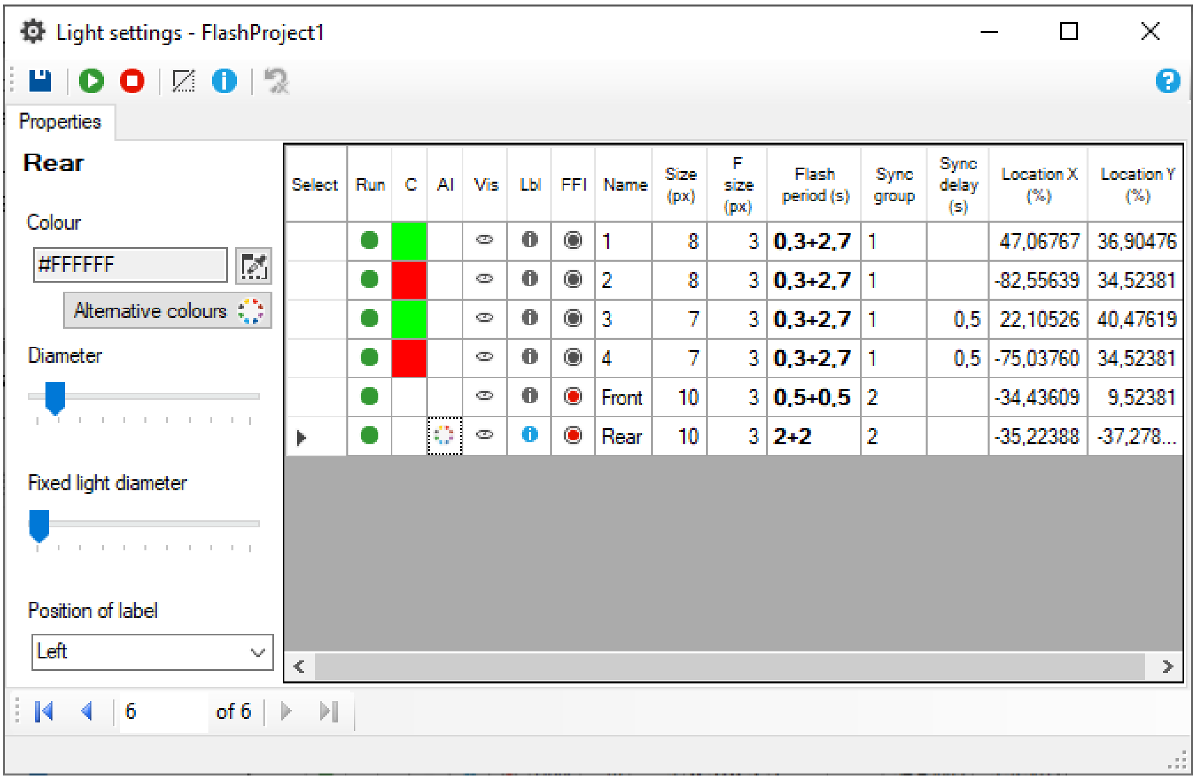

Figure 3: Settings window with parameters of the lights in Figure 2

In the table of the parameters of lights, the lights can be individually started and stopped (column Run), hidden from the screen (Vis), their information labels shown (Lbl), switched to fixed and flashing mode (FFl, column "F size" for changing the diameter of the fixed part).

The Simulator also has the possibility of simulating alternative lights, i.e. lights with multiple colours flashing in turn can be set up by selecting the alternative colours for them (column Al). In practice, there is hardly any AtoN lights with more than two alternating colours, but in the Simulator, one can set up as colourful lights as desired.

Some parameters that can be set up in the table can also be set in the Properties section on the left. The position of the information label relative to the lights to prevent the labels from obstructing important details in the background, however, can be changed only here.

Relative coordinates (as percentage of the distance from the centre of the screen to the sides of the screen) of the lights are in most cases of secondary importance, but they can be used for exact aligning of lights, for instance, if needed, by copying the same coordinates to multiple lights.

3 ACCESS TO THE FLASH SIMULATOR

The Flash Simulator can be downloaded via the AtoN software section of the IALA web page at the address https://www.iala-aism.org/technical/aton-software/aton-light-flash-simulator/.

AUTHOR BIOGRAPHY

I graduated Estonian Maritime Academy in 1997 and got a diploma in Hydrography. At the same year I started working in Estonian Maritime Administration (since 2021 Estonian Transport Administration, covering now also administering of roads and aviation). My specialities include design of fairways and design of AtoN from the viewpoint of navigational requirements. Since 2015, I have been participating in the work of ENG committee. I also give lectures in Estonian Maritime Academy of Tallinn Technical University and, on a voluntary basis, I participate in the work of Estonian Maritime Terminology Council.

S104.3 Lasers and saucepans - Investigating the alignment of a lighthouse optic (138)

Dr Alwyn Williams, General Lighthouse Authorities of the UK and Ireland (GLA), GRAD, Harwich, United Kingdom alwyn.williams@gla-rad.org

ABSTRACT

As the use of LED light sources fitted in traditional lighthouse optics become more prevalent, the relatively small size of the source compared to the size of the optic means that accurate focusing is critical to an efficient and reliable visual signal. Following a recent light intensity measurement of a lighthouse in the UK, it was found that the correct focusing of its light to the horizon varied with direction, creating sub-optimal performance from the lighthouse. The variation in focus suggested that the optic was actually tilted and required further investigation. A novel technique involving careful measurement using lasers was developed that could determine the alignment of a lighthouse optic in-situ. The technique was deployed, and results were gathered for further analysis. This paper describes the methodology, the results obtained, and how they compared to the amount of tilt found using the original light intensity measurement.

KEYWORDS: Faro, Óptica, Rendimiento, Metrología, Optimización de AtoN

RESUMEN DEL ARTICULO

En este documento, se describen los requisitos de formato para la 20ª Conferencia de la IALA. Revise este documento para obtener información sobre el formato del texto, los títulos de las tablas, las referencias y el método para incluir la información de indexación. Las actas de la conferencia se publicarán en formato electrónico. El trabajo completo en archivo MS Word se redactará de conformidad con estas instrucciones. En una etapa posterior, se convertirá a formato de documento portátil (PDF).

Un resumen de no más de 250 palabras debe aparecer en la parte superior de la primera página, después del título del trabajo en una sección titulada "RESUMEN" (sin número de sección), después de los nombres de los autores.

PALABRAS CLAVE: Faro, Óptica, Rendimiento, Metrología, Optimización de AtoN

RESUME DE L'ARTICLE

Dans cet article, les exigences de formatage pour la 20e Conférence de l'AISM sont décrites. Veuillez consulter ce document pour en savoir plus sur la mise en forme du texte, les légendes des tableaux, les références et la méthode pour inclure les informations d'indexation. Les actes de la conférence seront publiés sous forme électronique. Le document complet dans le fichier MS Word doit être rédigé conformément à ces instructions. À un stade ultérieur, il sera converti en format de document portable (PDF).

Un résumé n'excédant pas 250 mots doit apparaître en haut de la première page, après le titre de l'article dans une section intitulée "RÉSUMÉ" (sans numéro de section), après les noms des auteurs.

MOTS CLÉS: Phare, Optique, Performance, Métrologie, Optimisation de l'AtoN

1 INTRODUCTION

In 2017 [1] and 2019 [2], the GRAD carried out a field light intensity measurement of Needles Lighthouse (Isle of Wight, UK). Following a thorough review and analysis for the data captured, it was deduced that the optic was not properly aligned with the horizon. This conclusion was reached when the lamps were being focussed to the horizon towards the south, but the beam peak was pointing high towards the measuring site approximately to the north. In a follow-up investigation [3], it was estimated that the difference in elevation on the two sides was 0.57°. This discrepancy in the vertical alignment caused the estimated performance to vary significantly in the different sectors. This is due to the very narrow vertical beam (approx. 0.8°, see Figure 1) that the second-order fixed optic produced from the existing and trialled LED light source.

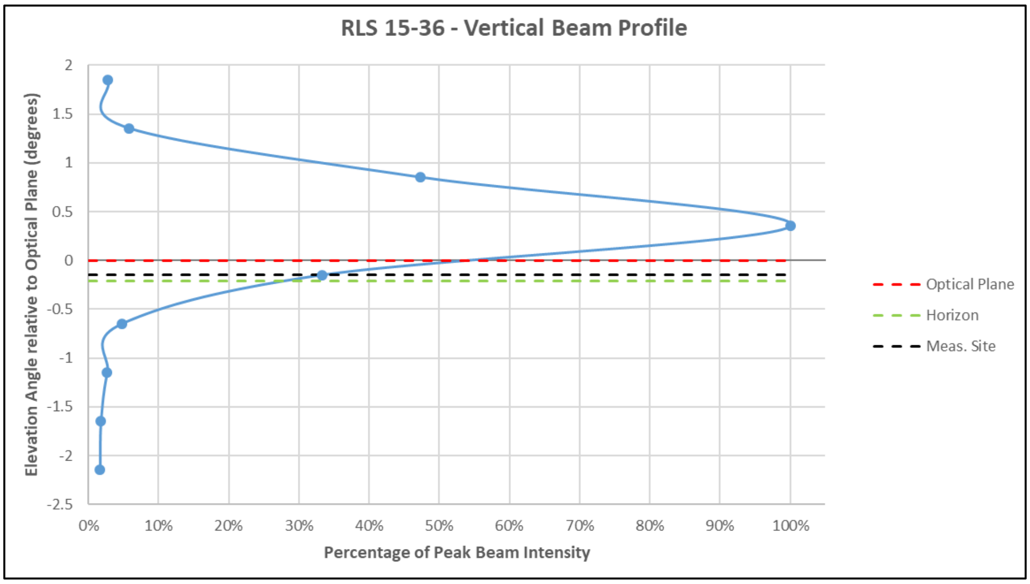

Figure 48 – Measured vertical beam profile of Needles Lighthouse with trial LED light source. After [2].

It was unclear at the time what caused the discrepancy, and Trinity House asked GRAD to investigate the Needles optic further. This paper details those investigations.

2 APPROACH

To the knowledge of the author, a lighthouse optic has not been investigated in this manner in-situ before, and so a methodology had to be developed in order to determine the condition of the optic. Whilst the methodology described below was created specifically to investigate Needles LH, it should apply to most other fixed-optic lighthouses, and potentially ones with rotating optics too.

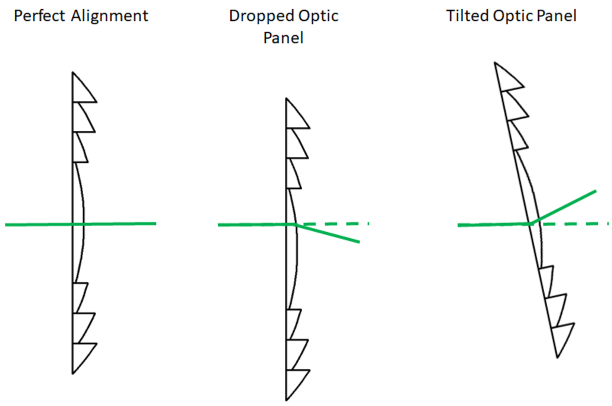

Figure 49 – Effects of Fresnel optic misalignment on a horizontal light beam

The premise of the investigation is shown in Figure 2, where the effects of in imperfect optic panel alignment on a true horizontal light beam is shown.

If an optic panel is dropped relative to the horizontal datum, the beam will strike the optic higher than intended that, after refraction in the optic, will cause the beam to point down.

In the case of the example tilted optic panel rotated about the light source, the horizontal light beam will strike the inside surface at an angle and at a point below the centre. Once again, due to the refraction of the light, the beam will point above the reference horizontal on leaving the optic.

Obviously, there can be many combinations of the above that an optic panel can be out of alignment, and the methodology employed at Needles is intended to determine the overall alignment of the optic. Whilst the

Needles optic contains both dioptric (refractive) and catoptric (reflective) elements, only a sample of dioptric elements of each lens section were measured. The implied assumption is that the remaining dioptric and any catoptric elements are aligned in the same direction.

In order to determine the true state of the optic panels, two datums are required – one inside the optic and one outside the optic.

The datum inside the optic provides a reference height at which light can be projected out through the lens. The datum outside the optic provides a reference height to compare the light that has propagated through the lens against.

During the measurement, the distance between the projected light from the lens and the outside datum is recorded around the optic. If the optic were perfectly aligned, these distances would be the same all the way around the optic. Any misalignment would show up as a *variation* in distances.

2.1 Equipment Used

Since the investigation of the optic involved resolving angular changes of less than 1 degree, a highly accurate means of measuring the condition of the optic was required. This was achieved by the use of self-levelling visible light lasers inside and outside the optic. GRAD obtained two Leica Lino L2P5G green line and dot lasers, which have a self-levelling accuracy of ±0.2 mm/m (~ 0.011°) and a dot/line accuracy of ±0.3 mm/m (~ 0.017°) or better [4]. This device outputs a horizontal and a vertical line in an arc of approximately 180°, and has bright dots directly above and below the device as well as to the left and right. A plumb bob, ruler and a spirit level with a digital display was used to measure various parameters around the optic.

3 METHOD

The following method was used to obtain the results during the investigation. At Needles Lighthouse, the existing lamps and lamp changer were removed for this test to provide room for the laser at the focal point of the optic.

3.1 Preparation

1. A spirit level was used to determine if there was an obvious tilt in the optic by resting it on top of it. A direction of maximum tilt was found and the level was rotated through 90°. The spirit level showed that the optic was level along this axis (Figure 3), which was the axis of tilt in the optic.

2. The vertical centre of the refractor belt in the direction of the axis of tilt was measured and marked on the inside of the optic, and this is the height of the datum inside the optic. At Needles, this mark was made on the nearest optic astragal.

3. The laser unit was mounted in such a way that the self-levelling mechanism operated correctly and that the horizontal line it produces is level with the datum mark made in step 2.

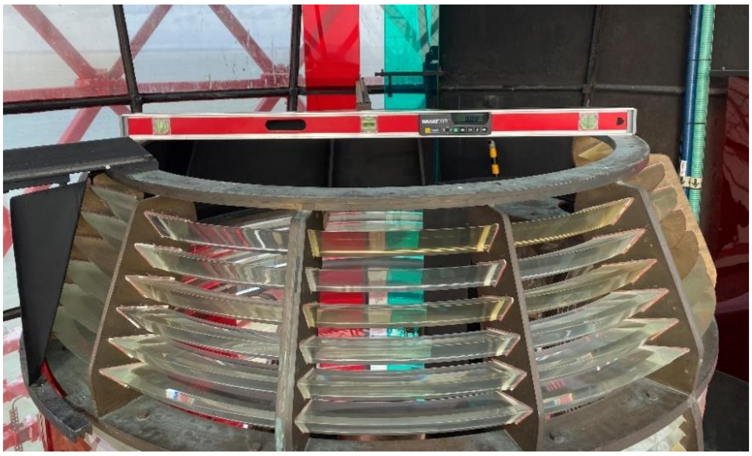

Figure 50 – Spirit level showing the axis of tilt of the Needles Lighthouse optic.

In addition, the vertical laser dot from the laser unit was centred inside the optic. To achieve this, a tape measure was used to find the optic centre, and a mark was placed coincident with the laser dot directly above the optic as a centre datum. At Needles, this mark was made on the level placed across the optic. This laser is called the “inside laser” (see Figure 4).

Due to construction of the pedestal and the existing wires, it was necessary to lift the laser above this to provide a stable, near-horizontal base. A saucepan from the lighthouse kitchen was found, and it proved to be perfect for this purpose!

Figure 51 – “Inside laser” mounted on the light source pedestal and saucepan.

4. Paper was placed securely on the glazing all around the optic so that the light from the lasers struck it. This made it easy to see the light, and provide a means of marking the position of the light.

5. The inside laser was switched on and the horizontal line it emits is seen on the paper. The paper is pressed against the glazing to provide consistency in distance from the optic and the height of the horizontal line in the direction of the axis of tilt of the optic is marked.

6. A second laser light is mounted on a tripod outside of the optic and switched on (Figure 5). Whilst ensuring that the self-levelling mechanism is operating correctly, the height of the laser is adjusted until its horizontal laser line matches the height of the mark made in the previous step. This is the height of the datum outside of the optic. This laser is called the “outside laser”.

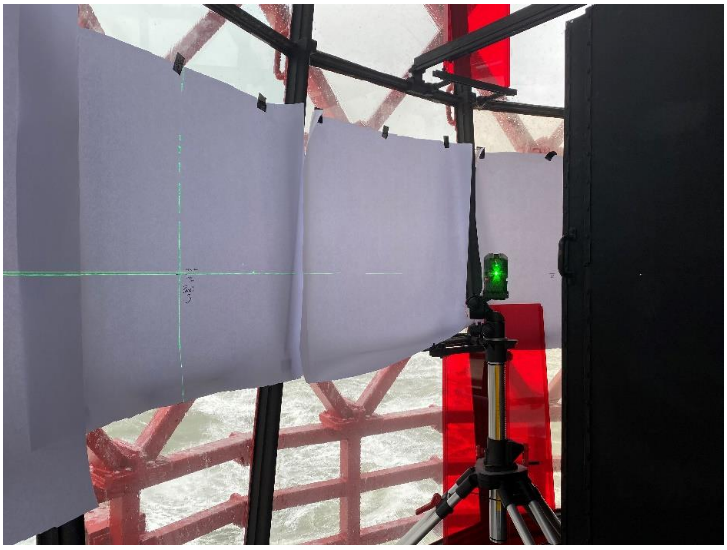

Figure 52 – “Outside laser” mounted on a tripod outside the Needles optic. The image also shows the vertical and one of the horizontal lines produced by the “inside laser” shining through the optic.

7. The height of the horizontal line produced by the outside laser was marked on different sheets around the optic. This allowed several marks to be used as datum points when it was necessary to move the outside laser around the optic and the original datum is not in the line-of-sight of the outside laser.

3.2 Making Measurements

1. With the lasers in place, marks where the inside and outside horizontal laser lines fell on the paper were made at regular points around the optic.

2. At Needles, measurements were taken at (a) approximately centre of each optic panel, (b) either side of each astragal and (c) along and perpendicular to the axis of tilt. This provided a good number of results in meaningful locations to analyse later. The measurements were made at the point where the inside laser vertical line was positioned. This line was used to determine the location of the measurement in the optic to ensure that the positions of any anomalies could be determined. An example of the process is shown in Figure 6.

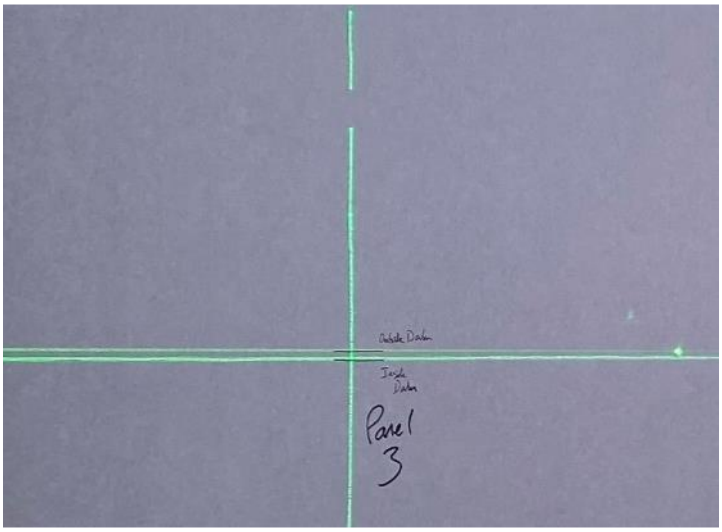

Figure 53 - Example of a measurement showing the difference in the inside and outside datum caused by the misaligned optic.

3. When moving the lasers to a different orientation or position, they were carefully arranged so that the laser lines or dots always struck the datum marks made earlier to ensure consistency in the results.

4. Using a ruler, the vertical distance between the horizontal lines produced by the two lasers were measured and recorded at each measurement location. In addition, the horizontal distance between the optic and the paper was also measured and recorded.

By this point, all the measurements required have been taken, and the light source was reinstated.

4 RESULTS

The horizontal datum shown in Figure 7 was used to define the locations of the measurements in angular form around the optic. Figure 8 shows the results in tabular and graph form. The red vertical lines show the locations of the optic astragals at the point where it crosses the central band.

The angular deviation is calculated using a distance from the optic to the paper of 1.46 m.

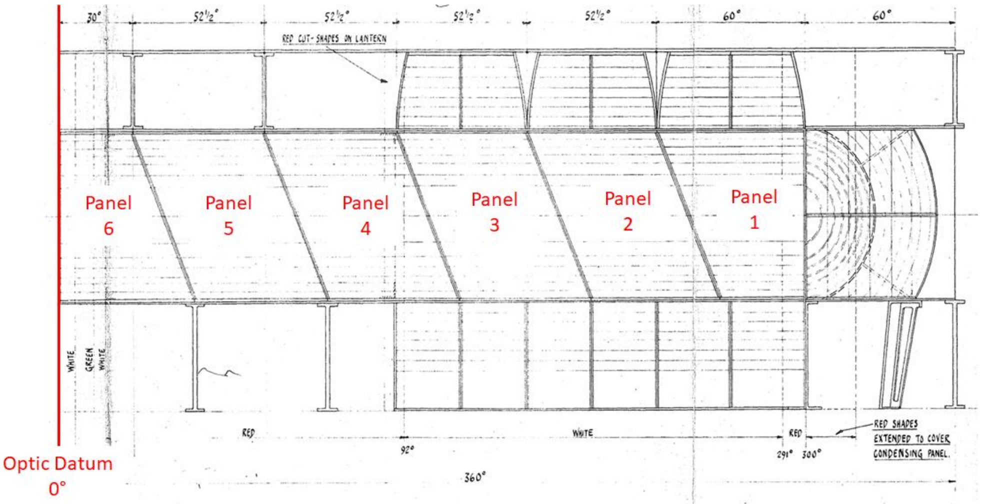

Figure 54 – Drawing of the Needles optic annotated with the optic (azimuth) datum and panel references used in the results. After [5].

Azimuth from Optic Datum (°)	Panel Number	Difference in Datum (mm)	Angular Deviation from Horizontal (°)
14	6	+6.0	+0.26
35	6	+5.0	+0.18
41	6	+4.0	+0.18
43	5	+6.5	+0.26
68	5	+4.0	+0.16
95	5	0.0	0.00
97	4	+2.0	+0.08
104	4	0.0	0.00
147	4	-5.5	-0.22
149	3	-3.0	-0.12
174	3	-5.0	-0.20
194	3	-6.5	-0.26
200	3	-6.5	-0.26
202	2	-9.0	-0.35
221	2	-10.0	-0.39
252	2	-9.0	-0.37
254	1	-5.0	-0.22
266	1	-4.0	-0.14
284	1	-4.0	-0.16

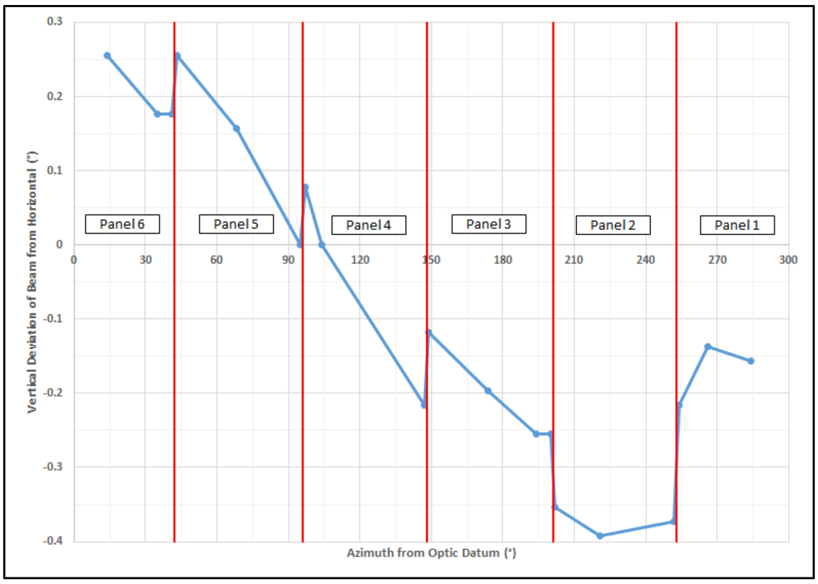

Figure 55 – Alignment of the Needles optic relative to horizontal.

5 DISCUSSION

The results of the Needles optic investigation shows a clear tilt in the whole optic. This is shown dramatically in Figure 8 where the maximum and the minimum are approximately 180° apart. The maximum is pointing in the direction of the narrow white sector towards the Solent, and the minimum is out to sea.

According to measurement reports [1] and [2], the light measurement took place in the direction through Panel 5. It was found that when the light source was focused to the horizon out to sea through Panel 2, the beam towards the measurement site was 0.57° high. Taking the difference between the average deviation of panel 2 (≈ -0.37°) and the deviation in approximately the direction of the measurement site (≈ +0.16°), we get a difference of 0.53°. This difference largely accounts for the vertical alignment discrepancy found during the light measurements.

Another apparent characteristic shown in the graph is the steps between adjacent panels. These were characterised by shining the inside laser across an astragal and measuring the output height from the adjacent lens panels relative to the outside laser. The most notable steps are between panels 1 through 4, which can deviate by as much as 0.15° between panels. The step between two lens panels can be seen in Figure 9.

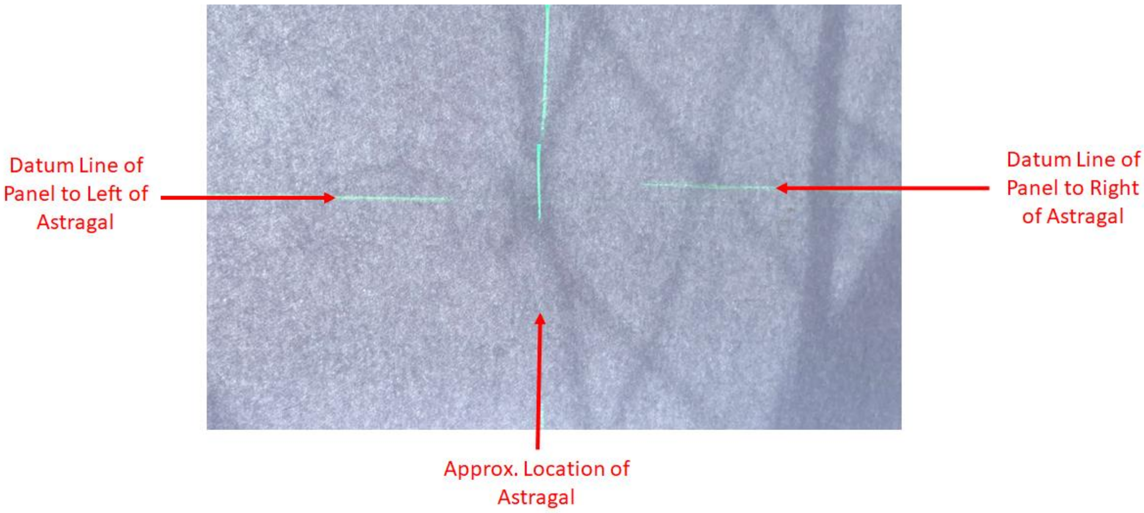

Figure 56 – Laser trace across an optic astragal demonstrating the step between panels.

5.1 Optimum Alignment

It is apparent from the results that the optic is tilted. It is possible to determine the best performance of the optic by estimating the tilt required to find the optimum alignment. This is carried out in two stages.

The first stage will need to find the mean deviation from the horizontal datum. This is because of potential error in the identified location of the tilt axis of the optic. The mean difference between the outside laser datum and the measurement points is -2.1 mm or -0.08°. By inspection of Figure 8, this is approximately 120° from the horizontal datum. Therefore, this is deemed the actual location of the tilt axis of the optic. This would also provide some optimisation by accounting for the steps between panels, a feature that introduces some error in the calculation that cannot be eradicated.

The second stage is to estimate the effect of tilting the optic around this axis. This can be done by applying a correction angle that is proportional to the sine of the difference between the measurement horizontal and the tilt axis. The correction angle was adjusted until the sum of the square of the deviation had reached a minimum. The results of the process is shown in Figure 10.

These results were achieved by tilting the optic by 0.28° around an axis set at 120° from the optic horizontal datum. This corresponds very well with the adjustment predicted by the light measurements too (i.e. half of 0.57° difference).

It should be noted that simply tilting the optic does not resolve any steps of alignment between individual panels. To adjust these would require substantially more work as it will be necessary to split the optic panels, and may result in no better outcome than the optimised alignment discussed here. As a result, the optimised alignment still contains steps between panels and a deviation of about ±0.1° around the optic.

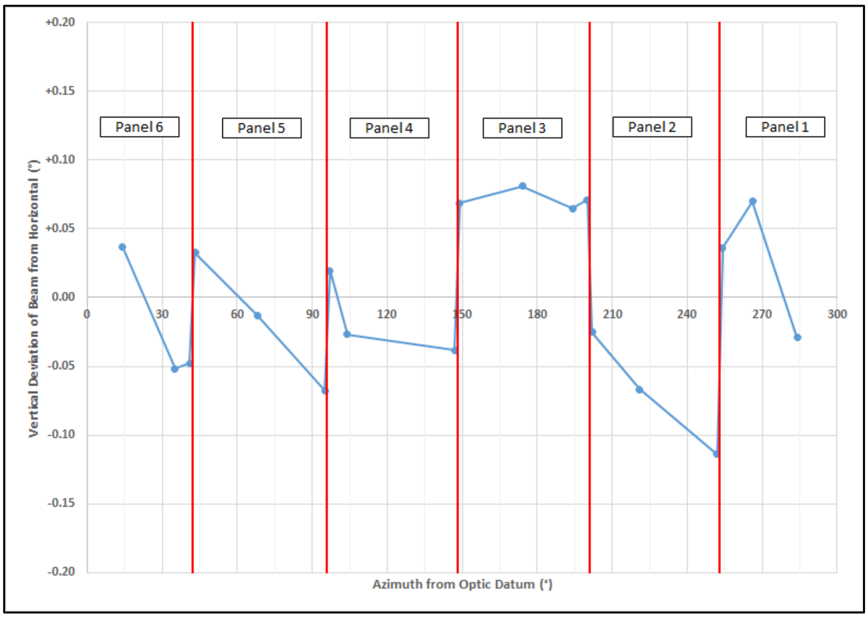

Figure 57 – Optimised optic alignment.

5.2 Effect of Performance

The results of the field light measurement carried out in 2019 allows us to determine the impact of the optic tilt on the performance of Needles Lighthouse. In Table 1, the performance of the lighthouse when using a 12-sided LED light source with 1000 mA flowing through the LEDs is shown, together with the proposed navigation requirement. With the tilt, it is possible to see that the lighthouse will not meet the required nominal range in all directions. This is due to the narrow beam pointing in the incorrect vertical direction.

Table 5 – Impact of optic tilt on performance of Needles Lighthouse

	Nominal Range		
Sector	**Navigation requirement**	**Measured/estimated before correction**	**Estimated after correction**
White	12 M	14 M ✓	17 M ✓
White Intensified	17 M	17 M ✓	17 M ✓
Red	12 M	9 M ✗	12 M ✓
Red Intensified	12 M	13 M ✓	13 M ✓
Green	12 M	11 M ✗	14 M ✓

The last column of the table shows the estimated performance of the lighthouse if the optic was corrected to provide an optimum performance in all directions. The nominal range in the red and green increase by 3 M from the relatively small change in the optic! This estimation has not yet been verified by measurement at the time of writing. In addition, it is expected that intensity variation in the direction of the horizon will be about 10% due to the remaining misalignment of the panels and the narrow vertical profile.

6 CONCLUSION

The investigation into the Needles Lighthouse optic was prompted by discrepancies found during the GRAD field light intensity measurements. This novel investigation required a method to be developed that could be employed on-site.

It was gratifying to see that the methodology and the results it produced confirmed the predicted existence and magnitude of a misalignment of the optic at Needles. As a result, it was found that the optic would need to be tilted by 0.28° around an axis set at 120° from the optic horizontal datum in order to optimise the performance of the light.

The results allowed Trinity House to understand the physical condition of the optic, implement corrective works resulting in a means of utilising it as effective as possible. Due to a number of reasons, a light measurement has not yet been carried out on the corrected optic, but this is due to take place later in 2023.

7 ACKNOWLEDGEMENTS

The author wishes to thank Trinity House and their engineering team for facilitating access to Needles Lighthouse to conduct this investigation. In addition, the token of gratitude is extended to Mr Link Powell for his assistance and advice during the investigation.

8 REFERENCES

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Alwyn Williams is a Principal Visual Signalling Engineer in the General Lighthouse Authorities of the United Kingdom and Ireland's Research and Development directorate (GRAD). He has been involved with radionavigation research since 1999, covering topics such as Differential GNSS, low-frequency navigation systems and Automatic Identification System (AIS). He has been responsible for the successful re-engineering of several marine aids-to-navigation (AtoN), using the latest technology to further improve reliability and performance of the service. He is the vice-chair of the visual signalling working group at IALA Engineering and Sustainability (ENG) Committee, and has been involved with IEC in setting international test standards. He was the Project Manager for the EU regional project, ACCSEAS, delivering an innovative e-Navigation test-bed in the North Sea Region. He is a Chartered Engineer, Member of the Institute of Engineering and Technology (IET), IALA Level 1 AtoN Manager and Associate Member of the Royal Institute of Navigation.

104.4 Visual Signaling in the digital era with machine vision (137)

Alwyn Williams, Principal Visual Signalling Engineer, General Lighthouse Authorities of the UK and Ireland (Trinity House, Northern Lighthouse Board and Irish Lights), UK and Ireland

ABSTRACT

Visual signals have been the primary of marine aids-to-navigation for millennia. With the advent of electronic navigation aids, the role of visual signals for the purposes of marine navigation has changed, but they still fulfil an important part in the mix of marine aids-to navigation.

Machine vision is an area of technology that has grown significantly over the last few years, and it can provide additional assistance to the mariner and (semi-) autonomous vessels alike. In this paper, we consider how machine vision techniques can enhance navigation at sea using marine visual aids. We investigate the detection of flash characters, 2-D barcodes, near-visual imagery, and object detection using machinelearning techniques. Based on a study carried out by GRAD, we report on the potential opportunities and limitations of the technology and consider how existing visual aids can be modified to enhance their conspicuity to such systems.

(*No paper submitted*)

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Dr. Alwyn Williams is a Principal Visual Signalling Engineer in the General Lighthouse Authorities of the United Kingdom and Ireland's Research and Development directorate (GRAD). He has been involved with radionavigation research since 1999, covering topics such as Differential GNSS, low-frequency navigation systems and Automatic Identification System (AIS). He has been responsible for the successful re-engineering of several marine aids-to-navigation (AtoN), using the latest technology to further improve reliability and performance of the service. He is the vice-chair of the visual signalling working group at IALA Engineering and Sustainability (ENG) Committee, and has been involved with IEC in setting international test standards. He was the Project Manager for the EU regional project, ACCSEAS, delivering an innovative e-Navigation test-bed in the North Sea Region. He is a Chartered Engineer, Member of the Institute of Engineering and Technology (IET), IALA Level 1 AtoN Manager and Associate Member of the Royal Institute of Navigation.

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