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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:

Volume	Session Name	Main auditorium session number	Speakers' Corner session number
1	AtoN Management	1	101
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Please note that throughout the proceedings, the title of the paper is preceded by the Conference session event number and followed by the unique paper number in parentheses, e.g.,:

"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 documento.

SESSION 5 - ATON SERVICES

S5.1 Tailored Maritime Services for the Norwegian waters (121)

Arve Dimmen, Director Navigation Technology and Maritime Services, Norwegian Coastal Administration, P.O. Box 1502, 6025, Ålesund

ABSTRACT

Norway has participated in the development of IMO e-navigation. In 2020, Norway developed a strategy for implementing Maritime Services adapted to the user needs in Norwegian waters. The digital services are based on the IMO's preliminary definitions, but tailor-made for Norwegian user needs. The Norwegian Coastal Administration provides digital routes along the coast and in arctic areas. Digital Maritime Services are linked to Routeinfo.no.

KEYWORDS: Maritime Service portfolio, IMO e-navigation, Maritim ITS, IHO s-100, Digitalization,

1 INTRODUCTION

The presentation informs about the methodology and how the work with development and implementation has been carried out, and the use of international standards that will also be the basis for future autonomous systems. Furthermore, it gives insight to the results from the DNV analysis of cost benefits (FSA), showing great benefits for the public society. The presentation provides some insight to the link to Intelligent Transport Systems (ITS) and how to learn from other modes of transport, primarily road transportation. The presentation also gives examples of a portfolio of services along the Norwegian coast.

2 THE SERVICES

The services are based on IMO Resolution MSC.467(101) “Guidance on the definition and harmonization of the format and structure of Maritime Services in the context of e-navigation” and MSC.1/Circ.1610 “Initial descriptions of Maritime Services in the context of e-navigation”.

In addition, the Maritime Service Portfolio (MSP) for the Norwegian waters considers:

- The Norwegian Coastal Administration's expertise, user needs and experiences
- Collaboration with industry and users
- Experience from several Norwegian and EU projects
- FSA carried out by DNV GL and Menon Economics.
- Collaboration with ITS Norway on strategy for Maritime ITS
- Workshop with relevant nautical environments in the Norwegian Coastal Administration
- Workshop with navigators with experience from coastal navigation
- User survey

The goal is to facilitate and provide digital information along the coast in the right place at the right time based on user needs and type of operation.

The first step was to develop and establish digital reference routes as a basic structure.

The routes are established by the Norwegian Coastal Administration in collaboration with several professional environments and quality assured by nautical personnel from the shipping industry, pilotage service, interdisciplinary expertise in the Coastal Administration, the Mapping Authority and the ECC. The routes support efficient and safe planning of seagoing voyages. The routes can be included in a suitable graphic display on the bridge and used in various tools available to ships for route planning. The ship can then sail along the route and monitor this on, for example, ECDIS, ECS and PPU.

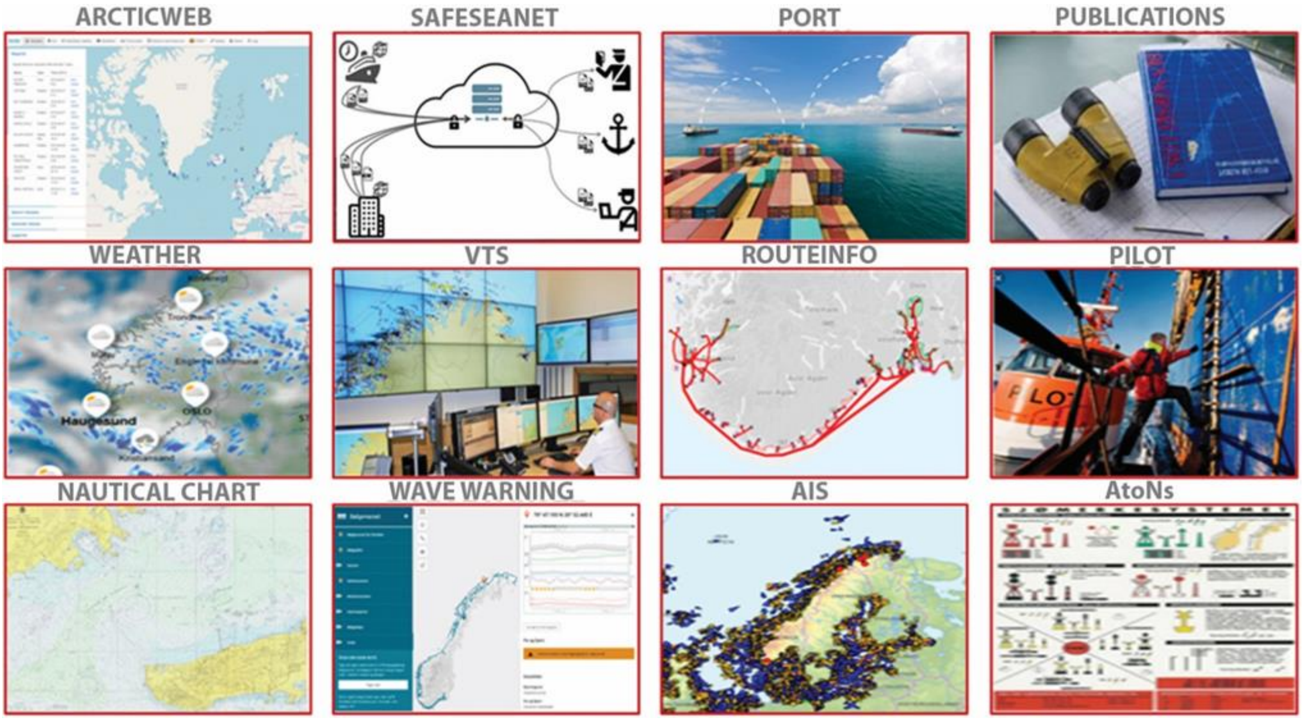

Figure 1: examples of services in the portfolio

Each service is structured with a description of goals, implementation, partners, references to IMO, IALA, IHO etc., resources and budget.

For Norway, the following services are defined:

1. Reference routes
2. Maritime Safety Information (MSI)
3. Establish the exchange of digital information related to efficient port operations, including anchoring opportunities
4. Establish the exchange of digital information for administrative pilotage services.
5. Establish the exchange of digital information for towboat and escort services
6. Establish digital information on ship reporting in Norway (National Single Window)
7. Establish digital information for Maritime Assistance Service (MAS) in Norway
8. Digital information from nautical publications
9. Digital information about ice navigation
10. Facilitation and dissemination of meteorological information from the Coast Guard's sensors
11. Establish the exchange of digital information between the Vessel Traffic Service (VTS) centres and vessels
12. Establish services particularly adapted to passenger ships/cruise ships
13. Develop services that enable autonomous processes and operations in the future

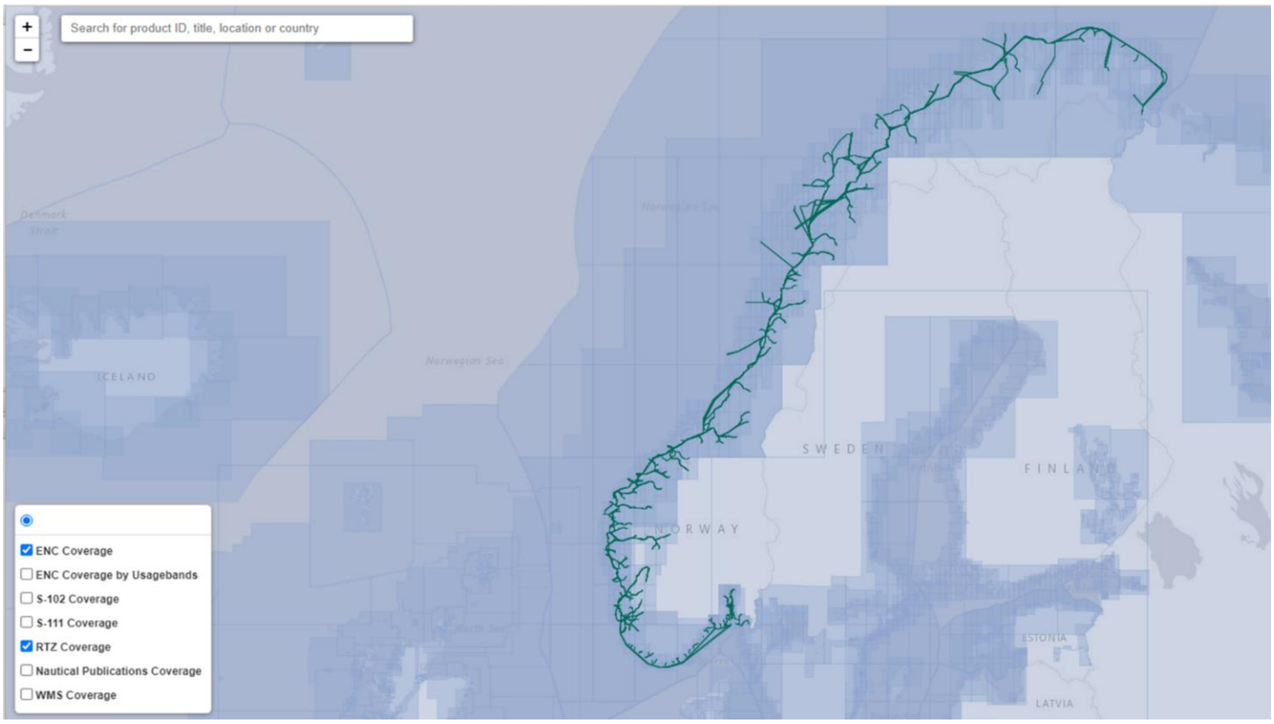

Figure 2: The structure of digital routes along the coast of Norway.

3 CONCLUSION

- Digital routes must be quality assured and evaluated by professional stakeholders.
- Digital information along the routes is useful for safe and efficient seagoing voyages, as well as fuel reduction and air emissions.
- IALA should consider working with a system that ensures that information is presented in a user-friendly way along the routes.
- IALA should work to ensure that VTS becomes a central player in the management and sharing of a portfolio of information as defined in IMO e-navigation service no 5.
- The VTS committee should coordinate the development of an own s-2xx product specification, ensuring a central, uniform and complete standardization for VTS services.

4 REFERENCES

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AUTHOR BIOGRAPHY

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S5.2 The connection between S-124 and S-125 Standard (147)

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ABSTRACT

S-124 is an S-100-based format for issuing Navigational Warnings in compliance with IHO S-53/IMO MSC.1/Circ.1310 as amended. S-124 is currently under development by the World Wide Navigational Warning Service Sub-committee (WWNWS-Sc) which is being led by the Canadian Coast Guard. S-125 can be described as an advanced digital list of Aids to Navigation (AtoN). IALA is drafting S-125 Product Specification and Technical Service Specification on behalf of IHO's Nautical Information Provision Working Group (NIPWG), as a means to communicate status of AtoN systems, including outages and prior notice of changes to AtoN systems. This paper will explore the envisioned operational interaction between S-124 and S-125 in shore-side and ship-board systems. This paper will explain the status of S-124 and S-125 developments, their intended use individually, and how information could transition from the S-124 data stream into the S-125 data stream. The paper will also explore how this interaction between S-124 and S-125 can help safe navigation, including autonomous navigation (MASS).

KEYWORDS: Navigational Warnings, NAVWARN, S-100, S-124, S-125, Aids to Navigation, AtoN, MASS

1 INTRODUCTION

S-124 [1] is an S-100-based [2] format for issuing Navigational Warnings in compliance with IHO S-53/IMO MSC.1/Circ.1310 as amended [3]. S-124 is currently under development by the World Wide Navigational Warning Service Sub-committee (WWNWS-Sc) and the work is led by the Canadian Coast Guard. S-125 [4] can be described as an advanced digital list of Aids to Navigation (AtoN). IALA's ARM Committee is drafting S-125 Product Specification and Technical Service Specification on behalf of IHO's Nautical Information Provision Working Group (NIPWG), as a means to communicate status of AtoN systems, including outages and prior notice of changes to AtoN systems.

S-124 and S-125 must be implemented in harmony for the benefit of the end user, since both can carry similar information about the same events. An added challenge is that the ENC (S-57 [5] or S-101 [6]) also contains AtoN information, with ENCs being the primary source of AtoN information in the ECDIS for over 20 years. These topical and content overlaps necessitate a clear rule set for how the three products will operate in a user system.

The IALA/IHO S-100/S-200 workshop [7] in Norway in September 2022 provided a venue for cross organizational discussion on how the IHO needs could be harmonized with those of IALA. The workshop recommended that S-125 be developed for ECDIS use, but only portraying the status updates of AtoN systems by including rules in the IHO S-98 Interoperability Catalogue that, by default, mask all AtoN information from S-125, except for the status updates. NIPWG, at its 9th meeting, picked up these recommendations [8] as a basis for the continued S-125 development framework and encouraged IALA ARM Committee to adopt it as well.

2 ENVISIONED OPERATIONAL INTERACTION

With the S-125 development framework that NIPWG has defined and with IALA's ARM committee adoption of the draft 0.0.3 release of S-125 its 16th meeting in October 2022, there are some considerations that need to be made when planning for operational use of S-125. First and foremost, will be to determine who should create the service that issues S-125 datasets. This will be a national decision including whether there will be S-125 in national waters. Regardless, there still need to be a set of common rules so that user systems can be ready for S-125 services.

The national authority historically has issued the List of Lights publication and this authority would be the primary candidate for any S-125 service. However, consideration should also be given as to which competent organization has historically been responsible for AtoN information, since this is the source of all S-125 datasets; consideration could also be given to which competent organization has historically been responsible for Notice to Mariners, since this is also a source of temporary and preliminary information related to AtoNs. A further consideration is the competent organization responsible for navigational warnings: this service is a significant conduit for short term AtoN information communicated to users, including information about outages and missing or damaged AtoNs. As noted, any organization involved with one or more of these tasks could be a candidate for an S-125 service operator. No matter which option is chosen, there is a strong need for good information exchange between the different entities to ensure the efficient flow of information so that the end user is not confused by having the same information through many sources.

The IALA/IHO S-100/S-200 workshop concluded that it would not be possible to give a general recommendation of which organization should do the work, but rather developed an information flow diagram to show the relationship between the tasks and services as a guide for anyone wishing to set up a S-125 service. This diagram is included below as Figure 1.

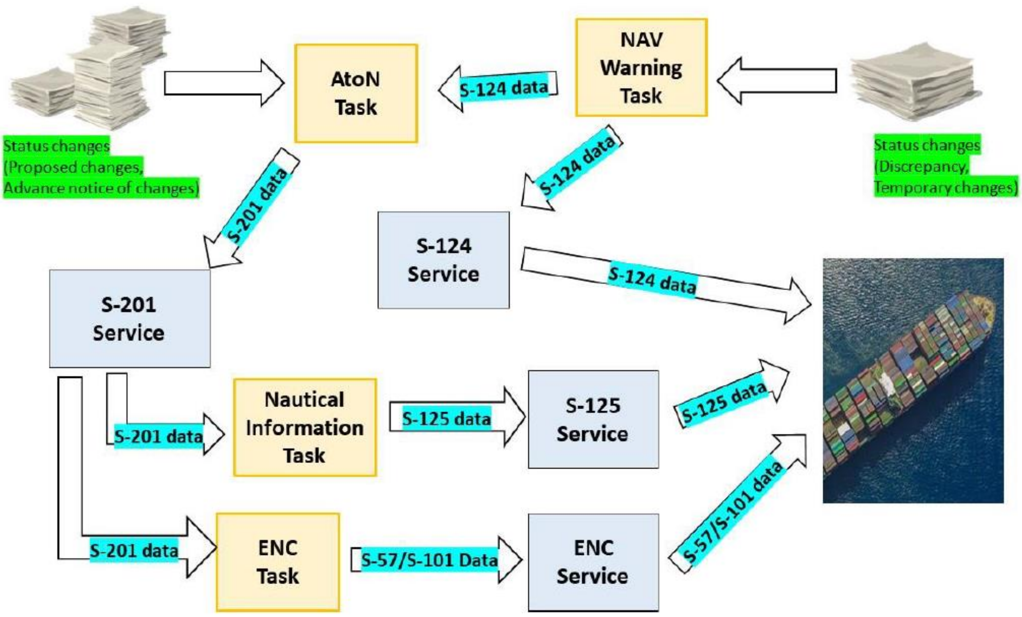

Figure 1 - AtoN information flow

The flow diagram shows that the two general inputs expected is through proposed changes at the AtoN service and by reported discrepancies or temporary changes via the navigational warning (NAVWARN) service. Both can serve as source material for S-125 datasets. At this point it is worth noting that although the information received via the navigational warning task will already have reached the end user, the S-124 format does not permit visualization of AtoN information in ways that differ from any other NAVWARN information, meaning the end user must still read and mentally digest the information before deciding how relevant it is for the situation the end user is facing. S-125 on the other hand, will have visualization that permits the specific portrayal of status changes to an AtoN based on the information from either the AtoN task or the NAVWARN task. Such portrayal can ease the mental burden on the end user by giving specific visual details as to the impact of information. Moreover, moving AtoN information quickly from a navigational warning service into an S-125 service, or if the circumstances permit, skipping the NAVWARN service and going directly to an S-125 service can significantly reduce the clutter from NAVWARN service.

As an example, out of a total of 20646 NAVWARNs issued in Canada between March 29, 2021 and March 29, 2023, a total of 10473 were related to AtoN in some way (including cancellation NWs). This represents almost 51% of all NAVWARNs issued during this period. As such, an S-125 service with frequent updates can significantly relieve the NAVWARN service and give the end user a overview of AtoN status since the portrayal of information in S-125 is better suited to AtoN information and convey the important parts of the information more quickly than S-124 can do. This can reduce the cognitive load on an end user when having to interpret data relevant to the task at hand.

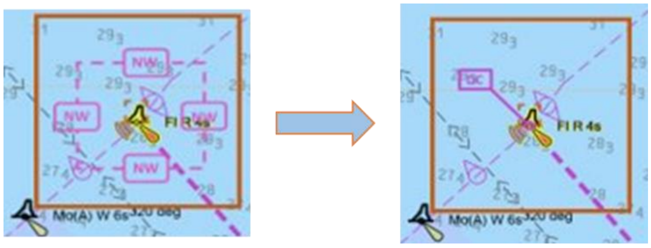

Figure 2 - visual of transition from NAVWARN to S-125

As NAVWARN has a potential distribution delay of up to 8 hours, while an S-125 service which is updated at least daily could be considered as a viable alternative for certain lower-risk AtoN information. Similarly, with NAVWARN, Notice to Mariners (NtM) have been a venue for longer term AtoN service discrepancies and preliminary notices of upcoming changes or temporary changes. Most hydrographic services fold this into the regular ENC service if the information has a duration sufficient to make sense according to the update frequency in the ENC service. This duration varies between hydrographic services from a few days to several weeks. Decreasing this duration would present ENC as an alternative for some of the information that would otherwise go into S-125, although it still could make sense to issue the information in both data streams: there is a significant link between S-57 ENC and S-101 ENC making it complicated to justify significant departures in the way the two services work; and since S-57 is a frozen standard, S-101 cannot deviate either in data model or in portrayal. In this case, S-125 is completely free to define a data model that can respond to stakeholder demands and portrayal that can do likewise. Recent interactions between IALA ARM Committee and the IHO S-101 Project Team have shown that there are significant barriers to adopting ENCs to support new AtoN developments, thus leaving S-125 as a potential means to be a quicker path for AtoN Authorities to disseminate richer AtoN information than what can be done in the ENC. This presents a good justification for why an S-125 service will be a good compliment to AtoN information in the ENC. The S-98 Interoperability Catalogue [9] will, by default, give priority to the AtoN information in the ENC, allowing only the status annotations from S-125 to be visualized. However, if the mariners have a compelling need, the full S-125 portrayal can be activated.

Since S-125 has a data model purposely built for AtoN information, it allows for better attributed data, which would also be a benefit for MASS type navigation. Since S-125 allows more data to be moved from prose into discrete data structures than S-124 permits, the data in S-125 would be better suited for MASS: the reduction in ambiguity permits the system behind the MASS navigation to do better analysis and support decision-making than what S-124. Testing these assumptions will be an essential in the coming years as competent authorities review options for how to implement S-100 services, S-124, and S-125 services. A more comprehensive understanding of the relationships and interdependencies between entities is necessary as well as validation of the service delivery paths and end user system behaviour.

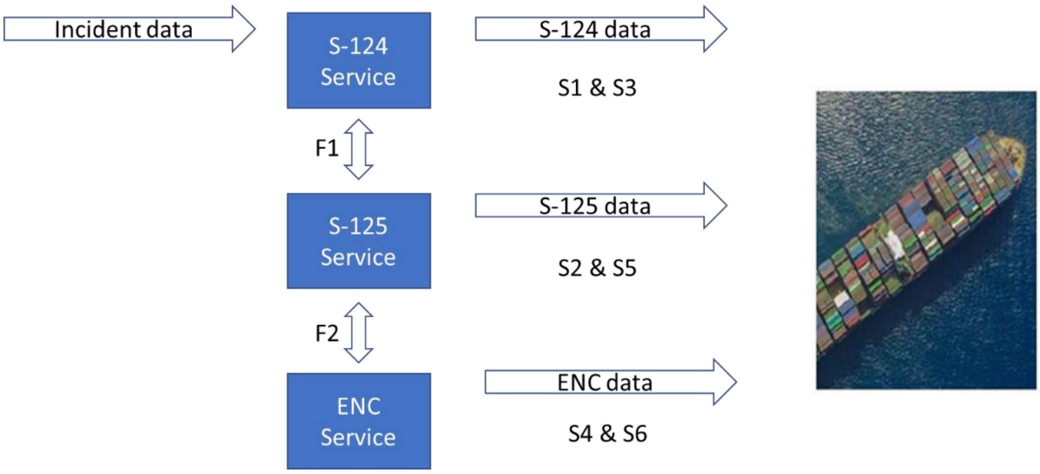

Figure 3 - Example of AtoN data dissemination sequence

Figure 3 demonstrates an example of how a sequence of data updates can be work in a scenario where there are S-124, S-125 and ENC services to support the end user. The example starts with an incident reported and a S-124 dataset (S1) created and sent to end users. This incident is of an AtoN nature and the S-124 dataset is received on the end user system using the appropriate communication channel. Within a defined time, e.g.: same day, the incident is analysed by the AtoN service through the F1 feedback loop, which confirms the incident and generates an S-125 dataset (S2) which is issued the next day, as per the nationally defined data dissemination cycle, and then received by the end user system. The publication of the S-125 dataset triggers the S-124 service via the F1 feedback loop to issue a cancellation dataset (S3) which is received by the end user system. There may be a period of several hours where the incident information is available in the end user system as both S-124 and S-125 datasets, but fine tuning the F1 feedback look can virtually eliminate this duplication. Moreover, the end user can be trained to easily understand the relationship between the services by way of visualization since S-124 will be quite basic, while S-125 will be specific to the AtoN information. In the scenario, the issue of dataset S2 is picked up in the feedback loop F2 and the ENC service is notified. A dialogue between the S125 service and the ENC service concludes that the incident will persist for a sufficient period resulting in a temporary NtM and a revision (S4) to the relevant ENC, which is disseminated by the nationally defined distribution path. The issue of the revision triggers feedback loop F2, which initiates a dialogue between the S125 service and the ENC service and a decision is taken to maintain both S125 dataset S2 and ENC dataset S4, since it gives an amplification for the end user to the seriousness of the incident. A period passes, and the incident is resolved, triggering the S125 service to issue an updated S125 dataset (S5) which removed the incident from its service. This triggers feedback loop F2, which results in the ENC service issuing an ENC revision(S6), which remove the temporary notice from the ENC.

The ECDIS systems are often thought of as the only end user system of consequence, however, since ECS and shore systems are also potential end user systems of S-124 and S-125The assumptions being built into S-124 and S-125 services should also work in non-ECDIS systems.

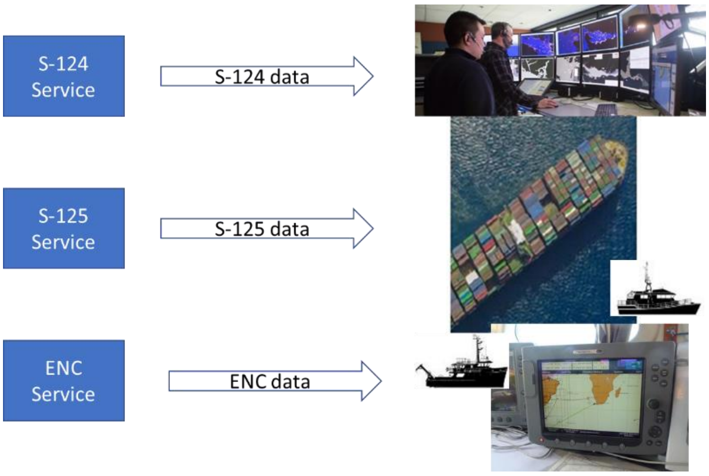

Figure 4 - Examples of users of AtoN information

Moreover, IMO recently approved amendments to the ECDIS Performance Standard and released the latest version of Resolution MSC 530(106) [10]. IHO has laid out a phased approach to the implementation of S-100 based services, where S-124 is in phase 1 and S-125 is in phase 2. It is important that S-125 development does not disrupt these plans as doing so could erode confidence in the overall process: rather, it is an opportunity for all involved in S-125 development more time to run test beds to get the details right before Phase 2 of the S-100 based services and full implementation of S-125 services is initiated.

3 CONCLUSION

All these envisioned benefits provide a strong rationale for why a S-125 service should be set up to support even safer navigation in national waters and explains why it could be advantageous to push AtoN data into an S-125 service as quickly as possible in the data dissemination process. In Figure 1, one can see that there are three avenues for AtoN information to arrive at the end user and this must be carefully managed in order to reduce the risk of confusion where different stages of the same information would require the end user to expend significant effort to deconflict the information presented. This risk is so significant that, in the opinion of the author, it risks undermining the whole value of a S-125 service and therefore necessitates careful coordination between all services that carry AtoN information to ensure that when AtoN information transitions from S-124 to S-125, there is a careful coordination to ensure integrity of the information and service. Similarly, AtoN information in S-125 should complement and enhance AtoN information in the ENC service. With S-100, where there are potentially several government services that issue data, the need for harmonization and cooperation is paramount for the end user. The goal of providing improvements to the situational awareness of the end user, must always be the priority as nations review their options for S-124 and S-125 services.

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[8] IHO / IALA S-100 / S-200 workshop related to ongoing NIPWG actions, NIPWG9-05.1A Rev1, September, 2022

[9] IHO S-98 Data Product Interoperability in S-100 Navigation Systems (Edition 1.0.0, May 2022)

[10] Resolution MSC.530(106) Performance Standards for Electronic Chart Display and

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AUTHOR BIOGRAPHY

Eivind Mong joined the Canadian Coast Guard in 2017 after having worked for nearly 20 years in the maritime industry. He is currently the Senior Adviser for e-Navigation and is actively working on implementing e-Navigation solutions in Canada. Mr. Mong is also the chair for the IHO Nautical Information Provision Working Group and leads the S-124 Project Team of the World Wide Navigational Warning Service Sub-Committee.

S5.3 S-100 Compatible AtoN Register in Cooperation ESRI Chart Technology (152)

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ABSTRACT

Establishment of a new solution for the Danish Maritime Authority's Aids to Navigation (AtoN) register was in 2021 decided to be "S-100" compatible (S-201). This paper describes the process of doing so, the partners involved and some of the obstacles and solutions found during the project. The Danish Maritime Authority AtoN register is viewed as critical software, containing the Danish Maritime Authority's total data on floating and fixed AtoN under the auspices of Denmark - a total of around 9,000 records. The previous AtoN register was based on an Oracle database with a custom built web based user interface. Support was however no longer available, the design of the user interface was inappropriate and often counter intuitive, leading to time consuming and faulty operations . Simultaneously the Danish Maritime Authority was phasing out Oracle solutions because of security issues and the high maintenance cost involved.

The chosen solution simplifies and streamlines a large number of workflows significantly. For example, the new system now has a map based graphical user interface which means that the execution of work orders can be based on a geographical overview of AtoN data without having to separately consulting a GIS program. The solution includes compatibility to S-201, which facilitates other S-100 based services such as S-124 and S-125 . The second part of the project will naturally be an integration with NIORD, the Danish Maritime Authority's system for handling MSI (Navigational Warnings and Notice to Mariners). This will streamline and secure a uniform efficient information flow regarding navigational safety in Danish waters. The work process of sending information to seafarers and the following necessary updates needed in the AtoN register was previously 100% manually processed, where the information was entered twice, first in NIORD and then entered into the AtoN register. The messages generated in NIORD will be S-100 compatible and ready to promulgate through the coming communication channels such as VDES.

KEYWORDS: S-100, AtoN Register, GIS map layer, MSI, VDES

1 INTRODUCTION

1.1 The need for a new AtoN Register

Above the main reasons for outfacing the old AtoN register in Denmark is noted being:

- The previous AtoN register was based on an Oracle database with a custom built web based user interface
- Support was no longer available, design of the user interface was inappropriate and often counter intuitive, leading to time consuming and faulty operations
- Simultaneously the Danish Maritime Authorities was phasing out Oracle solutions because of cost and security issues

Data from the AtoN Register is used in several of The Danish Maritime Authority's IT systems, e.g. NIORD in connection with issuing Notices for Seafarers, including chart corrections and navigational warnings, as well as a data layer within The Danish Maritime Authority's GIS systems. Integrations between these systems will reduce administration and reduce the risk of errors. Furthermore, the Aton data in is a vital component for the Danish Geodata Agency (the Danish Hydrographic Office) which are responsible for producing the sea charts in Denmark. The transfer of data presently takes place manually and on an ad hoc basis.

1.2 Gains

The positive gains are multiple:

- The Danish Maritime Authority will have an AtoN register on a fully supported and future-proof platform, which at the same time meets future needs in relation to options for data integration, simplification of work processes and fulfillment of national and international requirements for the display of data (open data)
- The Danish Maritime Authority will ensures that the standardisation process around AtoN data are implemented by an ongoing basis (IHO's S-100 standard)
- As the project is developed within the Danish Authorities own sphere, the project's deliveries can be completed at an acceptable development cost and operating expenses.
- Change in NIORD (MSI system) will ensure that data here is being integrated with the AtoN register and follow the roamap from IHO concerning S-124 and S-125.
- The Danish Maritime Authority will stay with a web based solution without an offline copy of the new registry on the buoy tender, as the buoy tender in Danish waters is on-line practically at all times.
- The new registry opens for an even closer collaboration between The Danish Maritime Authority and the Danish Geodata Agency - thus avoiding the need for redundant and possibly inconsistent AtoN data used by both authorities.

2 CONCEPTUAL OVERVIEW

2.1 The following drawing outlines the overall solution and is explained in more detail below.

In Figure 5. Shapes in white represent components developed as part of this solution. In contrast, grey shapes represent components external to the solution. Lines with arrow heads represent one directional data flows.

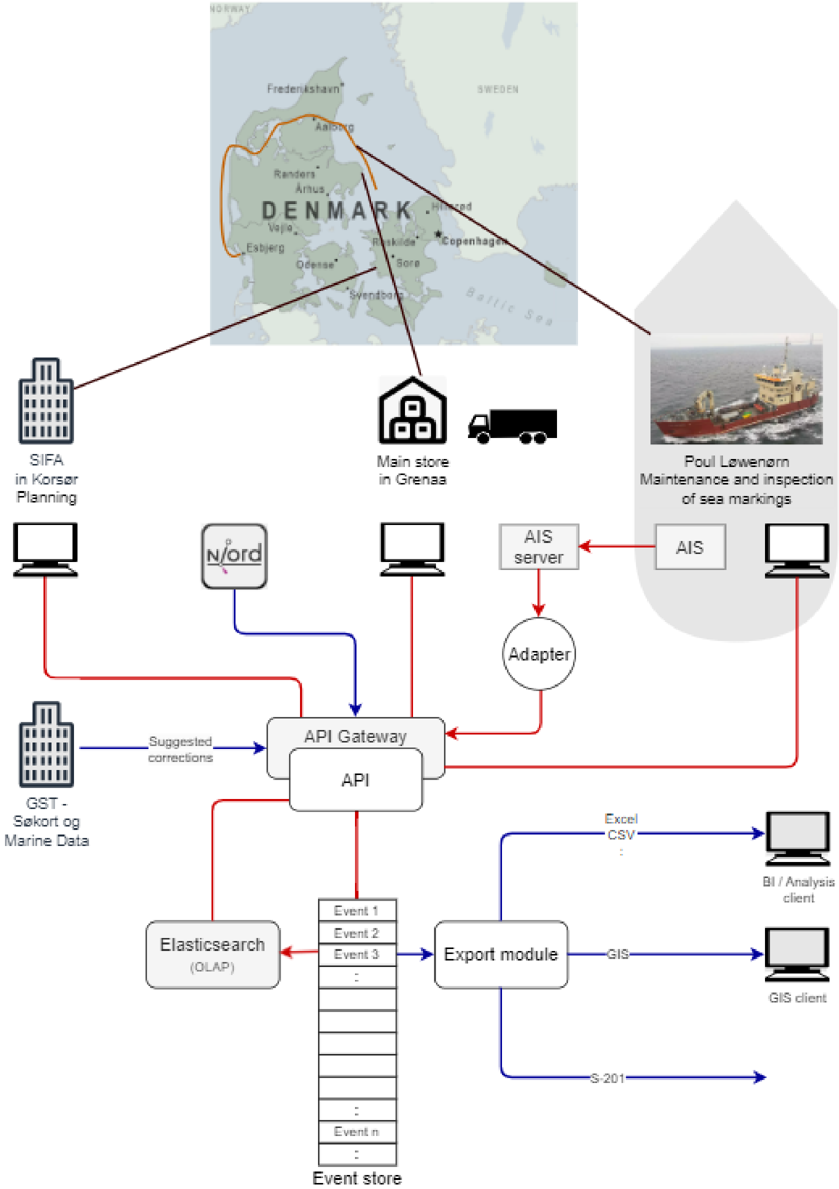


Figure 1: Outline of the overall solution

2.2 Basis information on premises

The Danish Maritime Authority is responsible for all safety of navigation at sea in Denmark. Maintenance and inspections of physical AtoNs are carried out by the crew on board the buoy tender POUL LØWENØRN. During the planning phase of this operation, many different aspects are considered.

AtoNs and related equipment is stored and repaired at the main store ashore (Grenaa). Equipment needed for maintenance/ replacements of AtoN on POUL LØWENØRN during a given voyage are transported by truck to the harbour wherever the buoy tender is docked at the time (if not in Grenaa).

A digital solution planned at the storage and maintenance facility ashore, and this will together with the crew on POUL LØWENØRN keep track of the status, characteristics, and history of every AtoN under the Danish Maritime Authorities' responsibility.

In the following sections, the chosen solution is named "the system" or "the registry", the latter hinting to the AtoN database in the core of the solution.

The system is used by the Danish Maritime Authority to communicate with the storage and maintenance facility ashore and the buoy tender concerning the equipment needed for a given voyage, the sailing route for the buoy tender on that voyage, and what is to be done during the voyage. During a voyage, the crew on the buoy tender will report to the Danish Maritime Authority what was done, and what was observed at each AtoN, and this might initiate chances to the initial voyage plan.

3 OVERALL DESCRIPTION OF SOLUTION

3.1 User Experience

Users will face a web interface showing a number of main tasks they can chose from. The main tasks are organised by user roles, which are related to the aforementioned locations - including the buoy tender.

When working in the user interface, the system will automatically remember specific identifiers and other key data from one screen to another screen, which might be needed by the user.

Some information is best represented on a map to allow a better overview.

Searching facilities are further examined and agreed upon during, the development of the solution.

It was viewed beneficial to use as many standard “off the shelf” products within the new register in order for easy access to support and up-dates.

3.2 Security

Users of any kind must provide their user name and password in order to gain access to the registry.

A few administrators will be allowed to assign roles to individual users. A given role will have access to functionality which is needed by that role. For example, one role will be allowed to update certain information while another will only be granted view access to that information.

During development, the Danish Geodata Agency will emphasize security by design and make use of best practice security mechanisms.

3.3 UI Technology

The UI is based on a commonly accepted framework, “*React*”, originally developed by Facebook. This is a very popular UI framework worldwide together with “*Angular*”.

The reason for choosing “*React*” is mainly that it is well suited for low data transfer capacity assumed available on the buoy tender . Furthermore, the “*Angular*” framework addresses large enterprise solutions with many users, far beyond the scope of this registry.

3.4 Data Transfer

By using “*React*” we ensure optimal utilization of data transmission bandwidth and consequently ensure acceptable response times on such a connection.

Whatever internet connections are used, it is up the Danish Maritime Authority to ensure sufficient stability of these connections, also on the buoy tender.

3.5 API

Best practice is to expose functionality via an API. The same API should be available no matter if it is used by workstations on the buoy tender or ashore.

Any complicated business logic will be hidden behind the API. An example is calculation of (remaining) battery life.

The AIS server is connected to the registry API via an adapter since we do not believe it will be possible to have AIS post requests to the system using the registry API.

3.6 Database

The data model covering the registry is extremely powerful, and fairly simple built. It is based on a pattern called Event Sourcing , and the type of database we call an Event Store.

Records / rows in an event store are immutable. Thus, there's basically only one write model, and that simplifies things. Changing the state of an object represented in the database is a matter of inserting an event that reflects the new state. Thus, create, update, and delete is done in the same manner.

In contrast there can be - and usually are - several read models, one for each purpose.

An event store is excellent at tracking history of its objects, meaning that it is capable of representing the state of the objects at any past time. That said, even event stores have their challenges and pitfalls, but as for the current solution, we find the pattern useful.

3.7 Analysis and Reporting

With a fixed frequency and/or triggered by a push on a UI-button, data from the event store can be transferred to databases from where reporting and further analysis are done.

When considering advanced search opportunities, we use the product called Elasticsearch. Elasticsearch can hold a vast amount of data and search for complex combinations of data with a modest effort. Although Elasticsearch is in general available for direct user interaction, in this solution Elasticsearch is hidden from the users.

Elasticsearch is different from BI-tools (like MS PowerBI) in that it doesn't require data in specific formats.

3.8 Integration With Other Systems

Anything that can be exported from the registry can be transferred to an external system.

Apart from that, it is possible to build integration capabilities with the NIORD system.

3.9 Data Migration

Immediately before operation start-up of the registry in use, all relevant Oracle data from the existing registry system was transferred to the new registry. This was done by a big bang process where updates to the existing database does not occur.

At the time of the migration, the migration process was automated and had been tested several times. After having transferred data one last time to the new production database, a number of semi-manual controls were be executed.

4 CRUCIAL ASPECTS OF THE SOLUTION, AVAILABILITY OF NEEDED INFORMATION

The solution proposed by the Danish Geodata Agency requires the system to be online and operational most of the time when in operation. This meant focus on improvement of the online properties of the underlying data transmission components and protocols. This approach is supported by a general trend worldwide that connectivity and data transmission stability are improving.

As a backup measure, should the ship be in an offline situation, a backup solution has been developed where the maintenance plan and other strictly necessary information is extracted from the registry to a spreadsheet and uploaded to the buoy tender immediately prior to a given voyage.

In case of an offline event, the crew locate the AtoNs from the information in the spreadsheet and update the sheet upon completion of the inspection or maintenance. When online again, or after ending the voyage, the spreadsheet is uploaded by the crew or by the Danish Maritime Authority, who then update the registry manually according to the spreadsheet.

5 FUTURE EXTENSIONS

It is possible to extend the architecture, and there are some obvious examples.

One such extension could be to add functionality allowing internal and external users for example at the Danish Hydrographic Authority to request corrections to specific data in the registry. The Danish Maritime Authority should be able to get a list of requests and approve or reject a given request. It should be possible for The Danish Maritime Authority to request additional information from the requester or to provide a rejection comment.

Another possible extension is the have the S-201 file generated on the basis of the new registry and exported via the new API.

Both extensions are illustrated in the drawing at the top of this page.

6 MAINTAINABILITY

A simple architecture facilitates high maintainability on the analysis and design level as well as at the operational level. At the construction level, using well known frameworks and tools reduces the risk of not being able to hire developers with sufficient competencies; the system is built using .Net/C#, React, and PostgreSQL as main products.

7 HOW ARE USER REQUIREMENTS SATISFIED?

The Danish Maritime Authority phrased a number of requirements to the new register.

These were non-negotiable requirements. However a group of user experts was formed. This group was involved from the very beginning, and any bumps along the road was discussed with the group ensuring compliance, with the aim and goals of the new system. New ways of working and awareness of possibilities arose from these meetings between the expert user group and the developers.

This had the added bonus for seamless implementation of the new system, as the group of expert users

8 REFERENCES

Project plan and documentation of the system within the Danish Maritime Authority.

9 CONCLUSION

The Danish Maritime Authority have arrived at the end of this project with a user friendly, robust and secure tool to handle all AtoN in the Danish waters. The system give a unique overview of all AtoN on the chart overview optimising voyage planning and maintenance intervals.

The system is compliant with S-201 and secures basis to introduce S-100 standards in the Danish MSI system NIORD within the time limits given by IHO and opening for the possibility to join an EU project to do just that.

10 ACKNOWLEDGEMENTS

Project management would like to thank the Danish Hydrographic Authorities developers and management; Niels Tvilling Larsen, Jens Søe Christiansen, Jesper Hedegaard Mortensen, Lasse Lyngdal Andersen and Karsten Zacher Nielsen.

We would also like to thank the expert user group for all their efforts, brilliant ideas, patience and understanding during the development of the system; Master Mariner, Captain of bouy tender: Lars Erik Darville, Storage handler and byer: Dorthe Deigaard, Master Mariner, Nautical Consultant: Karsten Søndergaard and Master Mariner, Nautical Consultant: Milan Falsing.

11 REFERENCES

[1] IALA. Standard 1060 Digital Communication Technologies with underlying Recommendations and guidelines

[2] IALA Standard 1070 Information Services with underlying Recommendations and guidelines

AUTHOR BIOGRAPHY

Ulla Bjørndal Møller is educated as a 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. Ulla 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 digitalization 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.

S5.4 MetOcean Data acquisition, transmission and sharing from fixed and floating Aids to Navigation (155)

Ronan Boyle, Director of eNavigation & Maritime Services, Commissioners of Irish Lights, Ireland

ABSTRACT

Irish Lights operates 204 individual sites for Aids to Navigation (AtoN) around the island of Ireland, composed of lighthouses, beacons and buoys. Ten of these sites are fitted with MetOcean sensors to capture meteorological and oceanographic parameters including wave height & period, wind speed and direction, and water temperature. Further use cases of sensors for current, turbidity and water quality measurement are under consideration. This paper will focus on the capabilities and limitations of fitting, operating, and maintaining MetOcean sensors on AtoN, including best practices for logging, transmission, warehousing and presentation of data. The paper will also provide details of collaboration with Met Éireann, Ireland's National Meteorological Service, to ensure data validation and quality control at four sites selected as part of a pilot study. Additional sites are planned as new requirements relating to flood forecasting and validation of weather forecasting models such as HARMONIE-AROME and ECMWF emerge, making these AtoN sites ideal as platforms for MetOcean sensors due to their proximity to shore and centres of population.

KEYWORDS: MetOcean, Data, Weather, Realtime, AtoN

1 INTRODUCTION

The Irish Meteorological service, known as Met Éireann, are collaborating with the General Lighthouse Authority for Ireland and Northern Ireland, known as the Commissioners of Irish Lights (Irish Lights), on a wave measurement project, with wave instruments deployed on Irish Lights aid to navigation buoys. The objective of this project is to provide near real-time Meteorological and Hydrographic data to Met Éireann from Irish Lights navigation buoys.

The meteorological and hydrographic information provided by Irish Lights supports stakeholders to make impact-based decisions and take actions that protect against the loss of life and to mitigate against damage to property and the environment.

The buoys will in effect be providing two services to Ireland, the first to assist in navigation of the seas around the coast of Ireland and secondly to provide observations that will be used by Met Éireann's to provide coastal flood forecasts and a sea area forecasting service. This joint approach will utilise the infrastructure twice rather than just once.

The location of the four test sites around the Irish coast will provide Met Éireann wave data at four key locations close to centres of population where currently there is no real time wave data available.

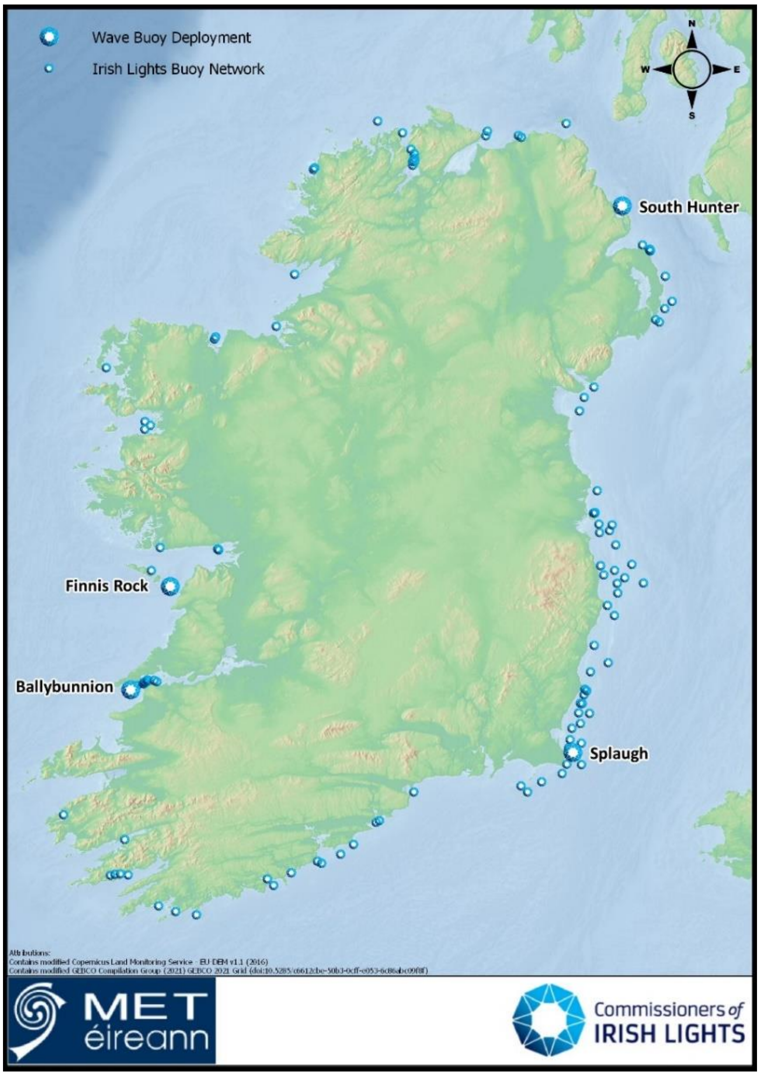


Figure 1: Location of Irish Light's Wave Buoys

The parameters required by Met Éireann and captured by the new instruments are outlined in **Error! Reference source not found.** below.

Table 1: Wave Parameters for Coastal Modelling

Requirement	**Tolerance**	**Mandatory/ Desired**
Spectral Significant Wave Height (H_{m0}):	+/- 100mm	Mandatory
Peak Wave Period (T_P):	+/- 0.5 seconds	Mandatory
Mean Wave Direction (qd):	+/- 10 degrees	Mandatory
Current Speed:	+/- 0.1m/s	Desired
Current Direction (qd):	+/- 10 degrees	Desired

The *mandatory* wave parameters identified in Table 1 represent the critical data required to operate a coastal flood forecast service in near real time. The *desired* parameters are required for coupled ocean models.

This report is a summary of the project undertaken by Met Éireann in collaboration with Irish Lights on the wave measurement project. There are five sections in the report including an Introduction and Conclusions as well as sections 2 to 4 which reflect the three stages of the project as shown below:

1. Background
2. Procurement & Testing- Stage 1
3. Deployment- Stage 2
4. Data transfer & assurance- Stage 3
5. Data Analysis
6. Conclusions & recommendations

2 BACKGROUND

Met Éireann's Flood Forecasting Division (FFD) aims to develop coastal predictive modelling systems for tidal, storm surge and wave forecasting for Ireland. The FFD approached Irish Lights with regards to collaborating on the collection of data from Irish Lights assets around the coast. The acquisition of near-real-time data will prove beneficial to the FFD before, during and after coastal flood events. The data will also be an important input to any new coastal flood forecast models and the verification of existing models.

Irish Lights is the General Lighthouse Authority for the island of Ireland, its adjacent seas and islands. Irish Lights, together with Trinity House in England, Wales and Northern Lighthouse Board in Scotland and the Isle of Man, operates the general Aids to Navigation (AtoN) service throughout the coastal waters of Ireland and Great Britain.

By utilising Irish Lights existing AtoNs (near and offshore) and Automatic Identification System (AIS) infrastructure Irish Lights can provide meteorological information at strategic locations around the coast of Ireland. The data collected from these sensors is used to populate the fields of the AIS Meteorological and Hydrographic data message (message 8) as defined in IMO's SN.1/Circ.289 and transmitted directly to the mariner.

3 PROCUREMENT AND TESTING: STAGE 1

3.1 Procurement

As part of stage one Met Éireann procured and provided Irish Lights with wave instruments, data loggers and modems for their navigation buoys. A new quality control process was developed by Met Éireann in collaboration with Irish Lights and the Irish Marine Institute. Irish Lights installed, tested, and commissioned the sensors on each buoy to enable the transmission of the data. Met Éireann developed the Quality Control (QC) checks for the data as part of the testing phase of the project.

Met Éireann procured the required equipment for this project on behalf of Irish Lights. Met Éireann prepared tender documents which Irish lights reviewed, for the supply of the wave instruments which included the following:

- Wave sensor
- Wave instrument cabling & connectors
- External compass
- Brackets and mounting.

The performance criteria for the wave sensor were specified in the tender documents as shown in Table 2 Performance Criteria of wave sensor below.

Table 2 Performance Criteria of wave sensor

Requirement	Measurement range at least	Resolution	Accuracy	Averaging Interval:
Spectral Significant Wave Height (H_{m0}):	0 to 25 meters	0.001m	±50mm or 1%	10 minutes average
Peak Wave Period (T_P):	1.5 to 30 seconds	0.05 sec	±0.5sec or <1%	10 minutes average
Mean Wave Direction (qd):	0-360 degrees	0.5 degree	±2degrees	10 minutes average

The wave sensor supplied for the project was the SeaView SVS-603 HR. For the data loggers, the Campbell Scientific CR6 was selected for this project. A current sensor was also to be procured and tested at one location to try and capture the current speed and current direction data, i.e., desirable parameters. As the current parameters are desired but not mandatory for this trial, this was to be tested on one buoy only. After research by Irish Lights and Met Éireann's teams it was concluded that no existing current sensor was suitability to be deployed on a navigation buoy. This was due to technical difficulty and health and safety concerns.

As the trial progressed it was decided to conduct a comparison between the wave sensor and a neighboring Waverider. This required the procurement of a Waverider from the Marine Institute at the Finnis location. For South Hunter and Splaugh Irish Light used their existing Waverider and for Ballybunnion the Shannon Foynes and Port Company Waverider data was used. All the Waveriders used were Datawell Waverider.

3.2 Testing and Commissioning

Irish Lights evaluated and commissioned the wave sensors and data loggers on four of their existing wave buoys. An interface for data had to be developed along with test of the new wave sensors before they were deployed. This work was carried out by Irish Lights at the facilities in Dun Laoghaire, Dublin.

The testing was carried out in line with the "*WMO No. 8, Guide to Meteorological Instruments and Methods of Observation) Data Buoy Cooperation Panel 10.3- Guidelines to Oceanographic Instruments*".

The World Meteorological Organization (WMO) had set accuracy requirements for wave sensors as shown in Table 3 Wave sensors Accuracy requirements below.

Table 3 Wave sensors Accuracy requirements

Unit:	Scale	Operational requirement Accuracy
Significant wave height:	m Dominant wave direction: degrees	5-10% or 10 -25cm
Dominant wave period:	s	0.1 -1 second
Wave 1D energy frequency spectrum:	m2. Hz-1	10%
Wave directional energy frequency spectrum:	m2. Hz-1. rad-1 7.1.4.	10 degrees

The buoys were configured to transmit near real-time spectral wave height, peak wave period and mean wave direction data at 20-minute intervals.

To enable near-real-time monitoring and reporting from the buoy, the wave instrument is connected to a data logger, the data logger enables recording of wave data from the wave instrument. This required programming of the logger to decode the data from the wave instrument and reorganising the incoming data into tables.

The data logger was then programmed to output the most recent summary data values into a proprietary message, which was then sent to the buoys onboard AIS unit. The AIS unit on the buoy then transmits the data to one of Irish Lights base stations via VHF. The base station then forwards the data onto Irish Lights headquarters.

At Irish Lights Headquarters the messages from the buoys are decoded and stored in a database, from here they are forwarded onto Met Éireann, and the Marine Institute.

As Irish Lights buoys location are generally within range of mobile networks the buoys were fitted with onboard 3G/4G modems, which enabled a secondary method of accessing the data stored in the data logger. This also enabled access to view the status of the equipment and change configuration settings of the wave instrument. For example, the date and time can be corrected on the wave instrument without a physical visit to the station.

For the installation of the wave instrument on Irish Lights buoys, the ideal location for the instrument is at or as near as possible to the roll centre of the buoy. This placed the instrument near to the steel hull of the buoy. Therefore, a reference compass was also incorporated, and positioned as far away as reasonably possible from materials that may cause interference. Due to the design of the navigational buoy and the location of the battery compartment the wave instrument was located 1.5 meters above the buoys roll centre, the location and configuration of the sensor were discussed in detail with the SeaView.

Irish Lights buoys are used as a navigational mark for safe navigation, the main parts of a buoy are the tail tube, buoy hull, daymark and topmark, see Figure 6: Irish Lights buoy example below.

- The purpose of the tail tube is to help keep the buoy vertical and stable, the tail tubes are hollow cylindrical tubes with ballast weights at the end.
- The buoys hull provides buoyancy for the buoy, most Irish Lights buoys are hollow steel hulls, they are also coloured in a specific way so the mariner can visually identify the type of buoy.
- The daymark is shaped and coloured in specific ways so the mariner can visually identify the type of buoy. Irish Lights daymarks are constructed of marine grade aluminium. The daymark also displays the name of the buoy and acts as a frame for mounting solar panels on the outside, with batteries and electronic enclosures located inside the daymark. The buoys light, **Ra**dar bea**con** (RACON), aerials, AIS unit are mounted on the top of the daymark.
- The topmark is used by the mariner to visually identify the type of buoy.

Irish Lights buoys are compliant with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) buoyage system for Region A.

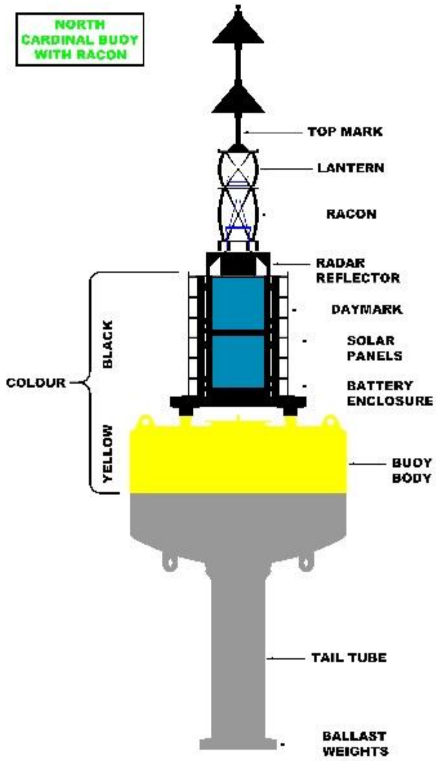


Figure 6: Irish Lights buoy example

3.3 Irish Lights Moorings

Irish Lights navigational buoys are in relatively shallow water; therefore, the mooring configurations are normally as follows and see Figure 8 Example of Datawell mooring , below:

- Bridle chain: The Bridle is made up of two equal lengths of chain, attached to the mooring eyes on the underside of the buoys hull. Each mooring eye is located at opposite sides of the hull. The two chains are joined together some distance below the buoy. Just below this join there is a swivel which allows the buoy to rotate.
- Riser chain: The Riser chain weighs around 29 kilos per meter. The total mooring chain length is calculated so that it forms a catenary curve from the seabed to the buoy. This allows the buoy to follow the waves and reduces vertical forces on the moorings.
- Sinker: The sinker is a large weight providing an anchor point for moorings to the seabed. The advantage of sinkers is that they resist loads in all directions. The buoy can swing around the sinker with the direction of water flow. In some instances, multiple sinkers are linked together to hold the buoy in position.

Detailed information for AtoN moorings design can be found in IALA Guidance document: G1066 The Design of Floating Aid to Navigation Moorings. (IALA, 2009)

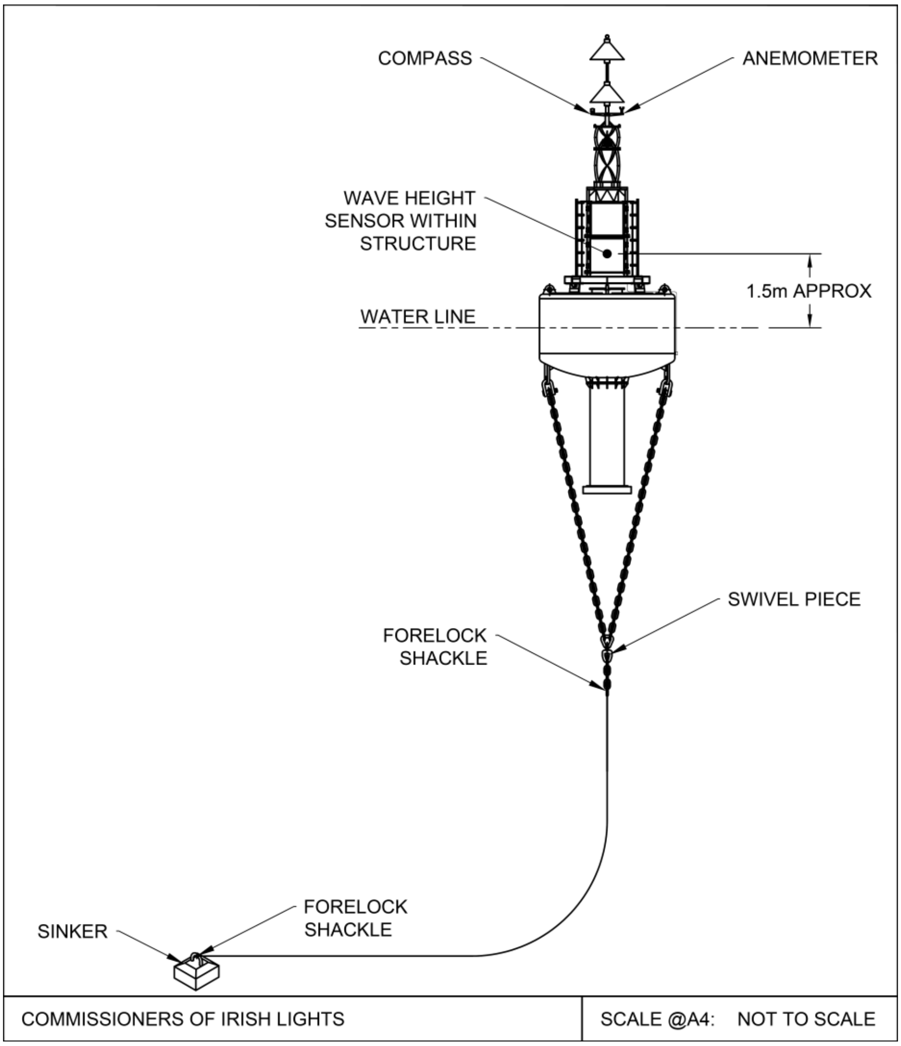


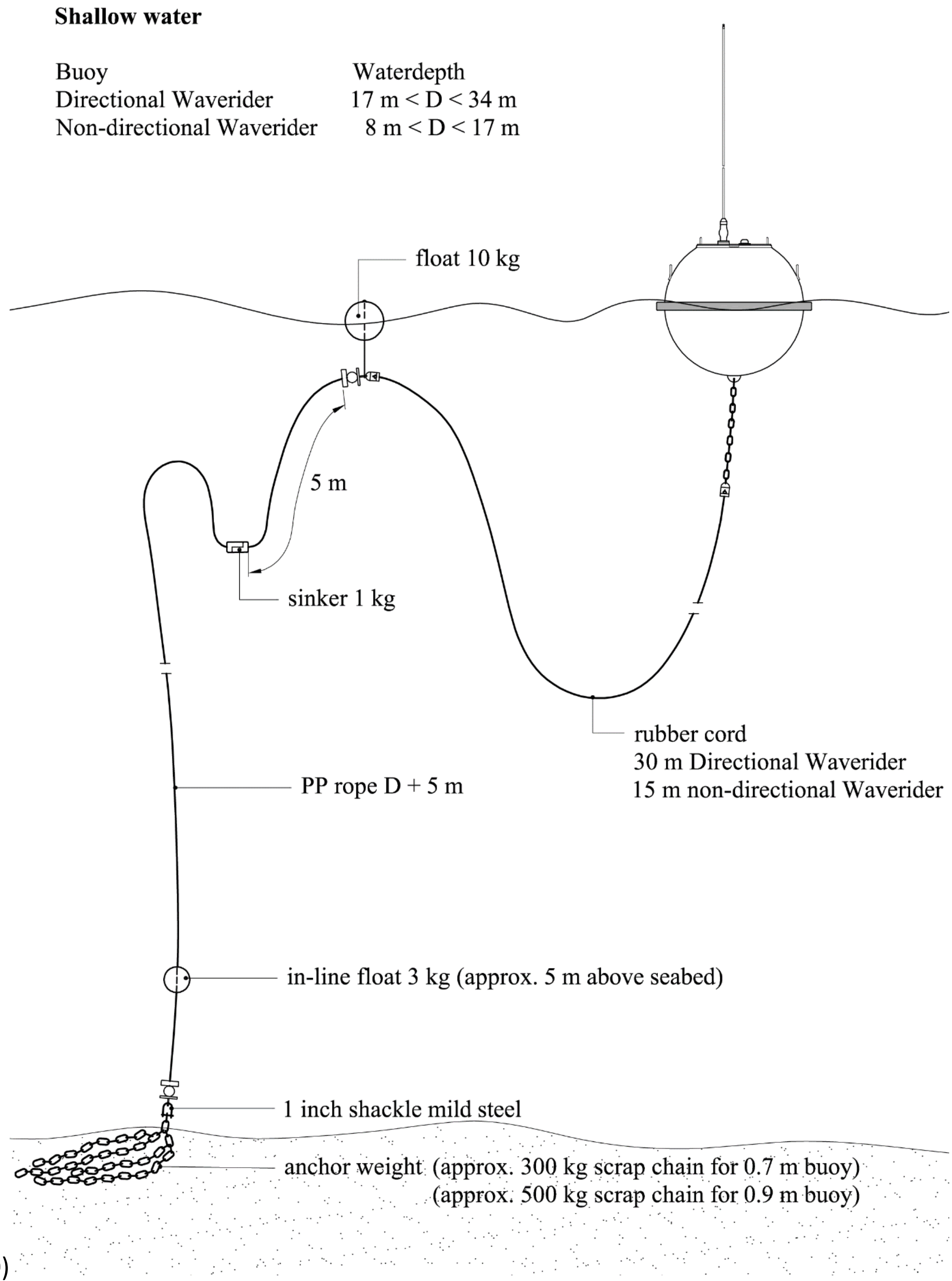
Figure 7 Irish Lights buoys mooring example.

3.4 Details of Waverider

The Waverider buoy has been the unofficial industry standard in wave measurement for many years and has been used around the world as the de-facto validation reference standard for measuring waves.

The Datawell buoy hull type used in this trial are the 90cm diameter spherical buoy, with a single point mooring. The configuration of Datawell Waverider moorings is specifically detailed in the manual for various depths. The Datawell Waverider mooring is designed to allow the buoy to follow the wave as accurately as possible.

Example of Datawell mooring configuration (Datawell, 2020):



(Datawell, 2020)

Figure 8 Example of Datawell mooring configuration.

Datawell has undertaken detailed research to ensure that the mooring has sufficient flexibility to allow the buoy to accurately follow the orbital motion of the water.

Details of Datawell Waverider mooring design from Datawell Waverider Reference Manual (Datawell, 2020)

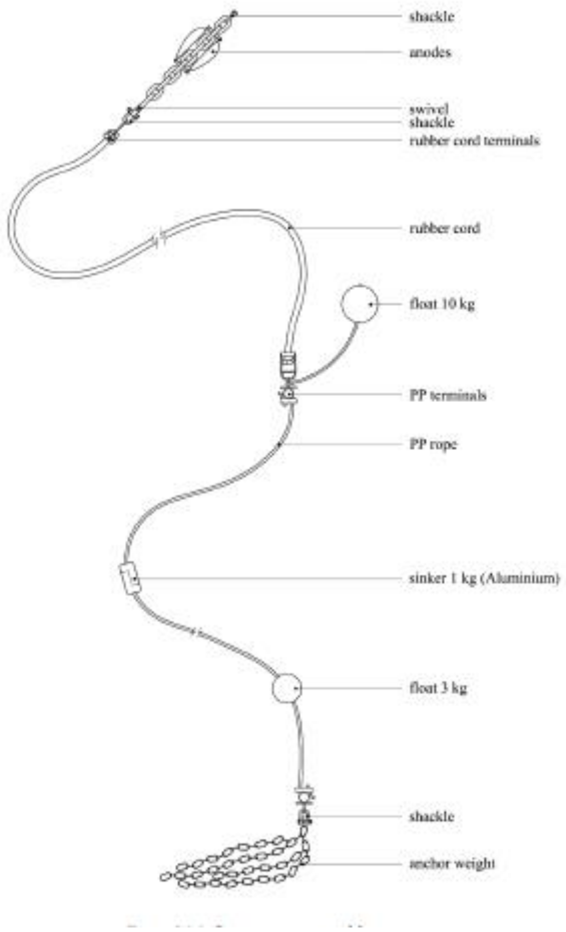


Figure 9 Example of Datawell mooring design.

Once testing and commissioning was completed the wave sensors and other instruments were installed on the wave buoys on the following dates as outlined below:

- Finnis SeaView wave sensor installed on 25th September 2021
- Splaugh SeaView wave sensor installed on 09th October 2021
- South Hunter SeaView wave sensor installed on 14th November 2021
- Ballybunnion SeaView wave sensor was installed 05th March 2022

3.5 Quality Control of the Data

Met Éireann developed Quality Control (QC) checks as part of their pre-operational processing of the buoy data. Code was written in Python and is available on GitHub. The checks developed were based on international best practices, as outlined in *Integrated Ocean Observing System, 2019. Manual for Real-Time Quality Control of In-Situ Surface Wave Data Version 2.1: A Guide to Quality Control and Quality Assurance of In-Situ Surface Wave*" (https://ioos.noaa.gov/ioos-inaction/wave-data/). Note that this manual lists QC tests for wave measurements collected by a range of instruments under various configurations, thus only a subset of the tests was relevant to the trial wave measurements.

This manual provides different tests for Short-Term and Long-Term data time series, which are defined by the manual as follows:

1. *Short-term (ST):* a time series of sample data points logged during a single sampling period. Each ST sample provides a single determination of wave characteristics, such as significant wave height, peak period, peak direction, and wave spread (collectively referred to as the bulk wave parameters). Editing and gap filling of the ST time series data are allowed.

2. *Long-term (LT):* a time series of wave data points produced from successive ST samples, typically a series of bulk wave parameters and other wave characteristics.

In this trial project, LT wave data (Spectral Significant Wave Height, Peak Wave Period and Mean Wave Direction) was received by Met Éireann in near real-time, whilst ST data was only available following retrieval of the data logger SD card from the buoy. Thus, different tests were developed for a) near real-time QC of LT data and b) delayed-mode QC of ST data:

a) LT Near Real-Time QC tests:

- Test 15: Mean and Standard Deviation
- Test 16: Flatline test
- Test 19: Max/Min/Acceptable Range
- Test 20: Rate of Change

b) ST Delayed-Mode QC tests:

- Test 9: Gap Test
- Test 10: Spike Test.
- Test 11: Range Test
- Test 12: Shift Test
- Test 13: Acceleration Test

All tests were developed using Python code and uploaded to GitHub. They were created with sample data provided by Irish Lights, in preparation for when live data would be received.

4 DEPLOYMENT STAGE 2

In stage two, the wave buoys were deployed by Irish Lights using their ship, the ILV Granuaile. The dates of deployment of the Wave buoy with the new sensors are shown in Table 4 Wave Buoy Deployment Dates below. During the project Irish Lights visited the wave buoys on six different occasions, see Table 4 Wave Buoy Deployment Dates below, as part of the maintenance schedule and to fix any issues with the wave sensors.

Table 4 Wave Buoy Deployment Dates

Name	Date of deployment	Maintenance Visits
Ballybunnion	5th March 2022	24/03/2022 12:00 to 12:30 18/06/2022 10:44 to 11:54 01/07/2022 10:15 to 12:17
Finnis buoy (Galway Bay)	26th September 2021	06/03/2022 09:24 to 10:53
South Hunter buoy (Larne)	12th October 2021	17/02/2023
Splaugh buoy (Rosslare)	09th October 2021	06/05/2022 11:10 to 18:55

4.1 Datawell Waverider

Alongside the SeaView wave sensors on Irish Lights buoys, at all sites, a Datawell Waverider buoy was deployed alongside for comparison. It was proposed to collect three months of data at each of the locations from the Waveriders.

Irish Lights deployed their Waverider at Splaugh and South Hunter. Shannon and Foynes Port company have a Waverider near the Ballybunnion buoy and they agreed to supply data to the project. In term of Finnis, Met Éireann engaged the Marine Institute to deploy their Waverider. The schedule of the Waverider deployments is outlined in Table 5 Waverider Deployment Dates along with the parameters they collect in Table 6 Parameters collected at each Wave Buoy below.

Table 5 Waverider Deployment Dates

Name	Date of deployment	Date of collection
Ballybunnion	04/05/2022	Ongoing
Finnis buoy (Galway Bay)	1/5/22	10/01/23
South Hunter buoy (Larne)	01/11/2022	Ongoing
Splaugh buoy (Rosslare)	10/10/2021	06/10/2022

Table 6 Parameters collected at each Wave Buoy

	South Hunter	Splaugh	Finnis	Ballybunnion
Pressure	No	No	No	No
Wind Dir	Yes	Yes	Yes	Yes
Wind Speed	Yes	Yes	Yes	Yes
Temp	No	No	No	No
Dew Point	No	No	No	No
Humidity	No	No	No	No
Wave Period	Yes	Yes	Yes	Yes
Wave Height	Yes	Yes	Yes	Yes
Sea Temp	Yes	Yes	Yes	Yes

5 DATA TRANSFER

For stage three of the project, with the data transmission from the buoys initiated, the next steps were to display, test, verify and quality control the data to ensure it is fit for purpose. The new sensors are producing wave height, wave period and wave direction measurements. The data produced by Irish Lights is provided in near real-time via an FTP to Met Éireann.

Near real-time data is transmitted from the CIL AIS land station to MÉ by sFTP. A script checks that the file format is as expected and rejects duplicate records before applying LT QC tests as described in the previous section. QC'd data is formatted into csv and XML formats for ingestion into the climate database and display on the met.ie website respectively.

The product for this data is openly available in near-real-time at the following websites:

- Met Éireann - https://www.met.ie/forecasts/marine-inland-lakes/buoys
- Irish Lights - https://cilpublic.cil.ie/metocean/

See figure 6 to 9 below for details.

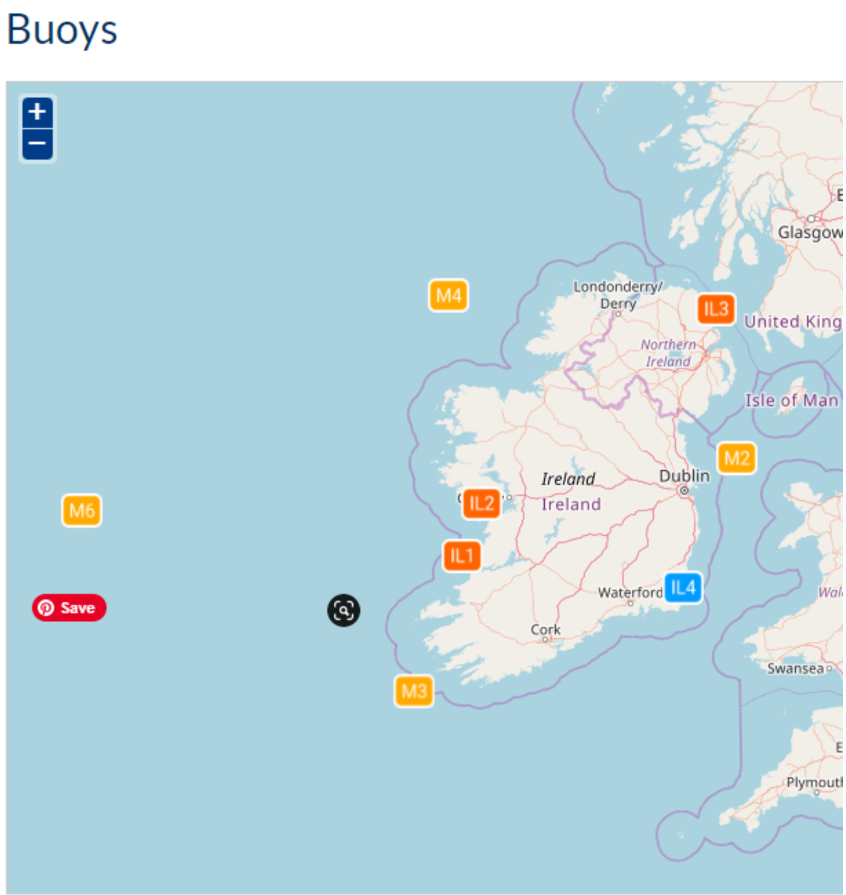
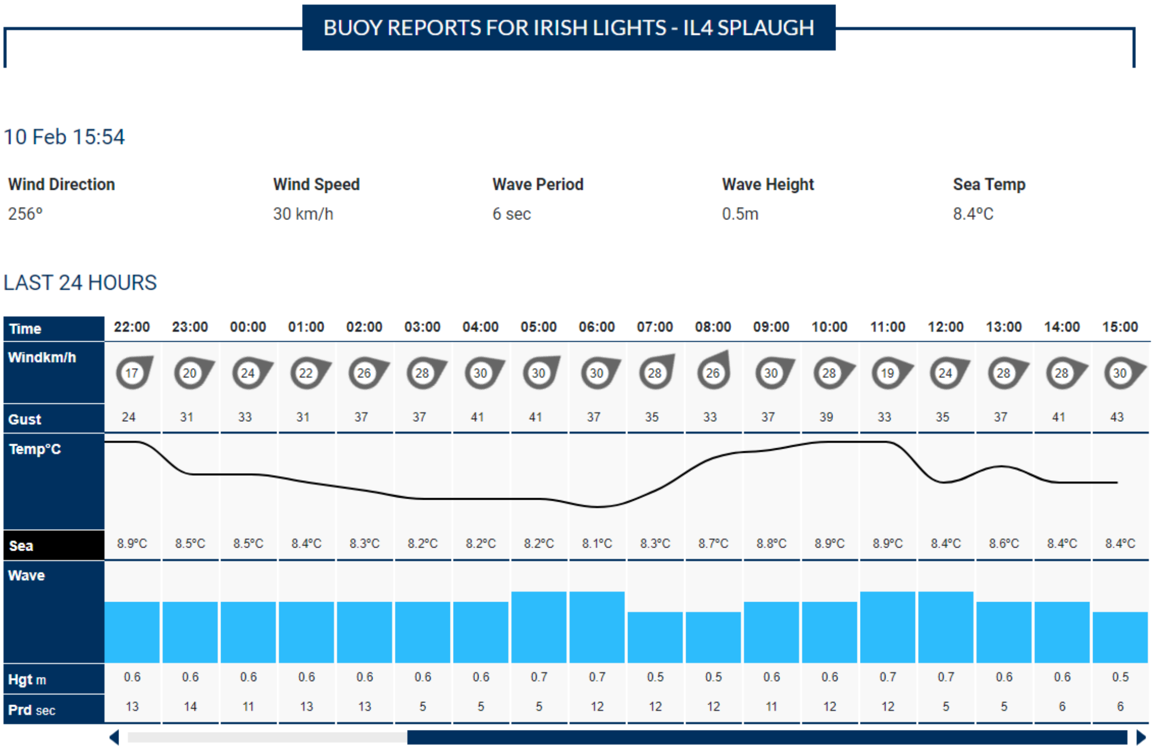


Figure 10 Met Eireann's Buoy Map on website



BUOY REPORTS FOR IRISH LIGHTS - IL4 SPLAUGH

10 Feb 15:54

Wind Direction	Wind Speed	Wave Period	Wave Height	Sea Temp
256°	30 km/h	6 sec	0.5m	8.4°C

LAST 24 HOURS

Time	22:00	23:00	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00
Windkm/h	17	20	24	22	26	28	30	30	30	28	26	30	28	19	24	28	28	30
Gust	24	31	33	31	37	37	41	41	37	35	33	37	39	33	35	37	41	43
Temp°C																		
Sea	8.9°C	8.5°C	8.5°C	8.4°C	8.3°C	8.2°C	8.2°C	8.2°C	8.1°C	8.3°C	8.7°C	8.8°C	8.9°C	8.9°C	8.4°C	8.6°C	8.4°C	8.4°C
Wave																		
Hgt m	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.5	0.5	0.6	0.6	0.7	0.7	0.6	0.6	0.5
Prd sec	13	14	11	13	13	5	5	5	12	12	12	11	12	12	5	5	6	6

Figure 11 Met Eireann's Details for the Splaugh Wave Buoy

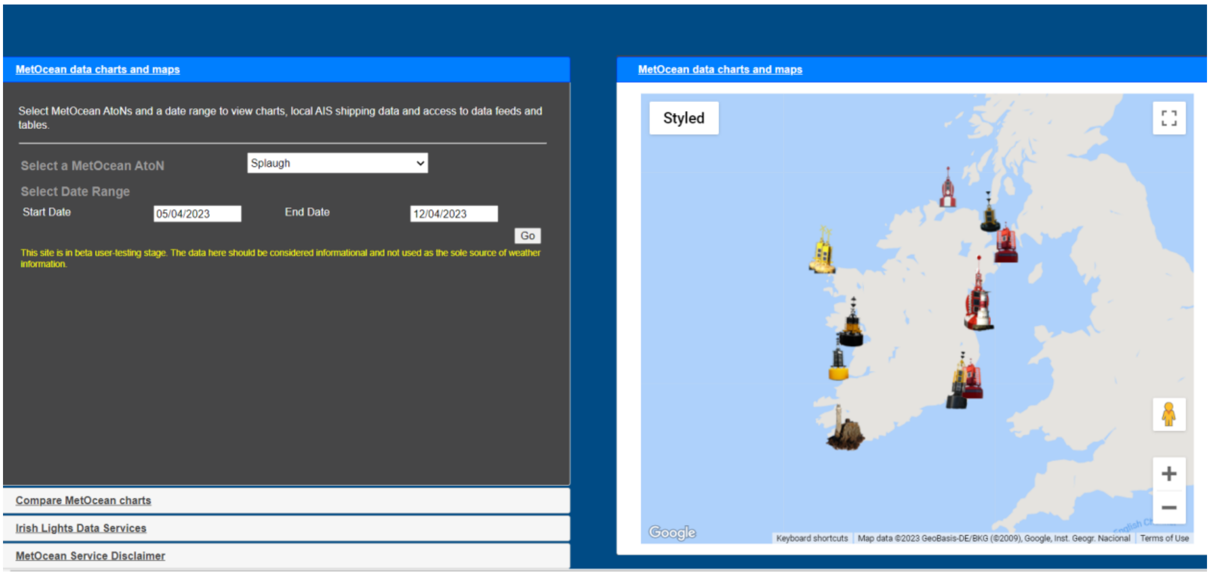


Figure 12 Irish Lights Overall Buoy Data page

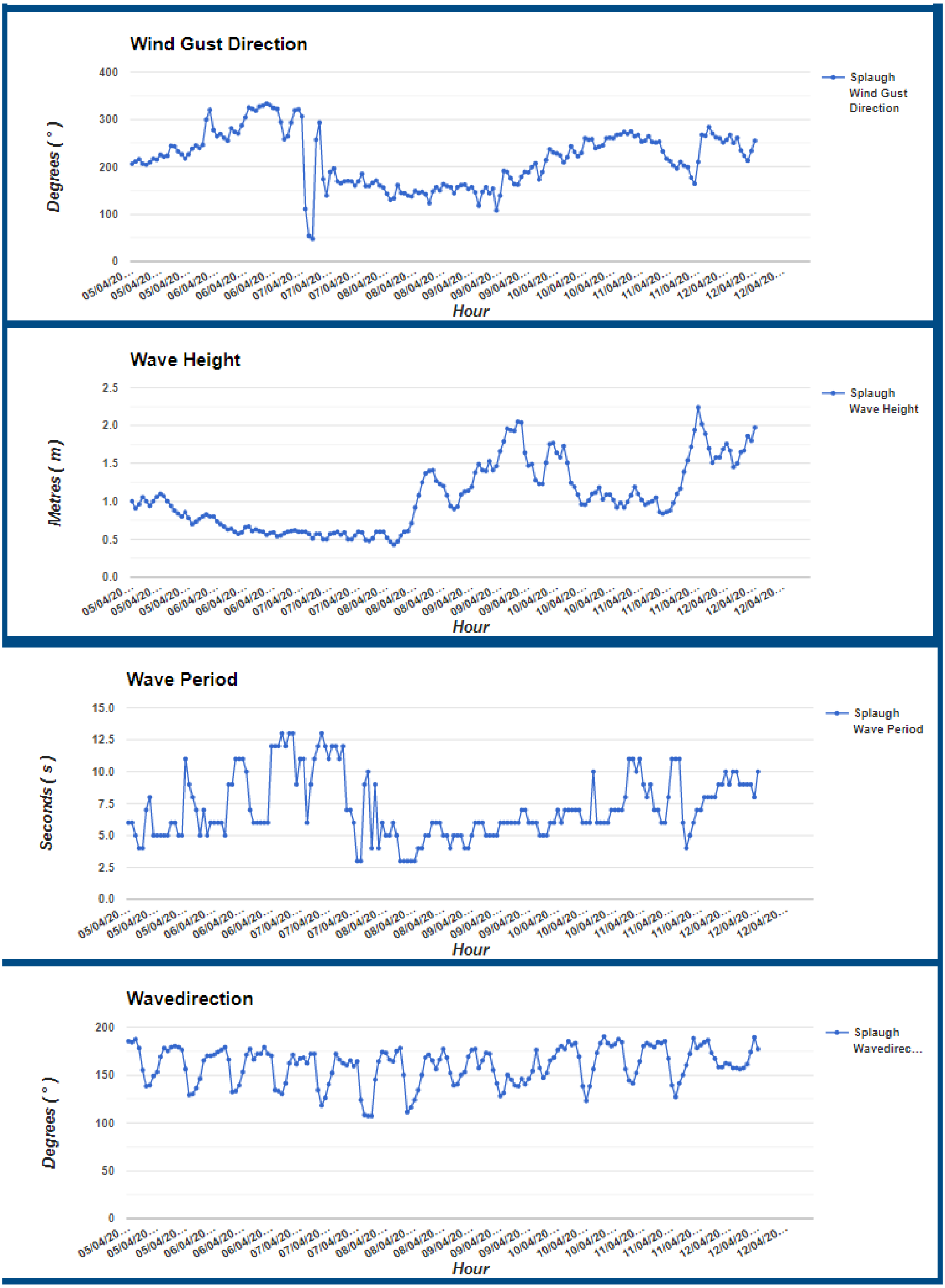


Figure 13 Irish Light's Splaugh Wave Data display

For the Datawell Waverider data the information was received via data transfer from the suppliers to Irish Light's and Met Éireann.

6 DATA ANALYSIS

To establish the accuracy of the new wave sensor within the Navigation Buoy, the data collected was compared to other available wave data. This was carried out initially by comparing the data collected by the wave sensor against the Marines Institute's Wave Model. This process informs us if the wave sensor was working and producing reasonably accurate data. A comparison with model data was useful for an initial check, however, a more in-depth comparison with the Waverider was used to verify the suitability of deploying a wave sensor on a navigation buoy.

6.1 The Wave Model versus Wave sensor results

The Marine Institute were supplied with the initial data from three of the wave sensors at Finnis, South Hunter and Splaugh for November 2021 to mid-January 2022. MI have an existing ROMS wave model which encompasses the trial locations. They compared the significant wave height, Peak Wave Period, and wave direction from the SeaView wave sensor to the model outputs for the same period. The time series from both sources wee plotted against each out and a visual inspection of the results was carried out, sees Figure 14 to Figure 16 below.

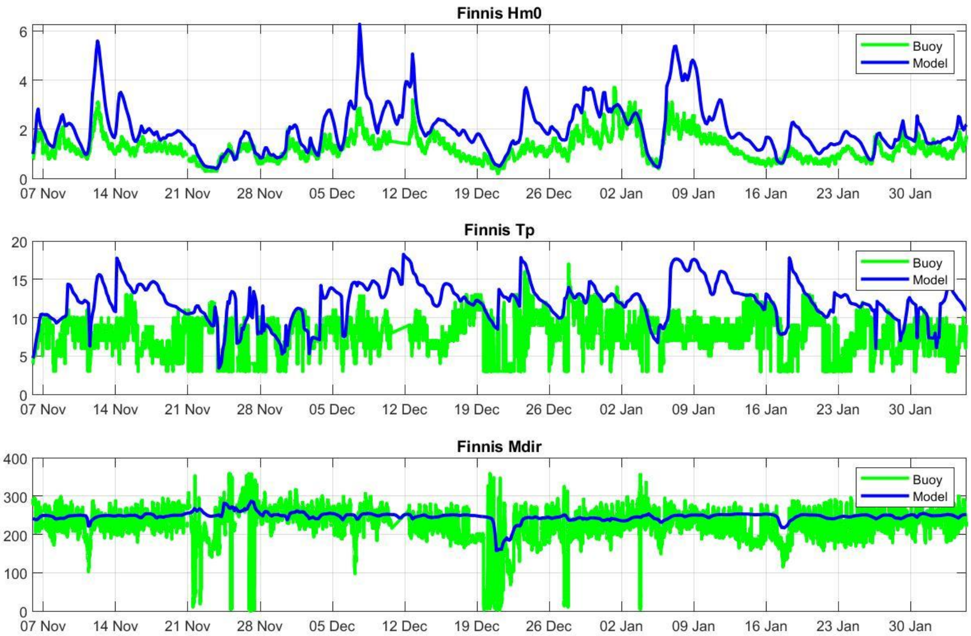


Figure 14 Finnis SeaView wave sensor versus MI Wave Model

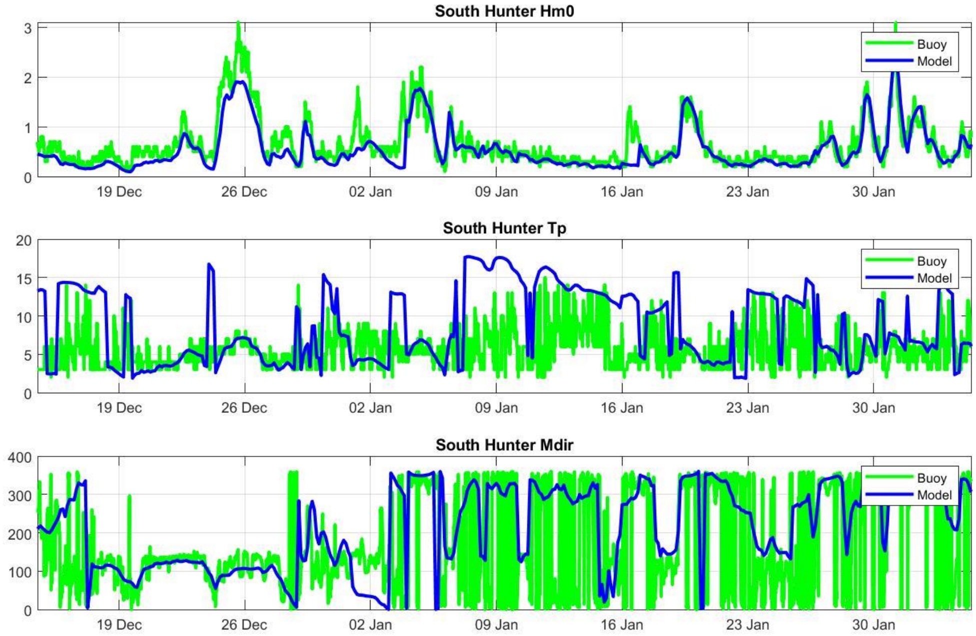


Figure 15 South Hunter SeaView wave sensor versus MI Wave Model

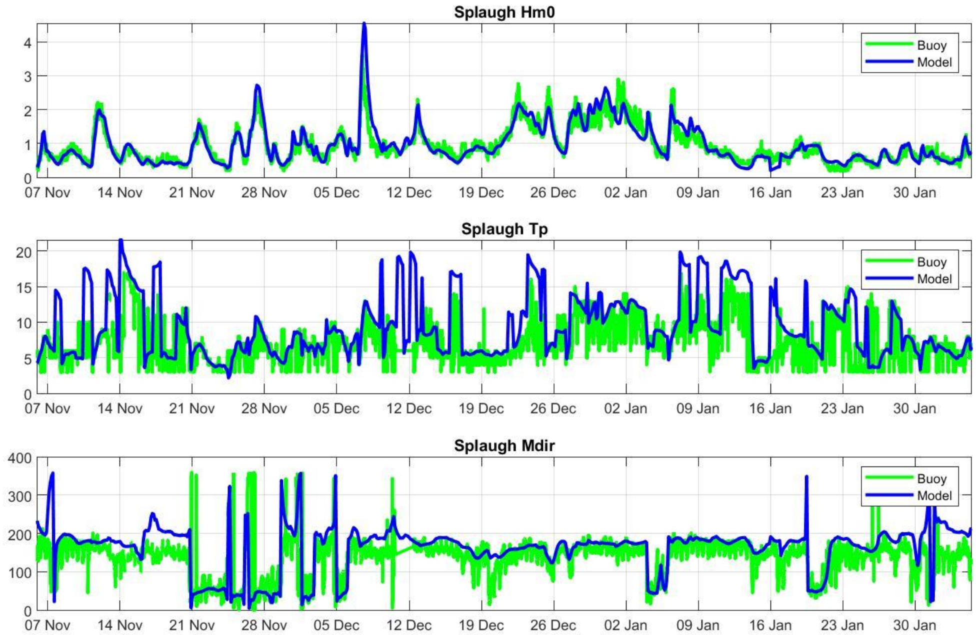


Figure 16 Splaugh SeaView wave sensor versus MI Wave Model

After this initial comparison was carried complete for a period of eight weeks at three of our locations, the next step was to deploy the Waverider next to the wave sensors to get a more accurate comparison.

6.2 Comparison of Wave Senor (SeaView) and Waverider (Datawell)

Table 7 Buoy locations

	Depth (m)	Buoy Positions (WGS84)		Distance (km)
Buoy details		Latitude	Longitude	
IL1 (Ballybunnion buoy)	16	52°32.528'N	09°46.944'W	
Ballybunnion Datawell Waverider MK 3	16	52°32.522'N	09°47.086'W	
IL2 (Finnis buoy)	50	53°02.812'N	09°29.126'W	
Finnis Datawell Waverider MK 4	45	53°02.964'N	09°29.161'W	
IL3 (South Hunter buoy)	37	54°52.691'N	05°45.284'W	
South Hunter Datawell Waverider MK 3	35	54°52.799'N	05°45.180'W	
IL4 (Splaugh buoy)	12	52°14.363'N	06°16.784'W	
Splaugh Datawell Waverider MK 3	15	52°14.425'N	06°17.056'W	

The Wave sensor (SeaView) data were collected at 20-minute intervals and Waverider (Datawell) data were collected at 30-minute intervals. A direct comparison of the time series data collected from each sensor was therefore not possible due to the differing collection intervals. A resampling approach was used to allow comparison of the two time series. The data was resampled to calculate hourly averages for significant wave height, maximum wave height, mean wave period, peak wave period and mean wave direction for comparison purposes. Subsequently, a quantitative comparison between the wave sensor and Waverider was conducted by calculating the bias, Root Mean Squared Error (RMSE) and Pearson's correlation coefficient.

$$Bias = \frac{1}{N}\sum_{i=1}^{N}(Wave\ rider - Wave\ sensor)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Wave\ rider - Wave\ sensor)^{2}}$$

Significant wave height displayed the best agreement between the SeaView wave sensor and Datawell Waverider with bias ranging from -0.08m at Finnis to 0.49m at Ballybunnion, RMSE from 0.09-0.63m and Pearson's correlation coefficients above 0.97. Bias indicated that the wave sensor underestimated significant wave height at all sites except for Finnis. The Splaugh and South Hunter sites exhibited the highest agreement while Ballybunnion showed the lowest. This finding was consistent with the greater distance away of the Datawell Waverider at this site.

For maximum wave height the bias ranged from -0.15m at Finnis to 0.79m at Ballybunnion, RMSE from 0.22-0.93m22-1.03m and Pearson's correlation coefficients from 0.92-0.98. Again, Ballybunnion showed lowest agreement among all sites as maximum wave height was underestimated by the wave sensor at Ballybunnion and South Hunter and overestimated at Finnis and Splaugh in comparison to the Waverider.

Mean wave period indicated a positive bias of between 0.11s at South Hunter and 1.30s at Splaugh, RMSE of 0.39-1.51s and correlation coefficients of 0.84-0.94. At each site the wave sensor underestimated mean wave period compared to the Waverider.

Peak wave period showed the poorest agreement among all calculated wave metrics with bias of between 1.10s at South Hunter and 1.66s at Finnis, RMSE of 2.49-3.00s and correlation coefficients of 0.61-0.73. The wave sensor also underestimated peak wave period at each monitored site.

Mean wave direction showed lower bias values of -0.717° and -5.45° at Ballybunnion and Splaugh in comparison to that observed at South Hunter (-18.68°) and Finnis (-30.91°). At South hunter and Finnis there was greater variation in mean wave direction which may have contributed to the divergence observed between the Waverider and wave sensor.

Table 8 Results of Datawell Waverider and SeaView wave sensor comparison analysis.

	Finnis	Splaugh	Ballybunnion	South Hunter
Sig. Wave Height				
Bias (± SE)	-0.08m ± 0.00	0.03m ± 0.00	0.49m ± 0.01	0.04m ± 0.00
RMSE	0.19m	0.12m	0.63m	0.09m
R	0.97	0.98	0.99	0.97
Max Wave Height				
Bias (± SE)	-0.15m ± 0.00	-0.02m ± 0.00	0.79m ± 0.02	0.02m ± 0.01
RMSE	0.35m	0.22m	1.03m	0.22m
R	0.96	0.97	0.98	0.92
Mean Wave Period				
Bias (± SE)	0.22s ± 0.01	0.41s ± 0.01	1.30s ± 0.02	0.11s ± 0.02
RMSE	0.83s	0.75s	1.51s	0.39s
R	0.84	0.9	0.93	0.91
Peak Wave Period				
Bias (± SE)	1.66s ± 0.04	1.40s ± 0.05	1.11s ± 0.05	1.10s ± 0.11
RMSE	3.00s	2.97s	2.33s	2.49s
R	0.67	0.7	0.71	0.61
Mean Wave Direction				
Bias	-30.91°	-5.45°	-0.17°	-18.68°
Sample size	3072	2438	1659	417[1]

[1] SE indicates standard error

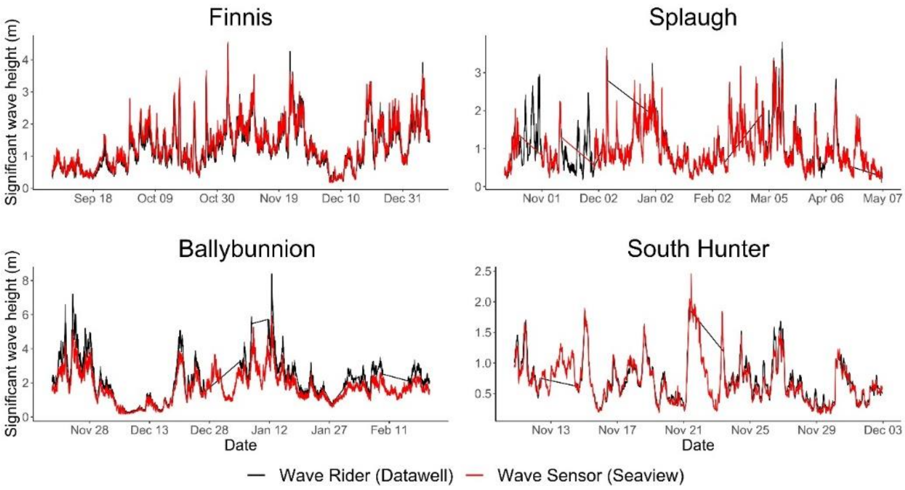


Figure 17 Time series of significant wave height for the Datawell Waverider and SeaView wave sensor. (Straight lines connecting datapoints indicate gaps in the data.)

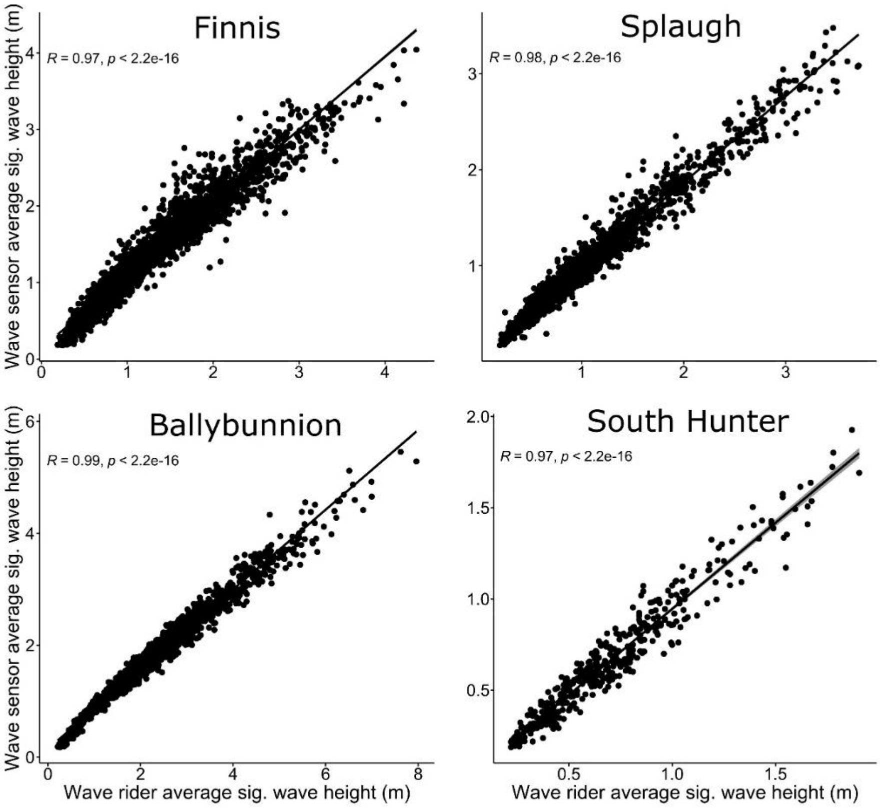


Figure 18 Scatter plot displaying Pearson's correlation coefficient and significance value for hourly averaged significant wave height between Waverider and wave sensor.

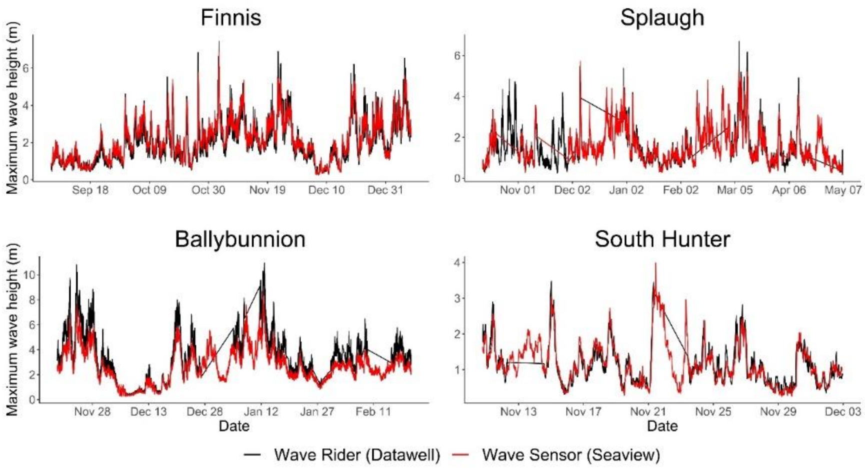


Figure 19 Time series of maximum wave height for the Datawell Waverider and SeaView wave sensor. (Straight lines connecting datapoints indicate gaps in the data.)

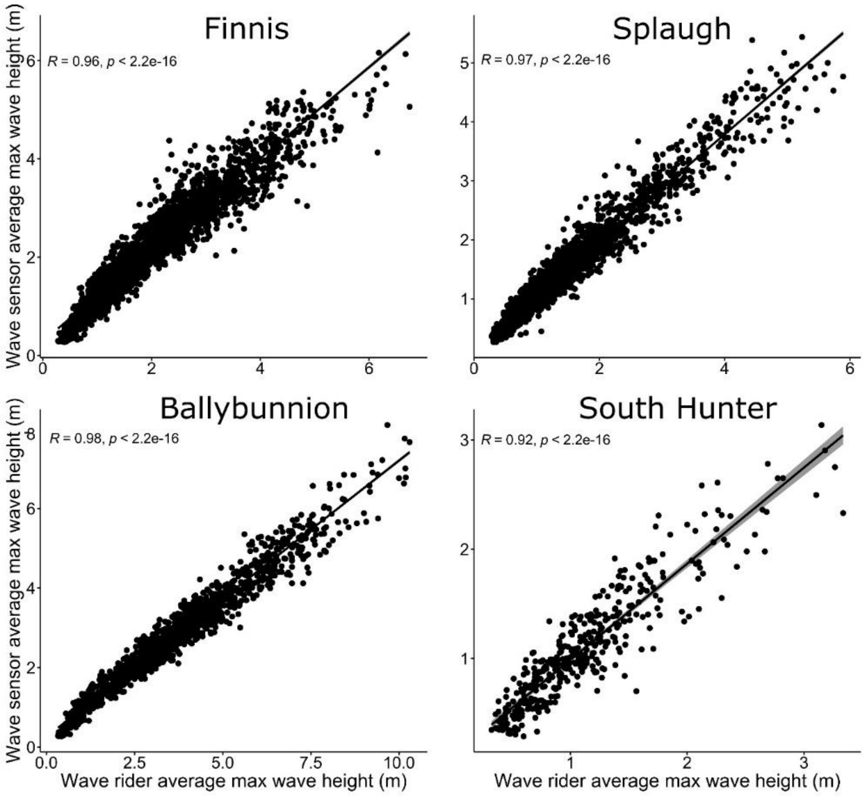


Figure 20 Scatter plot displaying Pearson's correlation coefficient and significance value for hourly averaged maximum wave height between Waverider and wave sensor.

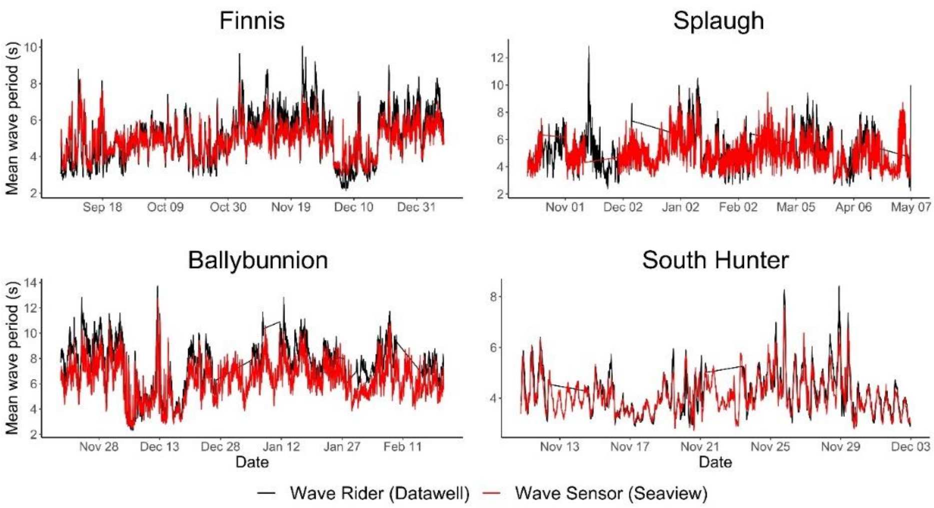


Figure 21 Time series of mean wave period for the Datawell Waverider and SeaView wave sensor. (Straight lines connecting datapoints indicate gaps in the data.)

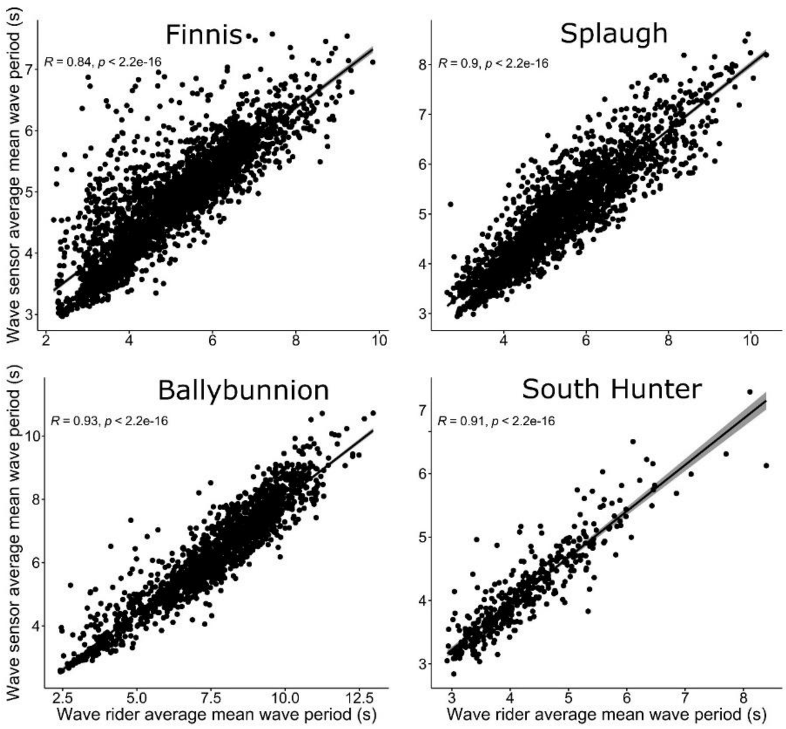


Figure 18 Scatter plot displaying Pearson's correlation coefficient and significance value for hourly averaged mean wave period between Waverider and wave sensor. Black line indicates linear relationships and shaded area represents 95% confidence intervals.

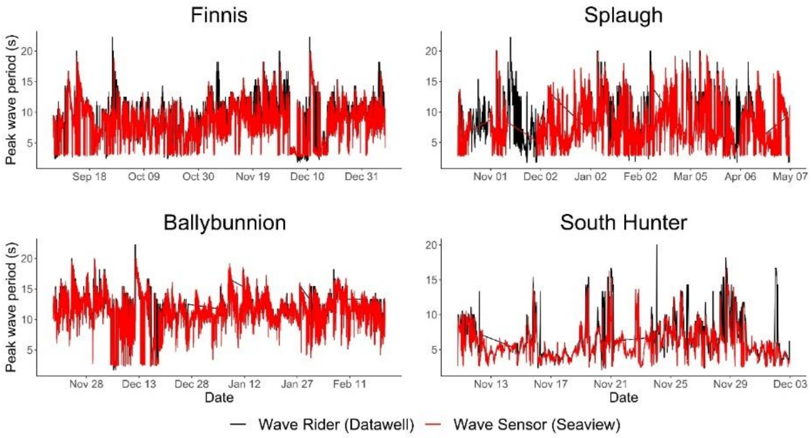


Figure 22 Time series of peak wave period for the Datawell Waverider and SeaView wave sensor. Straight lines connecting datapoints indicate gaps in the data.

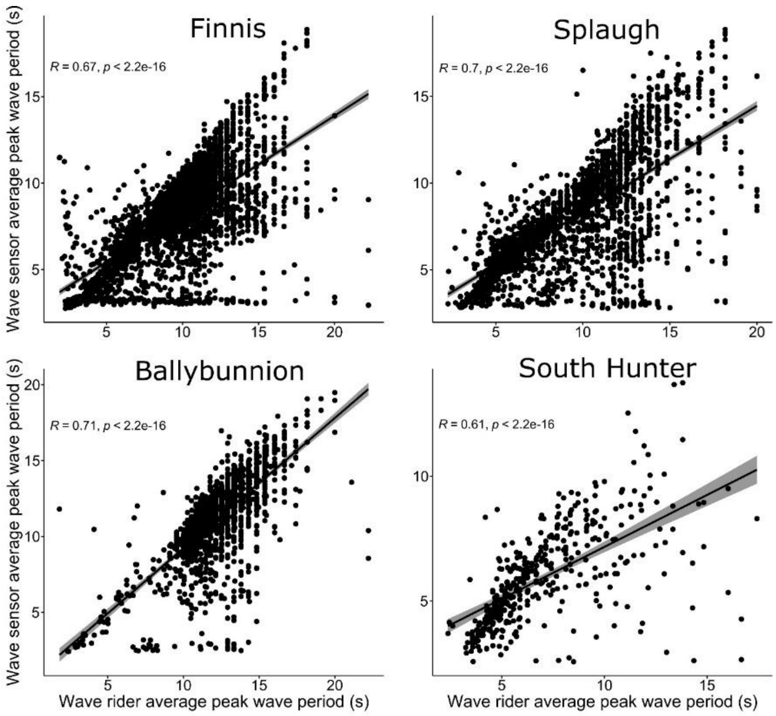


Figure 20 Scatter plot displaying Pearson's correlation coefficient and significance value for hourly averaged peak wave period between Waverider and wave sensor. Black line indicates linear relationships and shaded area represents 95% confidence intervals.

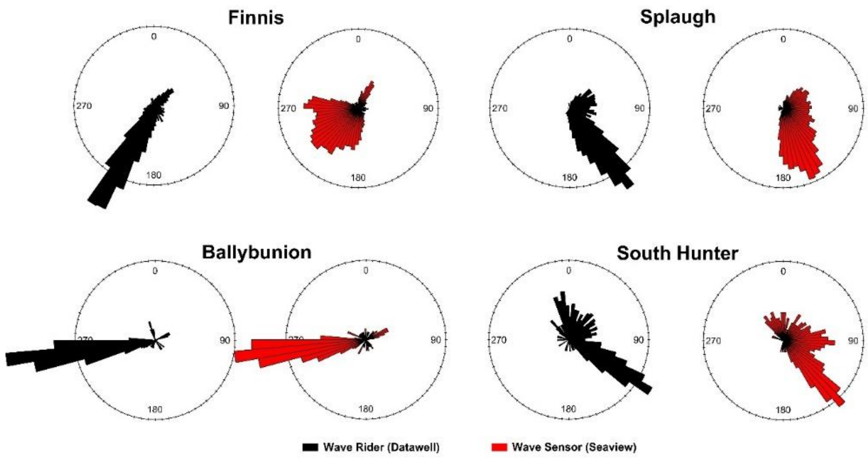


Figure 20 Comparison of mean wave direction between Waverider and wave sensor.

The data analysis conducted proved to our satisfaction, that the navigation buoys can be used to provide near-real-time Meteorological and Hydrographic data to Met Éireann from Irish Lights buoys. The acquisition of near-real-time data will be beneficial to the FFD before, during and after coastal flood events. The data will be an important input to any new coastal flood forecast models and the verification of existing models.

7 CONCLUSION & RECOMMENDATIONS

The data analysis carried out proved to the satisfaction of the Irish national weather service (Met Éireann) and the Irish national centre for marine science (Marine Institute) that floating aid to navigation buoys can be used to collect and transmit near real-time wave data. The next step will be to expand the network to existing navigation buoys at additional locations where the collection of coastal flood forecasting data is required. This work will be commenced by Irish Lights and Met Éireann in 2023.

A suitable current sensor was not available for this part of the trial. A new type of current sensor under development by Nortek may be suitable for attachment to an Irish Lights navigation buoy without causing the health and safety issues during the risk assessment for this trial. Once this new current sensor is available it is recommended that a future trial is conducted on a floating aid to navigation.

The results outlined in this paper can be used by Lighthouse Authorities internationally to support the re-use of floating aids to navigation assets for MetOcean data capture and transmission in support of more accurate weather and sea state information for mariners and the general population.

8 ACKNOWLEDGEMENTS

In addition to the authors, critical assistance was provided by Ryan McGeady and Columba Creamer from Met Éireann, and by Kieran Lyons and Alan Berry from the Marine Institute.

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AUTHOR BIOGRAPHY

Ronan Boyle is a former Lieutenant Commander with the Irish Naval Service. During his naval career he was captain of the L.E. AISLING and later the L.E. NIAMH, and served overseas with NATO in ISAF, Afghanistan. While ashore he specialised in communications and information technology including the introduction of a new maritime surveillance capability for the Navy. He also served at the strategic and policy level at Naval Headquarters.

In 2013 he left the Navy to take up a Divisional Management role with the RNLI, with responsibility for the delivery of RNLI Search & Rescue services on the South and South West coasts of Ireland. In 2019 he joined Irish Lights as Director of eNavigation & Maritime Services with a remit to advance the strategic goals set out in Safe Seas - Connected Coasts Irish Lights Strategy 2018 - 2023 and beyond. He holds a BSc (Hons) in Information Technology from DCU and a MSc in Technology Management from UCC. In addition, he holds an MA in Leadership, Management & Defence Studies from NUIM.

S5.5 The modernization of AtoN data portal (188)

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ABSTRACT

Since 1998, IALA has been conducting surveys aimed at gathering information on marine aid to navigation (AtoN) and analysing trends in the industry. This survey is a quite powerful tool for collecting, analysing, and providing statistics on Aton and VTS around the world. However, the ongoing questionnaire system has encountered several issues, such as difficulties in interpreting terminology between IALA and respondents, various questionnaire level issues that were designed by a limited number of committee members, and respondents' inability to immediately review survey results. Consequently, the response rate for the questionnaire has been severely low, significantly reducing the survey's reliability. Therefore, this research seeks to identify the problems with the current questionnaire system and propose a modernization plan to address them. Additionally, we will outline a plan to establish an Open Data Portal for IALA through the implementation of a modern questionnaire system.

KEYWORDS: Aids to Navigation (AtoN), S-201, International Association of Lighthouse Authorities (IALA)

1 INTRODUCTION

As the trend of the Artificial Intelligence (AI) era continues, AI technologies are being introduced in various fields, including the maritime and fisheries sector, where research based on AI, such as Maritime Autonomous Surface Ship (MASS) and AI-based fisheries management, is actively being conducted. In particular, research related to the digitization and standardization of marine information is being vigorously pursued in various fields such as smart ports, smart containers, and smart navigational aids, to cope with the rapidly changing future maritime environment [1,2]. Especially in the field of AtoN, efforts are underway to develop information exchange standards for the S-200 series, with IALA at the center, to enable efficient and systematic management and provision of AtoN information. AtoN information is a crucial component not only for marine safety management but also for AtoN management, and it cans serve as a key indicator of maritime traffic flow along with marine transportation information. The tasks related to AtoN management, such as inspection, replacement and recovery, generate numerous pieces of information, as do the sensing data obtained from various sensors attached to AtoN. As a result, a vast amount of AtoN data being generated worldwide on a daily basis.

The importance of information based on AtoN is increasingly recognized; however, despite its high significance and vast quantity, systematic management is not yet being implemented. Although the AtoN information exchange standard S-201 has been continuously updated since its development, many countries still manage AtoN information according to their own guidelines. As a result, AtoN data is managed in various formats according to each country's management guidelines, and even within a single country, there may be multiple agencies involved in its management, making it difficult to utilize meaningful navigational aid data. To address this issue and facilitate the meaningful use of AtoN data, this study proposes a data collection approach that utilizes the existing S-201 standard to collect, process, and integrate navigational aid data.

One method of gathering navigational mark data worldwide is through a survey conducted by the IALA, aimed at assessing the status and trends of AtoN in each country. IALA conducts IALA questionnaire among its member countries every 2-4 years, making it a powerful and unique tool for collecting AtoN information worldwide and analyzing data on AtoN. However, the irregular update cycle of 2-4 years poses a challenge for maintaining the up-to-dateness and continuity of the data, and the low survey response rate and inaccurate data of the collected data make meaningful data analysis difficult. Therefore, this paper analyzes the status of the IALA questionnaire, the only current tool for building AtoN data worldwide, in order to identify the information that needs to be managed. Based on this information, we propose a method for collecting AtoN data based on S-200.

2 STATUS OF THE IALA QUESTIONNAIRE

Every approximately two years, IALA conducts a survey, called the IALA Questionnaire, aimed at assessing the current status of AtoN around the world targeting its member states. The survey comprised a range of inquiries pertaining to navigational aids, encompassing details on the respondent's affiliated agency, the role of affiliated agencies concerning marine navigation aids, and information on fixed and floating AtoN. Many of the questions are answered using numerical values, and there are several questions that require a 'yes/no' response. These 'yes/no' questions pertain to quality management, such as performance indicators and ISO certification, as well as questions concerning the role of the organization being surveyed. However, since the questionnaire lacks clear definitions of terms, it is possible that each country or respondent may interpret the same terms differently. In some cases, it may even be impossible to properly understand the questions and terms.

Especially, upon examination of the response results to questions pertaining to AtoN in 2017, it was observed that the response rates for both 'Directly responsible' and 'National' were identical, as depicted in Figure 1. The causes of these findings are deemed to be attributable to: 1) the survey respondents holding positions within state-owned labels, 2) divergent interpretations of the term "directly responsible" due to the absence of a clear definition, and 3) the absence of privately owned AtoNs. However, the fact that these results were consistent across all surveyed countries, rather than being isolated to a few, suggests that the survey questions may need to be refined.

Number of AtoN						
	Directly responsible			National		
Country	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3
Argentina	381	1326	272	381	1326	272
Australia	960	1762	5470	960	1762	5470
Belgium	0	0	0	0	0	0
Bermuda	10	100	32	10	100	32
Brazil	3274	1748	1337	3274	1748	1337
Bulgaria	0	0	0	0	0	0
Canada	1861	10774	4672	1861	10774	4672
Chile	70	837	739	70	837	739
Colombia	135	92	0	135	92	0
Croatia	270	374	305	270	374	305
Cuba	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Denmark	186	1971	4382	186	1971	4382
Ecuador	64	289	70	64	289	70
England	154	949	10733	154	949	10733
Estonia	176	345	626	176	345	626
Finland	0	0	0	0	0	0
France	0	0	0	0	0	0
Germany	1837	3930	4850	1837	3930	4850
Greece	140	1092	363	140	1092	363
Ireland	69	592	1964	69	592	1964
Italy	150	1662	1174	150	1662	1174
Japan	975	2783	2719	975	2783	2719
Latvia	123	93	92	123	93	92
Netherlands	165	1665	2222	165	1665	2222
Norway	0	0	0	0	0	0
Portugal	53	86	939	53	86	939
Russia	1622	2501	476	1622	2501	476
Scotland	423	1344	784	423	1344	784
Singapore	0	70	100	0	70	100
Spain	334	1097	1482	334	1097	1482
Sweden	563	373	167	563	373	167
Turkey	240	180	191	240	180	191
Ukraine	119	106	502	119	106	502
USA	1281	10092	22544	1281	10092	22544

Figure 23: The results of the AtoN questionnaire (2017) response results for 'National' and 'Directly responsible'

3 HOW TO MODERNIZE

To establish an Open Data Portal, the initial task involves the construction of an AtoN DB utilizing the S-201 standard. The S-201 DB schema comprises of "catalogs", "features", "boundedby", and "dataset identification information", centered around the "dataset" entity. The majority of data types utilized in this schema consist of varchar, integer, and float, while the "lowercorner" and "uppercorner" data types of the "boundedby" class are composed of geometric data. When designing the AtoN DB, it is crucial to take into account the aforementioned data types, as well as compatibility with the Maritime resource name(MRN) service, which is a vital factor. The MRN system is the sole means for identifying maritime services and resources and can be utilized for AtoN data management. Therefore, ensuring compatibility with the MRN service is a critical consideration when designing the database. Utilizing List of Lights data is among the approaches that can be employed to create an S-201 compliant DB that is compatible with the MRN service. The information provided by List of Lights may vary depending on the type of AtoN, but generally provides fundamental data that can be associated with properties and also provides information on specific functions depending on the type of AtoN.

After building the DB to be compatible with the MRN service, the next step is to link the S-201-based AtoN DB of each member country with the Open Data Portal. The Open Data Portal, designed by IALA is an information linkage system that collects, manages, and analyzes AtoN DB information from around the world, and this system is scheduled to be operated from 2026. Several countries have already begun constructing DB based on S-201, and it is anticipated that more member countries will transition to S-201-based DB in the coming years. Once the majority of member countries have converted their AtoN DBs to S-201 format, it is believed that a variety of statistical analyses will be possible according to criteria such as AtoN type, country, and status analysis. In particular, it is expected that it will be possible to apply cross-validation by mapping web-based GIS that provides spatial analysis functions.

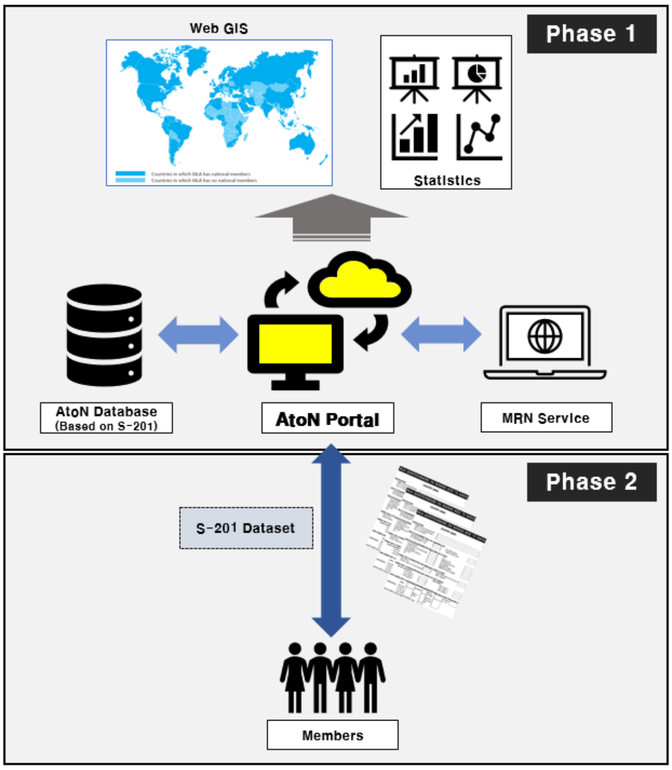

Figure 24: Open data portal system diagram

4 CONCLUSION

In contrast to the past, where limited access to data was enforced due to security concerns, the perception of data has recently shifted, resulting in the expansion of the concept of public data as the desire for open access to data grows. This expansion of public data usage has enabled the creation of various value-added benefits, including the development of new business models, the generation of economic value, and the establishment of policies and plans. Nonetheless, in the field of AtoN, the IALA Questionnaire currently stands as the only means of investigating global AtoN data. However, conducting a meaningful statistical analysis using this questionnaire is challenging due to inaccuracies in the questions, varying interpretations among respondents, and low survey response rates. However, in the navigational aids field, IALA Questionnaire, which is currently the only method to investigate global data, is difficult to perform meaningful statistical analysis due to inaccuracies in questions, different understandings of respondents, and low survey response rate. Therefore, in this study, we propose to build an Open Data Portal by constructing a database based on S-201 in order to obtain high-quality navigation aid data.

The database of the Open Data Portal is designed based on S-201, and the initial database will be built using the List of Lights. Additionally, some member countries, centering on developed countries for navigational aids, will build S-201-based navigational aids databases and link them with the Open Data Portal. Afterwards, when most member countries build a navigational aid database based on S-201 and link it with the Open Data Portal, the use of navigational aid time series data from around the world becomes possible, enabling various statistical analyses based on this data. In addition, in the final stage, the use of web-based GIS services is also possible, allowing users to check map-based statistical analysis results.

Through the establishment of the Open Data Portal, it is expected that the analysis of big data related to navigational aids will become possible, enabling the analysis of the rapidly changing marine environment. In addition to analysing the current status of navigational aids, this will serve as a preemptive response to securing safety at sea, introducing low-carbon and smart ships, and meeting their demands.

5 ACKNOWLEDGEMENTS

This research was a part of the project titled 'Marine digital AtoN information management and service system development(3/5) (20210650)', funded by the Ministry of Oceans and Fisheries, Korea.

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AUTHOR BIOGRAPHY

Yunjee Kim has been working as the researcher of the Korea Research Institute of Ships and Ocean Engineering (KRISO) since 2020. She holds a Master degree in Earth and Environmental Sciences (especially remote sensing) from Seoul National University in Korea. She is in charge of marine spatial information at KRISO, and is conducting SMART Aton and connectivity technology development project from 2021. She has also been attending IALA ARM meetings since the 13th ARM meeting.

SESSION 6 - ATON SERVICES (CONTINUED)

S6.1 Data Fusion to support MDA & Coast Guard Functions (142)

Giuseppe Aulicino, Rear Admiral Italian Coast Guard, Head of Planning and Operations Department

ABSTRACT

The Automatic Identification System (AIS) has been a sort of Big Bang for the Maritime Domain Awareness, making billions of information available to coastal States to be used for multi-purpose activities.The Italian Coast Guard, as National Competent Authority (NCA), has set up a complex network fully compliant with the IALA Recommendation A-124 "on the AIS services". Within his remit, the Italian Coast Guard ensures that the AIS information is merged with information provided by other sources (e.g. Long Range Identification and Tracking, Mandatory Reporting Systems, GMDSS), including those acquired by its own air-naval assets.

Even though the AIS is commonly associated to a mean used by coastal States to receive the information broadcasted by vessels, as highlighted by the IALA, the AIS is also a bidirectional communication channel to be used to provide services to the mariners. Some of these services, including those related to navigational warnings, are themselves sources of information to be integrated in the maritime picture with the purpose to get an even greater awareness. The aim of this paper is to provide the Italian Coast Guard state of art and developments on Data Fusion processes, as key element for Maritime Domain Awareness to support Coast Guard Functions.

(No paper submitted)

AUTHOR BIOGRAPHY

Giuseppe AULICINO is an Admiral of the Italian Coast Guard, currently Head of the Plans and Operations Department at the Coast Guard Headquarters. He attended Naval Academy between 1983 and 1987 as a Line Officer of the Italian Navy, Anti-Submarine Warfare specialist. After about 9 years of experience onboard Italian warships, he joined the Italian Coast Guard. He was responsible for various assignments at the Coast Guard HQs related to the ICT matters, participating to the main technological programs regarding the safety and efficiency of maritime traffic, the response to incidents, accidents or potentially dangerous situations at sea, including search and rescue operations. In particular, he was responsible also for the implementation and the management of the Italian AIS network implemented under the framework of the European Union directive 2002/59.

He was called to represent Italy in several international and European fora. Since 2013 up to the end of 2022 he has played the role of coordinator of the MAREΣ project of the European system SafeSeaNet, which allows the maritime information sharing in the Mediterranean and Black Sea. During his career, he served as harbormaster of Fano, San Benedetto del Tronto and La Spezia. Before assuming the current duty, between 2018 and 2020 he held the position of Head of ITC Department of the Italian Coast Guard Headquarters. He obtained the Diploma of Industrial Expert and graduated in Maritime and Naval Sciences at the University of Pisa, as well as in International and Diplomatic Sciences at the University of Trieste.

S6.2 Use of Metocean data to improve safety of navigation (159)

Cecile Zanette, Mediterráneo Señales Marítimas S.L. (MSM), CEO MSM Ocean

ABSTRACT

The transmission of accurate meteorological data and oceanographic data to mariners is key to improve the safety of navigation in port access or in areas that can be hazardous such as straights. This data is collected through a variety of sensors installed in instrumented buoys or on onshore stations, processed onboard and transmitted directly to vessels in real time through AIS and on appropriate VHF maritime channel, as well as to a Control Centre onshore.

This includes key Metocean parameters such as wind speed, wind direction, wind gusts, waves, currents, water levels (tides), and others, but can also include additional environmental parameters that may affect port activities such as the presence of contaminants or that are of special interest for Maritime Authorities.

Those solutions are custom designed to each project, its location, and the relevant issues to be monitored including to determine the adequate selection of sensor and structure. Specific analysis should be developed to design the communications systems, power systems, as well as mooring systems in the case of buoys.

An example of the implementation of such a system in the Kirke narrows in Chilean Patagonia to improve the safety of mariners will be used to illustrate the capacity of such systems.

KEYWORDS: Metocean, Data, Safety of Navigation, Data Buoys, Technology

RESUMEN DEL ARTICULO

La transmisión de datos meteorológicos y oceanográficos precisos a los navegantes es clave para mejorar la seguridad de la navegación en los accesos portuarios o en zonas que pueden resultar peligrosas como los estrechos. Estos datos se recopilan a través de una variedad de sensores instalados en boyas instrumentadas o en estaciones en tierra, se procesan a bordo y se transmiten directamente a las embarcaciones en tiempo real a través de AIS y en el canal marítimo VHF apropiado, así como a un Centro de Control en tierra.

Esto incluye parámetros metoceánicos clave, como la velocidad del viento, la dirección del viento, las ráfagas de viento, las olas, las corrientes, los niveles de agua (mareas) y otros, pero también puede incluir parámetros ambientales adicionales que pueden afectar las actividades portuarias, como la presencia de contaminantes o que son de especial interés para las Autoridades Marítimas.

Esas soluciones se diseñan a la medida de cada proyecto, su ubicación y los temas relevantes a ser monitoreados, incluso para determinar la selección adecuada de sensor y estructura. Se deben desarrollar análisis específicos para diseñar los sistemas de comunicaciones, los sistemas de energía, así como los sistemas de amarre en el caso de las boyas.

Se usará un ejemplo de la implementación de dicho sistema en la angostura de Kirke en la Patagonia chilena para mejorar la seguridad de los navegantes para ilustrar la capacidad de tales sistemas.

PALABRAS CLAVE: Meteorología, Oceanografía, Datos, Seguridad a la navegación, Boyas instrumentadas, Tecnología

RESUME DE L'ARTICLE

La transmission de données météorologiques et océanographiques précises aux navigateurs est essentielle pour améliorer la sécurité de la navigation dans les accès portuaires ou dans des zones pouvant être dangereuses telles que les détroits. Ces données sont collectées grâce à une variété de capteurs installés dans des bouées instrumentées ou sur des stations à terre, traitées à bord et transmises directement aux navires en temps réel via AIS et sur le canal maritime VHF approprié, ainsi qu'à un Centre de Contrôle à terre.

Cela inclut des paramètres météorologiques et océaniques clés tels que la vitesse du vent, la direction du vent, les rafales de vent, les vagues, les courants, les niveaux d'eau (marées) et autres, mais peut également inclure

des paramètres environnementaux supplémentaires qui peuvent affecter les activités portuaires telles que la présence de contaminants ou qui sont d'intérêt particulier pour les Autorités Maritimes.

Ces solutions sont conçues sur mesure pour chaque projet, son emplacement et les problèmes pertinents à surveiller, notamment afin de déterminer la sélection adéquate du capteur et de la structure. Des analyses spécifiques doivent être développées afin de concevoir les systèmes de communication, les systèmes d'alimentation ainsi que les systèmes d'amarrage dans le cas des bouées.

Un exemple de mise en place d'un tel système dans le passage de Kirke en Patagonie chilienne pour améliorer la sécurité des navigateurs sera utilisé pour illustrer la capacité de tels systèmes.

KEYWORDS: Météorologie, Océanographie, Données, Sécurité de la navigation, Bouées instrumentées, Technologie

1 INTRODUCTION

The development of sensor and telecommunication technologies as well as electronics has made more readily available the design and implementation of systems to capture Metocean data for a wider use, not only restricted to scientific applications. This allows National Maritime Authorities and Port Authorities to use the broadcast of key data to increase the safety of navigation and provide specific real-time data to mariners.

Investing in the design of such a system, through the installation of measuring stations (whether offshore through data buoys or onshore) and the set-up of a Control Centre, requires a careful preparation, design, and study to implement a successful project. This exposition, based on our experience in MSM in designing, manufacturing, and implementing this type of projects, details the key considerations to incorporate into such a design as well as the necessary studies and analyses.

2 DEFINITION OF PARAMETERS AND SENSORS

2.1 Definition of parameters

The first step for designing a system to obtain Metocean data is the definition of the relevant data to be measured. There is currently a wide offer of sensors that allow measurement of parameters that have implications for navigation safety and to support decision-making. Those include meteorological parameters as well as oceanographic parameters: winds and gusts, air temperature, barometric pressure, solar radiation, visibility, currents, waves, and water temperature. The competent authority should determine the data that is most relevant for each location, and the most adequate points of measurement in function of the risks to navigation that have been identified, as it might be necessary to measure the same parameters at different points of navigation to obtain accurate information.

Additionally, other parameters of interest for the competent authority can be included in the project, such as those relating to pollution monitoring (including hydrocarbons sensors) and water quality, to make the most use of such an investment.

2.2 Criteria for the selection of sensors

As noted above, there is now a large offer of sensors on the market, which can vary greatly in technical specifications (range of measurement, accuracy, and resolution) as well as in cost. To select the most adequate sensor for each parameter or group of parameters, competent authorities should analyse their data requirements in relation to the use they are able to do of said data. As an example, Conductivity, Temperature, Depth (CTD) sensors may vary in their precision of the measurement of the sea temperature between 0.01˚C to 0.0001˚C. Or wave sensors may include complex data such as spectral data or Fourier coefficients that might not be needed if an in-depth analysis of the wave will not be performed but only data of wave and swell height, period and direction will be used.

Additionally, care should be given to the reliability and quality of the sensors, as well as considering if the sensors are designed for marine environment, especially in the case of meteorological sensors as they can be designed for land use and not be adapted for marine applications, or do not include tilt compensation and/or compass (which will be necessary on a buoy installation), etc.

Some sensors can also provide more than one parameter so that an overall more cost-efficient solution can be designed. For example, automatic weather station may be considered instead of individual meteorological sensors for navigation safety applications, or if an Acoustic Doppler Current Profiler is included, it might be useful to check if the sensor includes water temperature measurement (commonly offered in ADCPs by manufacturers) so not to include an additional water temperature sensor. Industry specialists should be able to provide the necessary guidance to competent authorities.

3 DEFINITION OF COMMUNICATIONS STRATEGIES

3.1 Direct communications with users

A key part of setting up a system for the transmission of Metocean data to be used for the purpose of navigation safety is the definition of a communication strategy. To allow decision making in timely manner, a direct communication (broadcast) of selected data to navigators should be considered, and it even may be the only option available for transmission in remote locations. There are international standards, such as from WMO, IMO and IALA, that establish the information to be transmitted and its format. Such standards also indicate in some cases how the Metocean data should be measured by the measuring station, defining, in particular, sampling periods and frequency of measurement for the sensors.

For a direct transmission of data to navigators, the main channel to consider is AIS communications. With an AIS AtoN transponder connected with the station's datalogger, the relevant data can be transmitted through the application specific Message 8 for Meteorological and Hydrographic data, directly to the vessels in range of the station that are equipped with an AIS transponder Class A or Class B as per the SOLAS regulation. This message allows transmitting data (ultimately determined by the sensors installed on the station) on wind, wind gusts, air temperature, humidity, dew point, air pressure, visibility, water level, currents (up to three levels of measurement), waves, swells, water temperature, precipitation, salinity, and ice [1].

To transmit data to navigators, in the case of non-SOLAS vessels, other strategies may be used such as transmission through VHF maritime channels. Such transmission can also be implemented in a direct and automatic manner, without going through a Control Centre, using a voice synthesizer with a radio transmitter on the measuring station if enough power supply is available, or on an automatic repeater station onshore. The same data transmitted through the Message 8 can be selected and received in the vessels with the same frequency as the AIS message.

Some authorities may decide however on undirect communication strategies, where the data transmitted to navigators is filtered and selected in the Control Centre to be broadcasted to mariners through different media including VHF maritime radio, display panels, etc. In any case, even when a direct strategy is selected, the data measured by the station must be transmitted to the Control Centre for the compilation of a database and collection of historical data that may be used for different purposes.

With the rise of Internet and connectivity, making available this data on public websites can also offer the possibility of access to all users, including all mariners. Even though there are no currently available standards for this type of display of data, their use is an increasing part of a routine use of information and should be considered.

3.2 Communications analysis

To determine the optimum communications channel between measuring stations and the Control Centre, three main factors should be studied:

- Availability of coverage,
- Volume and type of data to be transmitted, for example the transmission of audio and video files within the framework of the ISPS (International Ship and Port Facility Security) Code will require a communication channel with a wide bandwidth,
- Power transmission and power consumption,
- Costs of communications,
- Security of communications.

Other factors to consider include evaluating administrative requirements, which can include lengthy procedures for authorisations for channels transmission and validation of transmission equipment, as well as the evolution of communication technologies, as much as it can be anticipated, to ensure the system remains operative for an adequate duration of time.

As an introduction, below are initial considerations on available communication channels to be evaluated:

- Mobile phone communications: it is a low-cost option however coverage might be challenging in some areas especially away from shore. Attention should be placed on available networks and compatibility with the modems used in the measuring station, as mobile phone technology is evolving quickly, and some networks are already unavailable in certain countries [2].
- Radio communications (including AIS communications): there are no costs associated with the communications per se, however costs of hardware in the Control Centre (receiving stations as well as antennas and the installation) must be considered. A clear line of sight between the receiving equipment and the measuring station must be available, a specific radio link analysis can be performed to estimate the range of communications and define the specifications of equipment.
- Satellite communications: they have a higher cost and require specific knowledge in the design of the data packages to obtain a solution that is most cost-efficient. They are in some cases the only option in communication due to the distance and isolation of the measuring station.

Other communication channels to evaluate include Wi-Fi, Internet, etc.

Communications strategies also should include the use of main and back up channels or the design of redundant systems to ensure availability of the data. Additionally, at least one bidirectional communication channel should be integrated to allow for essential remote controls over the measuring stations, especially for troubleshooting and corrective maintenance of the equipment (resets, reconfiguration, etc.).

4 DEFINITION OF STRUCTURES

4.1 Energy balance analysis

Once the sensors and communication strategy have been defined, an energy balance analysis should be performed to determine the power requirements of the system. For onshore systems, mains power might be available, therefore it might only be required to check power supply requirements of the equipment to be installed and its compatibility with the available power, and to design a back-up power supply system or back up battery system if mains power is not stable, in which case an energy balance analysis will also be required.

In the case of solar powered systems, this analysis is key to ensure a continuous operation of the measurement station with no interruption. Competent authorities should indicate the number of days of autonomy that are required based on the location and its specific solar radiation data, however a minimum of seven to fourteen days is recommended. All components of the system, sensors, datalogger, modems and any electronic device, should be included in the analysis. For projects where autonomy is challenging, due to low solar radiation, this is especially important, and suppliers should be able to advise of strategies that can be implemented to reduce consumption such as temporization of equipment or adjustment of sampling period and frequency as well as communications frequency.

Additionally, solar power system may be complemented with other renewable energy power systems such as wind generators (for onshore applications).

Once the required powered system has been defined, the design of the structure can be implemented.

4.2 Floating systems (buoy systems)

For floating systems, such as data buoys, once the required equipment and power supply system has been determined, the size of the buoy can be calculated according to the conditions of the planned location, in particular depth, currents, waves and wind, and mooring calculations should be performed according to IALA Recommendations [3]. Some projects might require specialized mooring calculations for example when measuring stations are located in high depths.

For the selection of the buoy, careful considerations should be placed regarding quality and durability of the system. An evaluation of the cost should incorporate cost of operation of the station, in particular cost of maintenance, which includes as well as maintenance of the buoy, maintenance of sensors that may require the buoy to be removed on a periodic base. It is recommended that competent authorities investigate if suppliers incorporate technologies and measures designed to reduce this cost of operation.

Additional scrutiny must be placed on the safety of the measuring stations to guarantee the availability of data, through ensuring a correct visibility as well as the incorporation of antivandal systems and measures. It may be useful that competent authorities check that the buoy manufacturer is an IALA Industrial member so to ensure that the buoy is adequately designed and equipped to protect this investment as well as attributing responsibilities in case of sinister.

According to the Maritime Buoyage System, ODAS buoys should be Special Mark, however this does not exclude a double use of other types of Aids to Navigation and measuring equipment can be placed on other types of marks. This could allow reducing multiplying systems, especially in areas where there are already a certain number of AtoNs.

4.3 Fixed systems

For fixed and onshore systems, a wide variety of structures can be selected to house equipment, including piled AtoN, lighthouses, towers, and poles as well as other structures in onshore installations (ports, marinas, etc.). The type of sensors to be installed will determine the type of structure.

Additionally, it is important to consider measures to reduce vandalism, especially on isolated structures and their equipment, as well as ease for maintenance.

5 PROJECT IMPLEMENTATION

5.1 Installation and maintenance

An equally important part of a Metocean data measurement project, once selected the equipment and supplier, is to ensure an adequate operation of the system. This requires following adequate procedures during the installation. Most systems require additional testing in location, as some conditions cannot be replicated in the manufacturing facilities, for example with regards to communications, and some sensors may require specific handling and levelling. If no specifically trained personnel are available within the competent authority, then it is essential to incorporate the supervision of the installation by the supplier as well as a solid training program with a transfer of the corresponding knowledge.

Additionally, dedicated maintenance plans should be followed, based on manufacturers' recommendations, and adjusted to local conditions (to consider any specific requirement with regards to vandalism, biofouling, etc.). Periodic maintenance activities are key for preserving the designed service life of equipment. Moreover, the cost of corrective maintenance interventions, caused by a lack of preventive scheduled maintenance, can be very high.

5.2 Use, post-analysis of data, and dissemination of data and collaboration with third parties

The main use of a such a system of measurement is to provide real-time data for real-time decision-making. However, it is important to consider other use of data that may be suitable for the competent authority to maximize the institutional benefit of such a project.

The data transmitted to the Control Centre is stored in a database and allows the compilation of historical data. For that purpose, the competent authority should evaluate the relevance of transmitting additional data measured by the sensors to the Control Centre, aside from those strictly necessary for navigation, if possible. For example, the AIS Message 8 referenced above only includes three layers of currents, however, ADCPs have the capacity of measuring more layers that can provide additional information on the current profile.

The data stored can be used for statistical analysis for the competent authority for operation planification or for models and prognostics.

Additionally, competent authorities should evaluate the opportunity of data sharing to third parties (whether internal or external, public, or private), as such data may be used for other applications such as research, industrial applications, tourism activities, environmental monitoring, civil protection, etc. This can be done under non-profit models, that can reinforce institutional image, or for-profit models providing additional source of funding that can be destined to maintenance activities.

6 CASE STUDY: THE USE OF METOCEAN DATA IN THE KIRKE NARROWS, CHILE

The Kirke Narrows, located in the XII Region of Magallanes and Chilean Antarctica, is one of the most complex navigation areas of the Southern channels. The difficulty of its navigation lies in:

- Tidal currents that normally reach eight to ten knots in intensity, coupled with the fact that the tides, slack tide, and tidal currents are very irregular.
- Strong prevailing winds in the area.
- Adverse weather conditions (snow, rain, and low temperatures)
- The bathymetry of the crossing with the Restinga point (a rock mass that restricts the passage at the location) that makes navigation difficult, leaving only fifty meters of navigable width.

All this reduces manoeuvrability, therefore navigation in the Kirke narrows is limited, large ships must navigate with a regional pilot and night navigation is prohibited. Such is the confluence of adverse atmospheric geographic factors in Kirke Narrows that, in the last ten years, this crossing has been the scene of eleven major accidents (the Amadeo I ferry, the Crux Australis ferry or the Le Soleil cruise ship, among others).

Considering the conditions of navigation in that area, DIRECTEMAR (General Directorate of Maritime Territory and Merchant Marine of the Chilean Navy) through DIRSOMAR (Directorate of Security and Maritime Operations) chose to improve the Aids to Navigation of that crossing in 2018 by installing a system of acquisition and broadcasting of Metocean data to improve the safety of navigation. This project was designed and implemented by MSM after a public tender process.

The improvement consisted firstly in the collection of fundamental hydro-meteorological data through a horizontal Acoustic Doppler Current Profiler and an Automatic Weather Stations incorporating the measurement of wind speed and direction, gusts speed and direction, air temperature, barometric pressure and relative humidity specifically designed for marine applications. All the measured data was captured, processed, and packaged onsite through MSM's datalogger to be broadcasted through AIS Message 8 and transmitted through a satellite modem to the Control Centre in Valparaiso. Additionally, the station is equipped with a voice synthesizer and radio transmitter to broadcast the data through the VHF marine channel vessels that do not have AIS every three minutes.

Table 9 Summary of the Kirke System

DATA ACQUISITION	The system measures the current that flows through the narrows, the swell, the air temperature, the wind and the gusts, the atmospheric pressure, and the humidity present in the area.
DATA INTEGRATION IN THE FIELD	The datalogger captures the meteorological and hydrological data. It also captures the parameters associated with the general operation of the system for transmission to the Control Centre.
INFORMATION BROADCASTING	The information collected is broadcasted via AIS and via radio on the VHF band.
TRANSMISSION OF THE INFORMATION	The system transmits all data through a satellite link, including meteorological, hydrological, operational data, as well as the AIS traffic in the area.
PRESENTATION AND STORAGE OF THE INFORMATION	The system stores the information on a server owned by DIRECTEMAR and displays this information on screens thanks to a software specially developed for this.
ENERGY COLLECTION AND STORAGE	The power system of the station consists of a non-conventional renewable energy system made up of solar panels, wind generator, a regulator and batteries that provide a total autonomy of two months.
STRUCTURAL SUPPORT	A modular fiberglass tower works as a structural support for the system, housing and protecting the equipment from environmental conditions.

Figure 25: Kirke Metocean Station

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AUTHOR BIOGRAPHY

Cécile Zanette joined MSM as a Business Development Manager in 2016 working mostly with North American, European, African and Asian markets. With a Master's degree in International Business and Negotiation, Cécile has extensive experience in managing international projects and relationships.

During her time in MSM, she has received extensive training on Aids to Navigation solutions and has been in charge of leading the design, development and implementation of several beaconing projects over the world including custom-design complex projects.

In addition, since 2020, she is the CEO of MSM's Oceanographic Division, MSM Ocean, where she works with her team as well as external collaborators, to develop instrumented solutions, both floating (data buoys) and onshore for different applications to increase the safety of navigation as well as for scientific research, environmental monitoring or provide data to the offshore energy and blue economy sector. She also has specialized knowledge on MSM's Tsunami Early Warning Systems.

S6.3 Development of maritime service provision system for exchanging AtoN information (187)

Sewoong Oh, Principal Research Engineer, Maritime Digital Transformation Research Centre, Korea Research Institute of Ships and Ocean Engineering (KRISO)

ABSTRACT

Aids to navigation (AtoN) is an important facility that supports the safe navigation of ships and has added additional functions of collecting marine environment information, as well as the traditional role of assisting the mariner in locating. Recently, as the importance of marine information has increased, international standardization activities such as maritime service description in e-Navigation strategy, S-100 and S-200 product specifications, Maritime Resource Name (MRN) guideline are being actively carried out. ROK is developing a AtoN information system and maritime service provision system in consideration of the latest standards developed by IALA and IHO to support digitalization of Aton information and respond to future autonomous ships. As a detailed research content, the project team is developing an information management system according to MRN and S-201 data model and preparing a database system to monitor AtoN status and manage collected information. In addition, by establishing a service platform considering e-Navigation maritime service, cyber security, and maritime connectivity platform (MCP), the project team is preparing to provide AtoN information in the e-Navigation level. This paper aims to present procedures and methods for digitalization of Aton information and establishment of maritime service provision system, and to share lessons learned from the research project.

KEYWORDS: Marine Aton, S-201, S-124, S-125, MRN, Aton Service

1 INTRODUCTION

Aids to navigation (AtoN) is an important facility that supports the safe navigation of ships and has added additional functions of collecting marine environment information, as well as the traditional role of assisting the mariner in locating. Recently, as the importance of marine information has increased, international standardization activities such as maritime service description in e-Navigation strategy, S-100 and S-200 product specifications, Maritime Resource Name (MRN) guideline are being actively carried out. ROK is developing a AtoN information system and maritime service provision system in consideration of the latest standards developed by IALA and IHO to support digitalization of Aton information and respond to future autonomous ships. ROK has been developing an information system to provide maritime service according to the IALA's S-200 series product specification and MRN guideline, and this paper introduce the progress. In addition, the major results of demonstration project on the Aton information service conducted as part of the cooperative activities between IALA and IHO are shared.

2 ATON DATA MODEL AND MRN

IHO NIPWG welcomed the IALA offer in drafting of S-125, Navigational Services, as a dataset-based on S-201, Aids to Navigation Information, and requested that S-125 should provide navigationally significant information additional to the data currently available in S-101. S-201 is a standard for exchanging all information related to any AtoN including metadata like maintenance schedules, equipment types (such as battery and bulb types). S-201 is intended to be the means of communicating such information within an AtoN organization or between AtoN organization and its main partners like hydrographic offices. S-201 is not intended to be for navigation systems like ECDIS, and therefore is not constrained by ECDIS requirements. This means the S-201 can include additional cartographic information to inform about AtoN services that would not be appropriate in a navigation system.

S-125 meanwhile, would be a derivative of S-201 service as the public facing information for use in ECDIS/ECS. In other words, S-125 would be the digital equivalent of the extended list of lights in order to meet IMO SOLAS V requirements of having list of lights on board and serve as a continually updated list of AtoN, including virtual

AtoNs. It is also envisioned that following scenario illustrates how S-125 would work with the S-124 MSI Product Specification:

- An AtoN Outage is reported and immediately communicated by S-124. Upon confirmation of the outage, the responsible AtoN authority will move the report of outage from S-124 into the S-125, thereby relieving S-124 of old, but still active information.

S-125 will include the attributes necessary to digitally populate discrepancies, proposed changes, Advance Notice of Change and Temporary changes. S-125 will support both route planning and route monitoring functions of any voyage. It is further envisioned that S-125 can contribute to the check route function of S-100 based ECDIS. In order to support the above vision, S-125 will be developed using the latest version of S-100. S-125 compliant datasets will contain the AtoN information within the dataset area of coverage and delta changes to these datasets will contain the change information.

An S-125 service will be able to issue any change information more rapidly than what is expected in an ENC service. This is required to provide the navigationally significant information additional to the data currently available in ENC. The ENC service subsequently should include the updated information, this information status change can then be reflected in the S-125 service.

AtoN information must be of highest possible quality to be considered useful in ECDIS/ECS. Some AtoN information currently in ENC have been altered from the source information to better fit with related features such as coastline using cartographic principles. Providing for such alterations would be unlikely in a S-125 service, and the focus should therefore be on providing the most accurate positional and descriptive information possible. S-125 will contain sufficient instructions to highlight the need to focus on data quality. Figure 1 shows the overview of S-201 and S-125 data model.

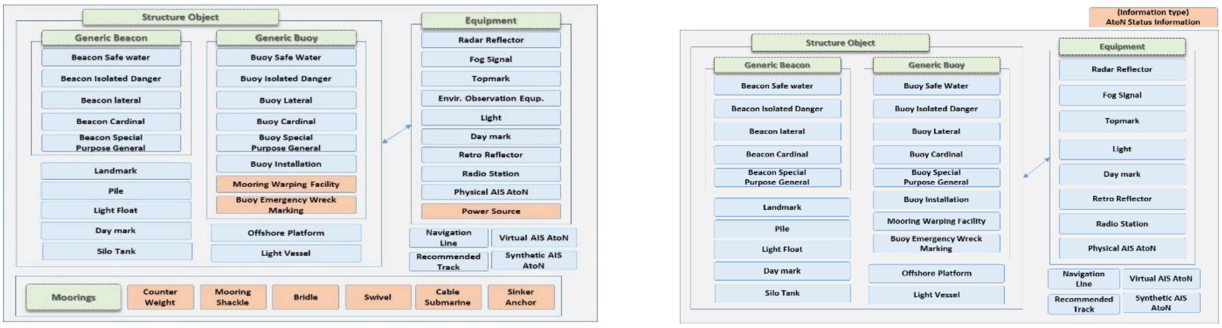

Figure 26: S-201 and S-125 Data Model

IALA and IHO had a workshop on S-100/S-200 development and portrayal on Sep. 2022, Norwegian Coastal Administration, Ålesund, Norway. Two organisations discussed the Aton and Navigation warning service. IALA and IHO discussed the generation and data flow of navigational aid information, and created a diagram for information service data flow such as navigational warning, Aton change information, ENC update.

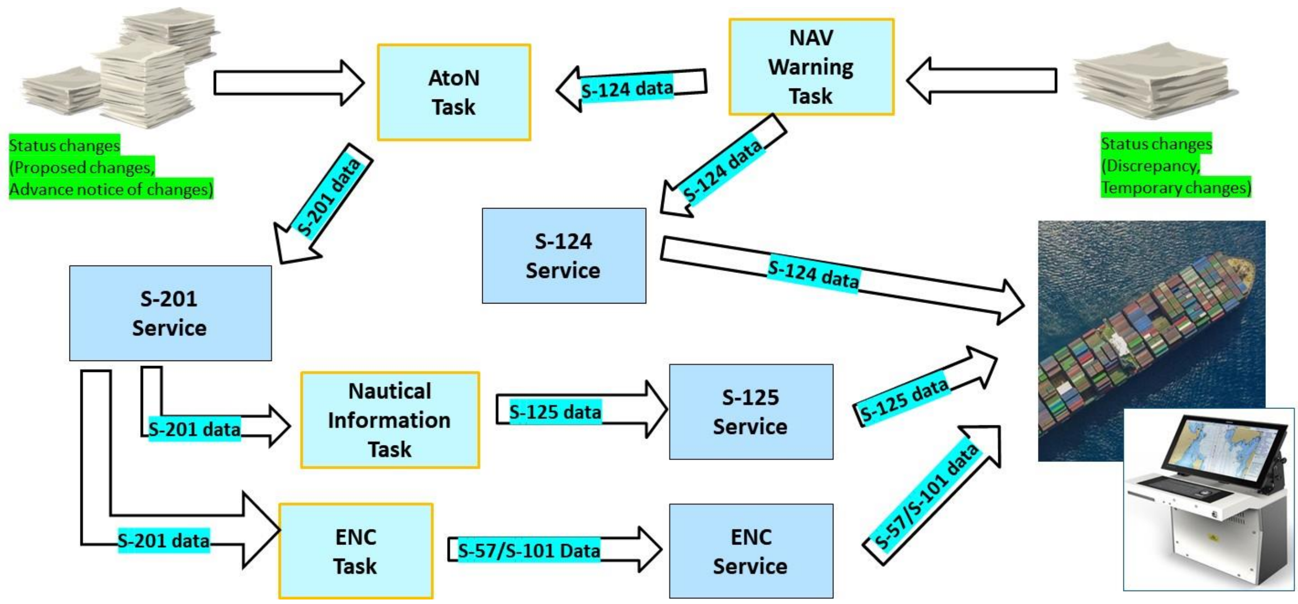

Figure 2: Data flow and S-101, S-124, S-125

Meanwhile, in order to support the development of marine services from the perspective of e-Navigation and the management and digital conversion of marine information, IALA has developed technical guideline for maritime resource name. The use of unique identifiers is a necessary development of e-Navigation to maintain harmonization across domains and services. Navigationally unique objects such as Marine Aids to Navigation (AtoN), and Vessel Traffic Service (VTS) products and services and other maritime services require identification numbers to avoid duplication and misalignment of AtoN and Maritime Safety Information (MSI).

Worldwide harmonized identification of unique identifiers for maritime resources can:

- assist in the development and maintenance of enhanced data exchange applications for ship to ship, ship to shore, shore to ship and shore to shore in the context of e-Navigation;
- assist administrations in the efficient delivery of MSI; and
- reduce the administrative burden associated with the maintenance of international list of lights numbers and other navigation products.

Essential properties for a naming scheme are the following:

- Uniqueness: An ID within the MRN namespace is never assigned to more than one resource and never reassigned to a different resource. Ensuring uniqueness within a namespace is the responsibility of the respective governing organization of the namespace.
- Decentralization: It must be possible to create IDs without relying on a single global source that must be used every time an ID is created. A central source for creating specific types of ID, for example, route ID, may exist.
- Forward compatibility: A global naming scheme must be designed for evolution enabling the addition of new naming schemes for new maritime domains in the future.
- Flexibility: The naming scheme must be flexible and allow for identifying any type of resource such as documents, routes, equipment, ships and mariners, giving no preference to any specific type of IDs.

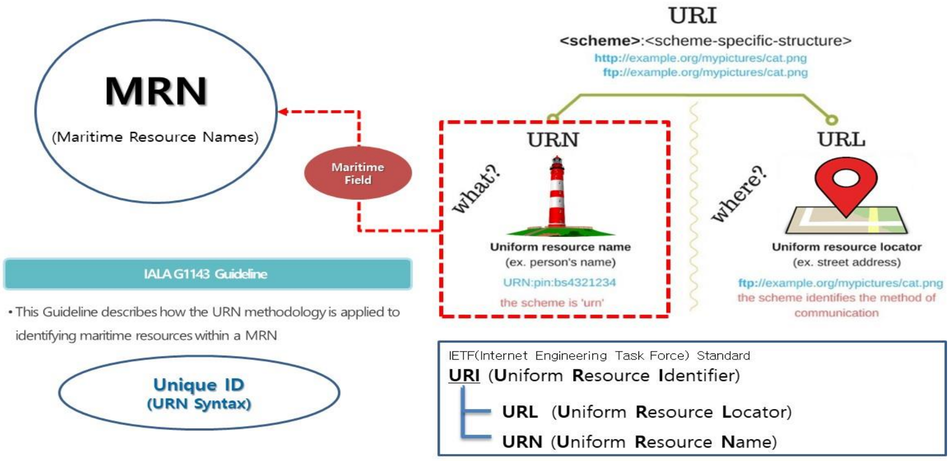

Figure 3: Concept of MRN

ROK Korea defined the MRN naming rules for the management of Aton as follows. Marine Aton is largely classified into mark, structure, and equipment, and Aton MRN numbers were composed of the year of installation, type of Aton, and serial number.

IALA G1143	Type	Sub code
urn:mrn:iala:aton:kr	Mark	Mark code
	Structure	Structure code
	Equipment	Equipment code

urn:mrn:iala:aton:kr:mark:2021LH001

Mark	2	0	2	1	L	H	0	0	1
	Year				Type		Serial number		

Aton	Mark Type	
Light Aids	Light House	LH
	Lighted Beacon	LC
	Leading Light	LL
	Projector Light	PL
	Sector Lights	SL
	Light Pile	LP
	Bridge Light	BL
	Vessel Traffic Light	TL
	Light Buoy	LB
	Spar Buoy	SB
	Large Automatic Navigation Buoy(LANBY)	LY
	Light Ship	LS
	Marine Structure Light	ST

Aton	Mark Type	
Shape Aids	Beacon	BC
	Leading Marks	LM
	Bridge Marks	BM
	Vessel Traffic Marks	TM
	Buoy	BY
Fog signal	Fog Signal	FS
Radio	Radar Beacon	RB
	Differential Global Positioning System(DGPS)	DG
	Loran	LR
Special Purpose	Marine Weather AtoN	WA
	Tidal Current Signal AtoN	TA
	AIS AtoN	AA
Other	Other	OT

Figure 4: Concept of MRN

3 MARITIME SERVICE SYSTEM FOR EXCHANGING ATON INFORMATION

There has been a need to develop new Aid to Navigation system in response to rapidly changing marine traffic and it was lack of research on standardization and system integration and need to improve facility/equipment advancement due to structural limitations. ROK promoted R&D project for SMART aids to navigation and digital service from 2021 to 2025 to upgrade aid to navigation and expand new aid to navigation system in response to future marine environment paradigm (MASS, AI Port, Digital Twin, ect), and monitor Aton status and collect marine digital data. The main goal of the project is to develop digital facility for SMART Aids to Navigation, intellectualize new marine traffic infrastructure and develop aton digital service. The research theme is as follows;

- (Advance Aton facilities) changes its roles to a marine platform that enable smart facility operation through AI-based fault diagnosis and high-efficient and light power supply technology
- (Stabilize information transmission system) provide the optimum information transmission system for the limited marine environment and purpose based on the world's first exclusive communication network for AtoN
- (Develop AtoN information system) Reorganize the existing dispersed Aids to Navigation information into standardized and digitized integrated information system

- (Develop digital service) Use SMART Aids to Naivgation to collect information, turn information to big data, and develop new digital service.

One of the project's themes is the development of SMART AtoN based digital Service Technology establishing AtoN information system in compliance with the international standard for new digital service with quality control and AI technology based on automatic Aton information connectivity and big data management system. Figure 5 shows the overview of Aton information system and digital service.

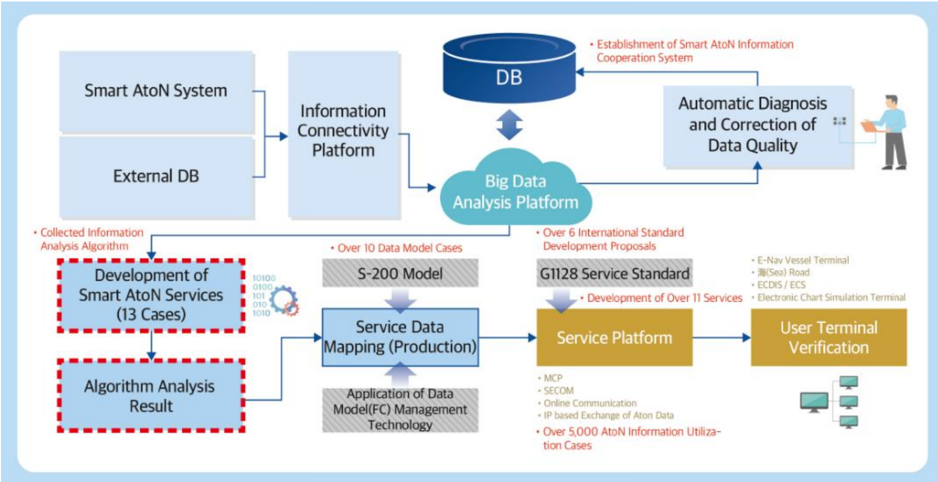

Figure 5: Overview of Aton information system and digital service

SMART Aton information management system is developed to manage Aton information based on IALA S-201 and it includes information management for SMART Aton and equipment/structure which didn't have classification system. It can be also connected with MRN service for integrated management of equipment, structure and Aton resources managed by 13 regional offices in ROK based on integrated number system to digitize Aton resources. It can be also used as basic data for establishing global Aton number system and information exchange system. Main characteristics are as follows;

- Better information management: Improvement of equipment/structure/Aton based on S-201
- Connection with MRN service: MRN based management of Aton resources to support international maritime standard (S-124, S-125) service, Easier management of metadata for AtoN, utilize serial number system with rules to manage marine resource to share Aton information
- Data reliability: Improve manual data input system to minimize manual input/expand automatic input

SMART Aton service platform is as service system that produces and provides Aton information data based on S-200 data model defined by IHO and IALA. It utilized basic Aton information and connects with MRN system to manage the standard information of Aton. When the end user requests the Aton service, the service platform uses the mapping information, converts data provided from integrated SW into S-100, and provide information to the end user. The main characteristics of service platform are as follows;

- Service data compatible with the S-100 data model: Able to receive S-200 data without separate conversion system, uses standard version and no need to update system, saves costs of developing system for standard conversion
- Management of S-200 based feature catalogue: uses digitized FC to automatically check product information model in platform, saves FC management costs

The Figure 6 shows the overview of Aton information management system and service platform

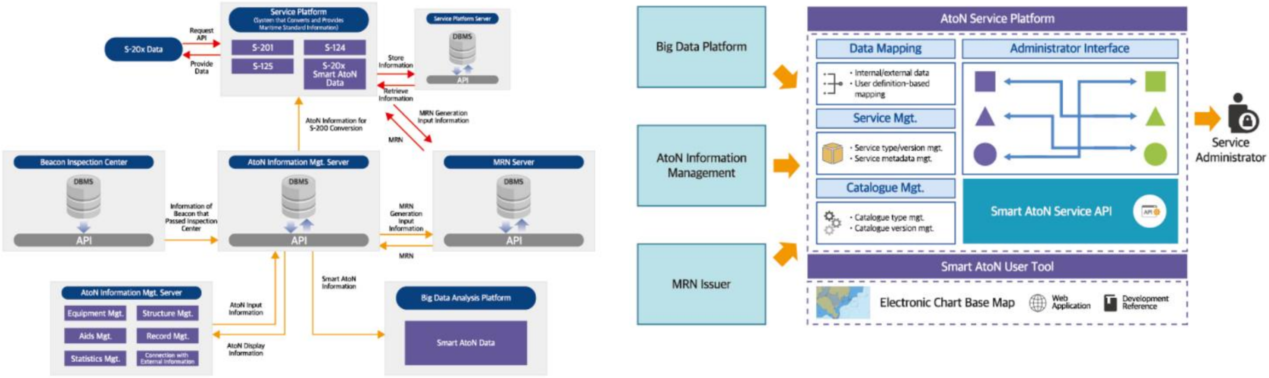

Figure 6: Overview of Aton information management system and service platform

Figure 7 shows the web-based user interface of Aton information management system

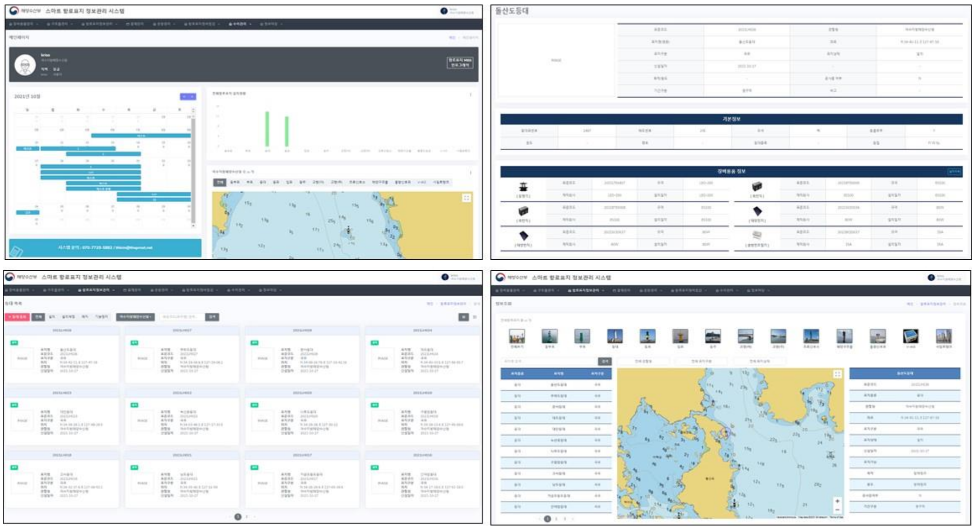

Figure 7: Web based user interface of Aton information management system

4 DEMONSTRATION OF ATON SERVICE

The joint IALA/IHO workshop on S-100/200 development and portrayal was held in September 2022 at the Norwegian Coastal Administration in Ålesund, Norway. The joint workshop agreed on the importance of cooperation between the two international organizations on marine digitization, and it was essential to inform the shipping domain of the cooperation efforts between the two bodies. Hence, it was recommended that the relevant working group and task group prepare presentations and demonstrations of S-201 Aids to Navigation (AtoN) Information /S-125 Marine Aids to Navigation /S-124 Navigational Warnings data service.

Specifically on S-125, one of the important outcomes of the workshop was a clear and concise understanding of the purpose and use of S-125 was agreed upon. It was agreed that S-125 would be a suitable replacement for the List of Lights and Fog Signals and act as a bridging mechanism. It was also agreed that the joint IHO/IALA development of S-125 should continue and the dataset should include, at a minimum, the same Aids to Navigation (AtoN) data contained in the S-101 Product Specification. S-125 should be tested at the earliest opportunity utilizing the services of the IHO-Singapore Innovation and Technology Laboratory (IHO-Singapore Lab). The project was scheduled to be held in conjunction with the Singapore Maritime Week in April 2023 as there would be a wider shipping audience attending the event.

Approved Project Scope. To test the interaction of S-124 and S-125 to better understand its interaction and to validate the proposed development by various groups under the IHO and IALA umbrellas.

The testing was planned for April of 2023 and its aim was to test the feasibility of updating the navigational information services using S-124 and S-125 services, as well as the process of transferring data between these different data services as the information goes through its lifecycles. Proposed Project Deliverables were as follows;

- Test results from S-124 and S-125 overlap for the same AtoN on S-101 ENC.
- To evaluate that the S-124 should take priority over the S-125.
- Operate S-124 and S-125 in S-100 testbed system considering the S-98 Interoperability Specification.
- Test results of interoperability between S-124, S-125 and S-101 through interleaving and overlaying which was agreed from the joint IHO/IALA workshop.
- Results on suitability of AtoN status symbols in S-125 product specification considering other symbols in ENC, as shown in diagram below, and
- Test results of technical specifications for the provision of AtoN information service to end-users in terms of e-Navigation maritime service.

When the user requests the service with the ECDIS onboard the vessel in the Singapore Waters via the 4G/5G network service, the service which is installed in Korea will respond with the requested S-124/S-125 dataset. The user then receives the response and then can verify the Navigational Warning or AtoN symbol update according to the service data on the electronic chart screen, as shown in the following test configuration diagram. The project team define the testing topics and designed the network diagram between shore system and end user system to exchange Aton information as S-124/S-125 dataset. For creation of Aton database, the team used the Singapore S-101 ENC provided by MPA.

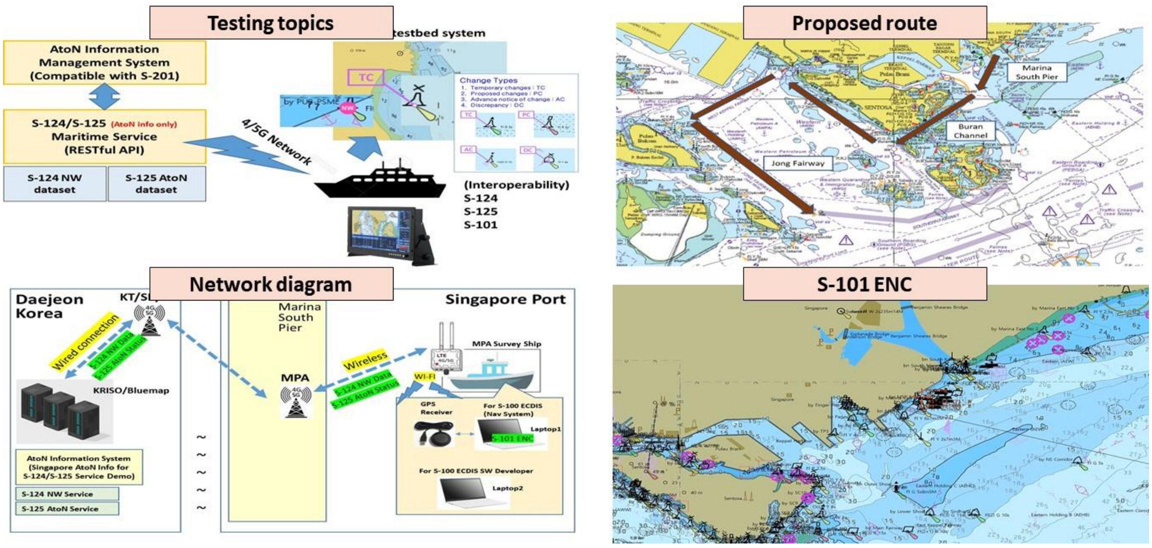

Figure 9: Preparation for Aton service demonstration project

For the Aton service demonstration project, testing scenarios of S-124/S-125 data service were drafted. The following table shows the proposed scenario which include two scenarios before departure and two scenarios while sailing.

Summary of Test Scenarios

#	Test Item	Test Date
1	Request and receive S-124 before departure. - Receiving test of S-124 dataset in route + buffer - Non-receiving test of S-124 dataset unrelated to route - Receiving test of S-124 dataset where nominal range and route intersect	20th April, 2023
2	Request and receive S-125 before departure. - Receiving test of S-125 dataset in route + buffer - Non-receiving test of S-125 dataset unrelated to route	20th April, 2023
3	Update S-124 while sailing. - Receiving test of new S-124 dataset in sailing - Receiving test of S-124 cancellation dataset in sailing	20th April, 2023
4	Transit from S-124 to S-125 while sailing. - Transition from S-124 dataset to S-125 dataset in sailing	20th April, 2023

Figure 10 shows the targeting Atons for S-124/S-125 data service and confirmed sea route for sea-trial demonstration.

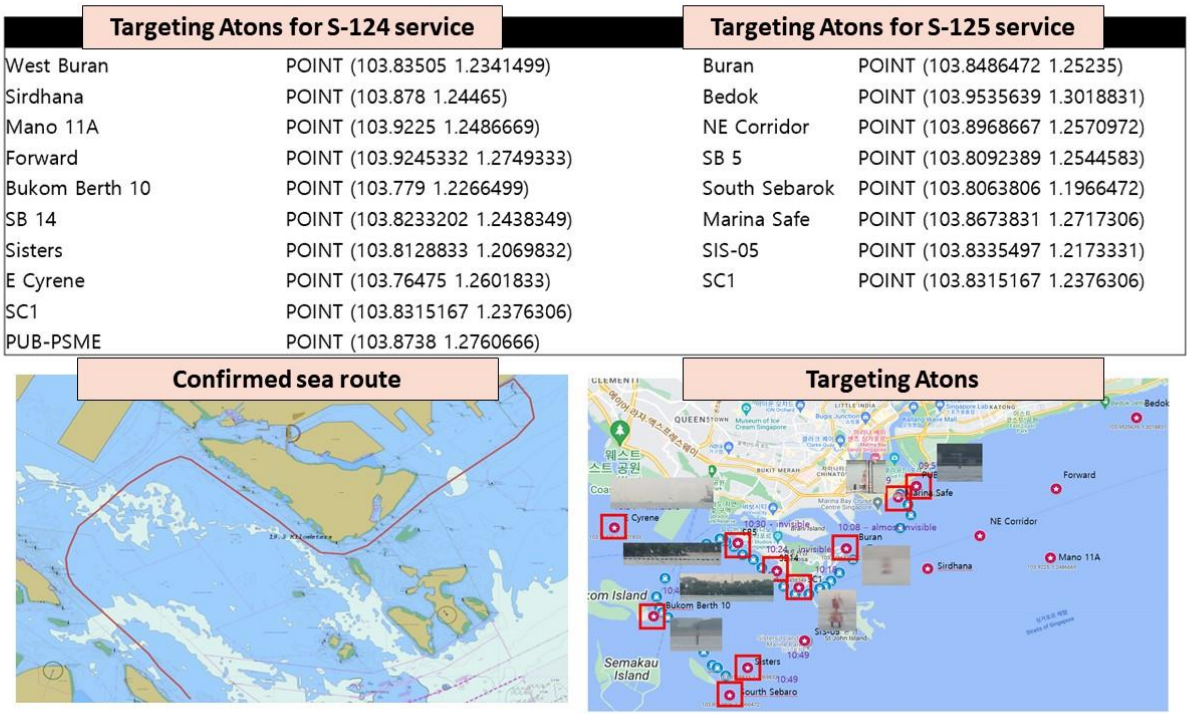

Figure 10: Targeting Atons and Sea route

The Proof of Concept Sea Demonstration tested the feasibility of updating the navigational information services using S-124 and 125 services. It also tested the process of transferring data between these different data services as the information goes through its lifecycles successfully. The key takeaways are from the Sea Demonstration were:

- The project would provide the AtoN authorities a chance to own their datasets (i.e. S-125), rather than rely on Hydrographic Offices (HOs).

- Authorities need to consider developing a central S-201 database to support updating service and have it operationalised before January 2026.
- The protocols for sequencing and priority to send and display S-124 and S-125 needs to be further examined using Marine Resource Names for AtoN unique identity.
- The project also demonstrated a low barrier to entry. System requires only a simple cellular network connection for a wide spectrum of users onboard to adopt and benefit from these services.
- During the sea demonstration, deviations had to be made between the planned route and actual route. As a result, it was interesting to discover the effects of the display when the AtoN information relevant to the route fell outside the pre-set buffer. The protocols for setting such buffer needs to be further examined, for example whether the S-124/S-125 information should be guided by Nominal Range of the AtoN, or simply specific to a passage plan.

Figure 11 – 13 shows results for exchanging Aton data, Testing log for Aton service and Photos of Aton service demonstration project.

		Dataset list in Information System							
Test Scenario		S-124				S-125			
Test Procedure	Expected Result	#	Type	Name of AtoN	Note	#	Type	Name of AtoN	Note
1. Create S-125 data for S-124 cancellation in the AtoN information management system. [Create S-125] - Near route: 1 case 2. Request S-125 service from ECDIS with route + buffer polygon. 3. In the AtoN information management system, Cancel one of the S-124 near the route of the TC-03-002 result. (Create S-124 cancellation data) [Create S-124 cancellation] - Near route: 1 case 4. Request S-124 service from ECDIS with route + buffer polygon.	1. Service transmits data near the route to ECDIS. (Do not transmit out-of-route data) [Service response] - Added 1 case of S-124 cancellation near route to the result of TC-03-002 (8 cases in total) - Added 1 case of S-125 near route to the result of TC-02-002 (5 cases in total) 2. List and S-125 state flag of data registered by ECDIS are displayed on the screen. (Symbols of S-124 and S-125 are overlapped on same AtoN) 3. List and symbols of data excluding data canceled by ECDIS are displayed on the screen.	1	relevant	PUB-PSME	Symbols are displayed on ecdis screen	1	relevant	Buran	Symbols are displayed on ecdis screen
		2		West Buran		2		SB 5	
		3		Bukom Berth 10		3		South Sebarok	
		4		E Cyrene		4		Marina Safe	
		5		SB 14		5		SC1	
		6		NEA-WRM-MP		6	irrelevant	Bedok	Symbols are not displayed on ecdis screen
		7		*Sisters*	Symbol is removed on ECDIS screen according to S-124 cancellation data	7		NE Corridor	
		8		*SC1*		8		SIS-05	
		9	cancellation (relevant)	Sisters	cancel #6				
		10		SC1	cancel #7				
		11	irrelevant	*Forward*	Symbol is removed on ECDIS screen according to S-124 cancellation data				
		12		Sirdhana	Symbols are not displayed on ecdis screen				
		13		Mano 11A					
		14	cancellation (irrelevant)	Forward	cancel #10				
		Total S-124 dataset		14 cases		Total S-125 dataset		8 cases	
		relevant S-124 dataset		6 cases		relevant S-125 dataset		5 cases	
		relevant S-124 cancenllation dataset		2 cases					

Figure 11: Final results for exchanging Aton data

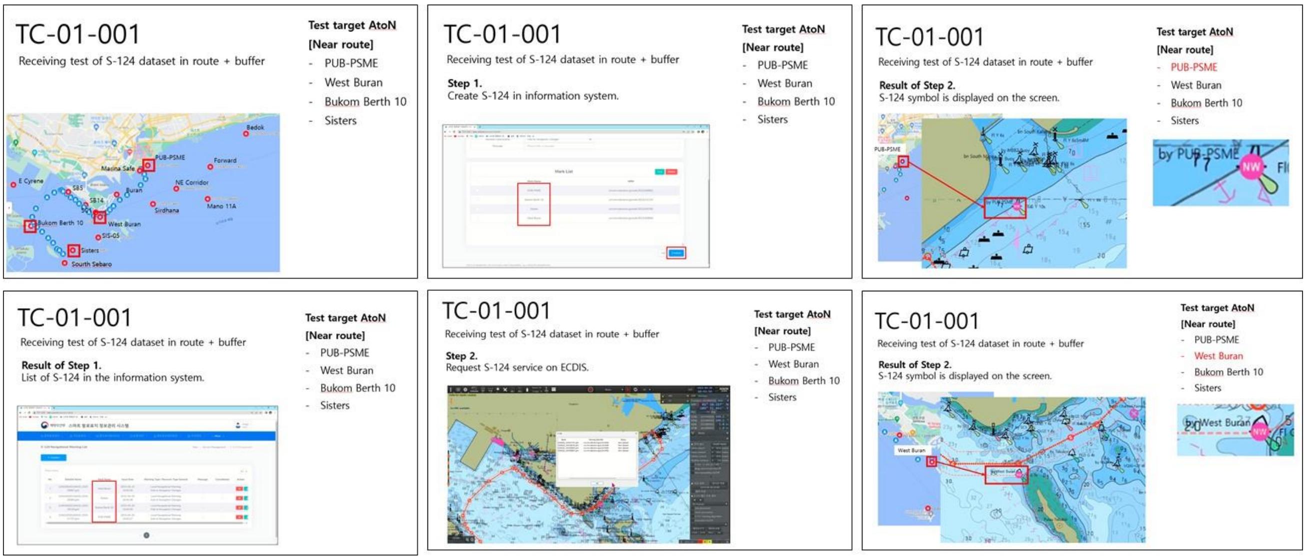

Figure 11: Testing log for Aton service

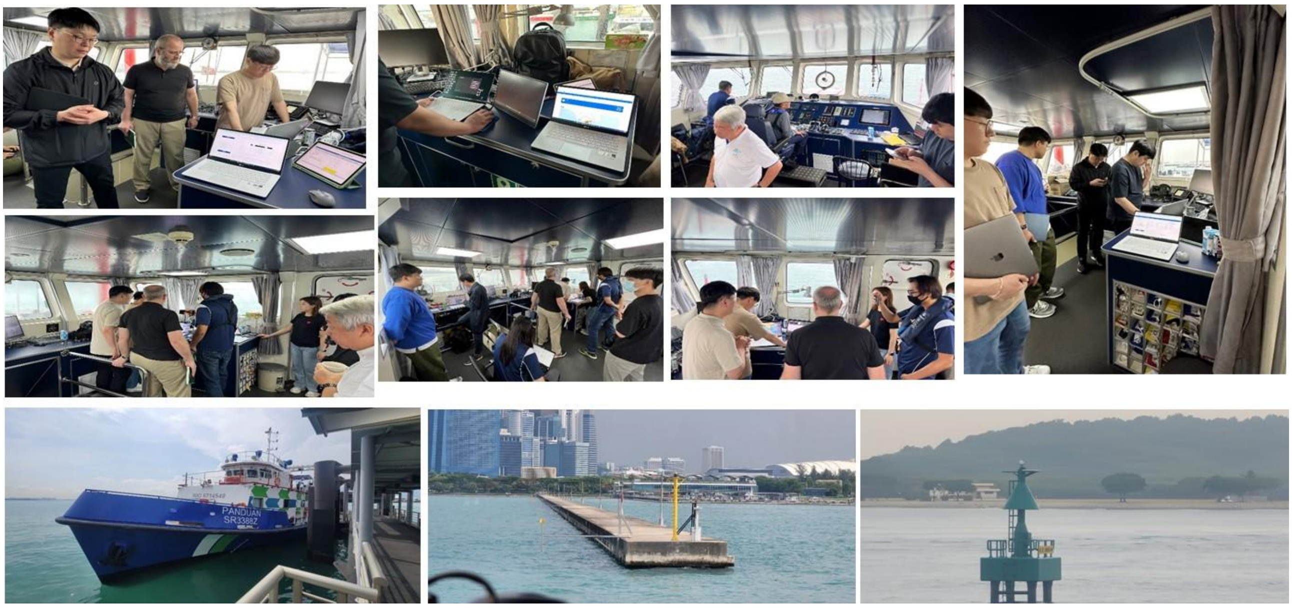

Figure 11: Photos of Aton service demonstration project

After the sea demonstration, there was a focused group workshop. They discussed the Aton service topics including below items.

- Symbology of NAVWARN and AtoN status; are there improvements needed to the symbols defined? Maybe transparency in NAVWARN symbol, highlight in AtoN status information etc
- Discussion for service providers; is a description of the system dependencies useful to highlight the interdependencies between a NAVWARN system and an AtoN information system?
- Discussion for mariners; how often should system check for updates (e.g. is more often better or is for example every 8h enough?)
- Discussion for mariners; user system GUI, how to present new information to user? What type of functions are needed to give user sufficient tools to discover changes and what they entail for situational awareness.

- Cognitive load; NAVWARN service and AtoN information service are both intended to improve the visual information presentation to end users. This means they intend to lessen administrative burden in information updating, and by being shown on same screen as ENC, reduce cognitive load for the user versus considering information from different sources and mentally combine the information.

5 CONCLUSION

ROK promoted R&D project for SMART aids to navigation and digital service from 2021 to 2025 to upgrade aid to navigation and expand new aid to navigation system in response to future marine environment paradigm (MASS, AI Port, Digital Twin, ect), and monitor Aton status and collect marine digital data. One of the project is the development of SMART AtoN based digital Service Technology establishing AtoN information system in compliance with the international standard for new digital service with quality control and AI technology based on automatic Aton information connectivity and big data management system. As a cooperation activity between IALA and IHO, the Aton service demonstration project was conducted in Singapore on April 2023. After the sea demonstration, focused group workshop was held and they had discussion on proposed usage of new symbologies, for example use of magenta, translucence, boxes, shading, shapes etc. The dialogue with shore-based personnel (Mariners, AtoN authority, Cartographers, Hydrographic Surveyors, Port Systems) provided significant value in terms of their different perspectives on the pros and cons for different forms of portrayal of the S-124/S-124 overlays onto S-101. There is a need to support non-ECDIS systems and users, such as PPUs and ECS used by pilots and other users. The project serves as an opportunity to kickstart dialogues between AtoN authorities and HOs to align respective responsibilities. This collaborative project has provided a great opportunity to raise awareness of the value of the IHO-Singapore Lab in facilitating innovation works jointly embarked by the IHO and IALA. The IHO-Singapore Lab looks forward to more opportunities to i) facilitate the conduct of innovative or investigative projects, ii) enable knowledge creation and foster collaboration to evaluate specifications of global standard setting, and iii) foster a multidisciplinary and collaborative environment for investigators.

6 ACKNOWLEDGEMENTS

This research was a part of the project titled 'Marine digital AtoN information management and service system development (3/5) (20210650)', funded by the Ministry of Oceans and Fisheries, Korea.

AUTHOR BIOGRAPHY

Dr. Sewoong Oh is a principal research engineer of Maritime Digital Transformation Research Centre in Korea Research Institute of Ships and Ocean Engineering (KRISO). His research activities focus on the marine data exchange standard and maritime safety services. He has been involved in the S-100 test bed project of Korea and led two research topics which was ENC service for non SOLAS vessel and marine safety information service in the SMART Navigation project. He is also the project lead researcher of SMART AtoN Project which aims to establish AtoN information service centre and develop AtoN information service using the MRN, S-200 series PS and maritime service guideline. Currently, He is a member of IHO S-100WG and also contributing the development of S-200 product specifications of IALA.

S6.4 Navigational Warnings (012)

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ABSTRACT

The Navigational Warnings are messages transmitted to ships in order to provide urgent and relevant information to safe navigation, according to the statement in Rule 4 of Chapter V of SOLAS, 1974. Along with the SAR Warnings and Weather Informations, they comprehend what is called by Maritime Safety Information or MSI. For a better understanding of the content, it is essential to highlight that Maritime Safety Information means navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages broadcast to ships, according to the subitem 2.1.8 of IMO Resolution A.705(17), replaced by MSC.1/Circ.1287/Rev 1. Distress alerts sent by ships to request Search and Rescue are not considered MSI.

The Navigational Warnings are registered in a local database where it is possible to search for area, chart, topic, and other categories. After registering Maritime Safety Information, the system requires review and verification before approval. The text files JSON (JavaScript Object Notation) are generated and sent to broadcast channels. Those channels are the Brazilian Navy Radio Station in Rio de Janeiro (ERMRJ), Inmarsat (communication carried out by satellite whose ground station is sited in Burum, Netherlands) and Brazilian Navy Hydrography Center (CHM) on internet and intranet.

KEYWORDS: navigation, warnings, maritime, safety, information.

1 INTRODUCTION

In the modern era of maritime navigation, the safety of ships at sea depends heavily on accurate and timely information about hazards to navigation. Navigational Warnings (NWs) are an essential component of this information, providing mariners with critical updates. The International Hydrographic Organization's (IHO) Standards for Hydrographic Surveys, known as the S-124, has brought standardization and efficiency to the production and distribution of NWs worldwide.

Nautical warnings are an essential element of marine safety, providing mariners with timely and critical information about hazards, navigational restrictions, and other dangers to navigation. These warnings are broadcast via radio or other communication channels to ensure that all vessels in the vicinity are aware of the potential dangers and can take appropriate action to avoid them. NWs can include warnings of hazards to navigation, such as rocks, shoals, or sunken vessels, as well as meteorological and oceanographic warnings, such as storm surges, strong winds, or rogue waves.

The S-124 standard provides a framework for the exchange of navigational warnings that ensures interoperability among different maritime communication systems. It establishes standard formats for the content of navigational warnings, including the type of hazard, the location of the hazard, and the time and duration of the warning. The standard also provides guidelines for the dissemination of warnings, ensuring that all relevant information is transmitted to all affected vessels in a timely and efficient manner.

Navigational hazards in the form of submerged objects, shallow waters, and other obstructions pose a significant threat to maritime safety. Therefore, having access to reliable and accurate data on such hazards is crucial for safe navigation. In this paper, we present a secure database system capable of storing navigational hazard data and providing geographic visualization of danger zones. The system supports input from various sources and allows for real-time updates, ensuring the most recent and accurate information is available to users.

2 AIDS TO NAVIGATION

The maritime industry relies heavily on accurate and up-to-date navigational information to ensure safe and efficient shipping operations. The friendly interface of the system allows for easy search and analysis of navigational hazards based on specific criteria.

In addition to the S-124 standard, the IHO has also developed other standards and guidelines related to navigational safety. These include the S-101 standard for electronic navigational charts (ENCs) and the S-102 standard for digital hydrographic data. These standards are also essential for ensuring safe navigation and have been widely studied to be adopted by maritime nations around the world.

2.1 SYSTEM ARCHITETURE

The database system is designed using a three-tier architecture, with a presentation layer, application layer, and data storage layer. The presentation layer provides a user-friendly interface for accessing and analyzing navigational hazard data. The application layer handles user requests and provides access to data from the data storage layer. The data storage layer contains all navigational hazard data, which is securely stored in a relational database management system.

2.2 GEOGRAPHIC VISUALIZATION

The system provides a geographic visualization of navigational hazards, enabling users to view danger zones on a map (Figure 1). The user can filter and search for specific hazards based on parameters such as location, depth, and type of obstruction. The system also provides real-time updates of danger zones, ensuring users have access to the most recent information.

2.3 FIGURE

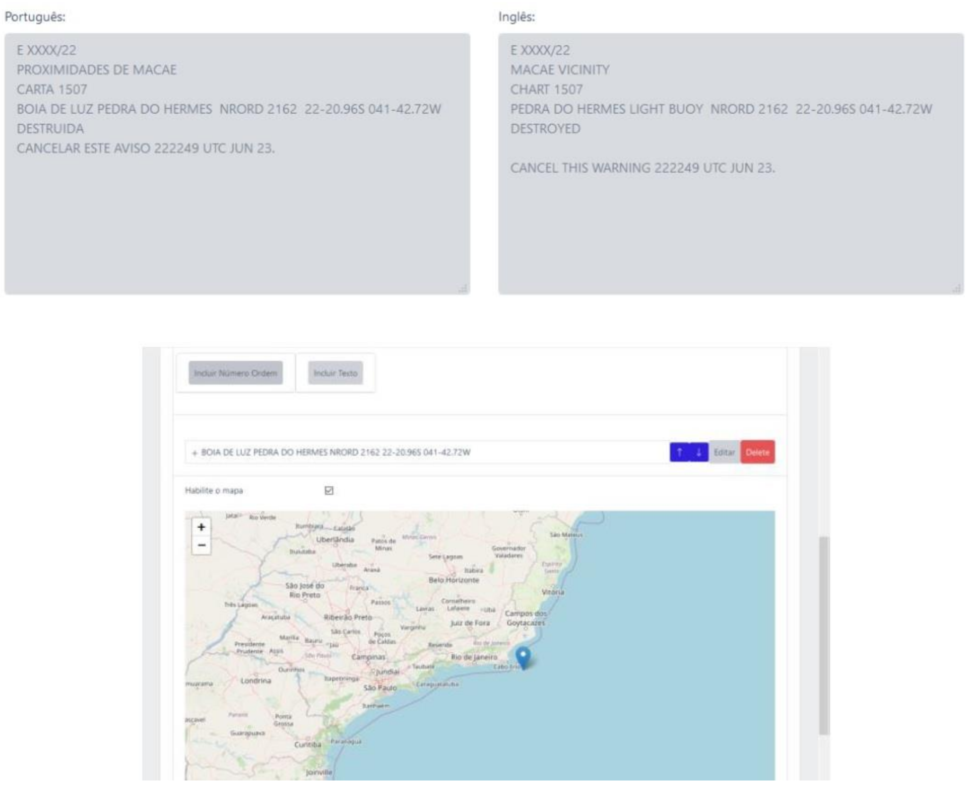

Figure 27: Geographic Visualization

3 CONCLUSION

In conclusion, I presented a secure database system capable of storing navigational hazard data and providing geographic visualization of danger zones. The system enables data input from various sources and supports real-time updates, ensuring users have access to the most recent and accurate information. The user-friendly interface and streamlined data input process make the system easy to use, while the security measures ensure the data remains safe. The system has the potential to enhance maritime safety and improve the efficiency of shipping operations.

4 REFERENCES

[1] IHO. Universal Hydrographic Data Model. Edition 5.0.0

AUTHOR BIOGRAPHY

Graduated in Cartographic Engineering from the State University of Rio de Janeiro (2010). I am currently Lieutenant Commander - Head of Safety of Navigation Information Section in Navy Hydrographic Center. I have experience in the area of Geosciences, with emphasis on Remote Sensing, acting on the following subjects: aerial photogrammetry, geodesy and geoprocessing (GIS).I am currently responsible for the dissemination of Maritime Safety Information (MSI) through Navigational Warnings for the maritime community, in addition to the Notices to Mariners and other publications to aid navigation.

I am a representative of NAVAREA V (navigation area of responsibility of Brazil) at the World Wide Navigational Warning Service Sub-Committee (WWNWS-SC) whose objective is to monitor and guide the International Hydrographic Organization (IHO) / International Maritime Organization (IMO) and provide network of other NAVAREAs Coordinators. I am also part of the S-124 Project Team (S-124PT) which brings together representatives from different countries to discuss the migration of *txt* data from Navigational Warnings to structured and geospatialized data for the IHO S-124 format.

S6.5 The Canadian Coast Guard experience on the implementation of the S-201 (148)

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ABSTRACT

This paper will elaborate on the Canadian Coast Guard's work to implement S-201 and how the work impacts the international development of S-201. The Canadian Coast Guard (CCG) has been using its Aids to Navigation information system (SIPA) to manage its aids to navigation for nearly 30 years. SIPA is now nearing the end of its lifecycle and CCG is exploring options for replacing SIPA and simultaneously implementing S-201. This paper details the process of finding a replacement for SIPA and further explains how CCG is using the SIPA replacement process to test S-201, and its operational relevance for the Canadian Coast Guard. The paper further explains envisioned data flows and integration with Canadian Hydrographic Service (CHS) and how potential solutions may be implemented, including options for mixing commercially-off-the-shelf software and expanded roles of other existing databases. Lastly, the paper itemises the inputs that CCG has made to the S-201 development, and also encourages other Aids to Navigation (AtoN) authorities to share similar experiences for the overall improvement of S-201.

KEYWORDS: SIPA, S-201, Aids to Navigation, AtoN, Notmar, NAVWARN, RAMN, Sailing Directions

1 INTRODUCTION

The Canadian Coast Guard developed SIPA in the mid-1990s to help operate the Canadian AtoN system. SIPA represents the main source of AtoN information for navigational products in Canada such as charts, nautical publications, notice to mariners, and navigational warnings, and any replacement needs to support a close integration with these services. SIPA supports the day-to-day operation of the Canadian AtoN system, which is critical in the delivery of one of CCG's core mandate. The age of SIPA necessitates a complete replacement in order to implement support for S-100 [1] and S-201 [2] specifically.

This paper provides an update to a briefing on the Canadian plans that were presented to the International AtoN Forum, October 2020 [3].

2 SIPA BACKGROUND

SIPA is the authoritative reference for fixed and floating aids to navigation information in Canada. Over its lifetime SIPA has adopted to the operational realities and now includes the following functionalities:

- Used as reference data for the following publications (the intention is to fully automate this process in the future):
  - Notices to Mariners (NOTMAR) (linking with CHS Dir)
  - Notices to Shipping (NOTSHIP/NAVWARN)
  - Radio Aids to Marine Navigation (RAMN)
  - Nautical charts (CHS)
  - The List of Lights, Buoys and Fog Signals (LL)
  - Sailing directions (CHS)
- Manages aids requests
- Manages AtoN information
- Manages AtoN service discrepancies

- Plans and monitors aid maintenance in parallel with Maximo
- Plans and tracks level of service of aids and systems
- Maintains service agreements
- Maintains cost estimates for aid category and equipment
- Allows data capture on ship and the updating of the shore systems later date
- Queries the database through the use of query tools (Cognos) and provides statistics for reporting purposes

3 SIPA REVIEW

The SIPA database has come to a crossroad where the effort to maintaining it further outweighs the cost of developing a new system. In particular, the age of SIPA is such that the database technology and system of scripting languages are outdated and no longer used, which increasingly complicates the task of ensuring that staff can support the stability of the system. Coupled with poorly documented changes over time, any new changes would likely increases the risks to the stability of the system.

Recognizing these increasing challenges along with the impact and options that have arisen with the development of the S-100 based product specification S-201 Aids to Navigation Information, the Canadian Coast Guard started a review of SIPA in 2015, noting in particular the following reports and primary scope of the analysis:

- Business Requirements - Enhancement of AtoN Program Support Tools (2015)
    - This document represents the amalgamation and prioritization of the requirements from a national perspective.
- Recommendations for Modernization (2017)
    - This document describes the AtoN program mandate and work flows, AtoN support tools and interfaces with other systems, SIPA functionality, issues and initiatives. It describes considerations regarding SIPA modernization options and, and short and long-term recommendations.
- Review of SIPA and IALA S-201 for the purpose of finding synergies and gaps (2017)
    - This review investigated whether the SIPA database model could support some form of S-201 output, and what changes are required in SIPA to establish full support for S-201 output, including what processes may be needed to ensure the longevity of this support.

These reports have helped to formulate the modernization plans for SIPA with a new AtoN database and have highlighted the importance of proper assessments of the challenges and requirements before embarking on modernization efforts, as the reports have uncovered the interdependence of the data usage between systems and how critical data integrity is to any modernization efforts.

4 ATON SYSTEM RENEWAL PROGRAM

Based on the reviews, a decision was taken to replace SIPA with a new system. This new system aims to use S-201 data model as the foundation and would be augmented with the specific requirements of the Canadian AtoN Program. An AtoN System Renewal Program was initiated in 2019, however, the project was delayed and has only recently been re-started (2023). Before the project was delayed, phase 1 artifacts were created giving the renewal team a business analysis report and data architecture requirements. These requirements are outlined further in the document.

4.1 Phase 1 – Business Analysis

The business analysis consisted of a review of the current state of the SIPA system and associated operations. A review and investigation with support from current SIPA stakeholders documented all current and relevant data flows, as well as all stakeholders, which would require support in a future system. This review investigated the type of information to be exchanged, the direction and path of this information, as well as the stakeholders involved in the exchange. This information exchange was documented in the following Data Flow Diagrams (DFD).

Figure 28 - Current state data flows

The current state of data flows were then used to create a vision for a future state data flow to ensure all relevant data flows and stakeholders were documented. The envisioned future state data flows can be seen in Figure 2.

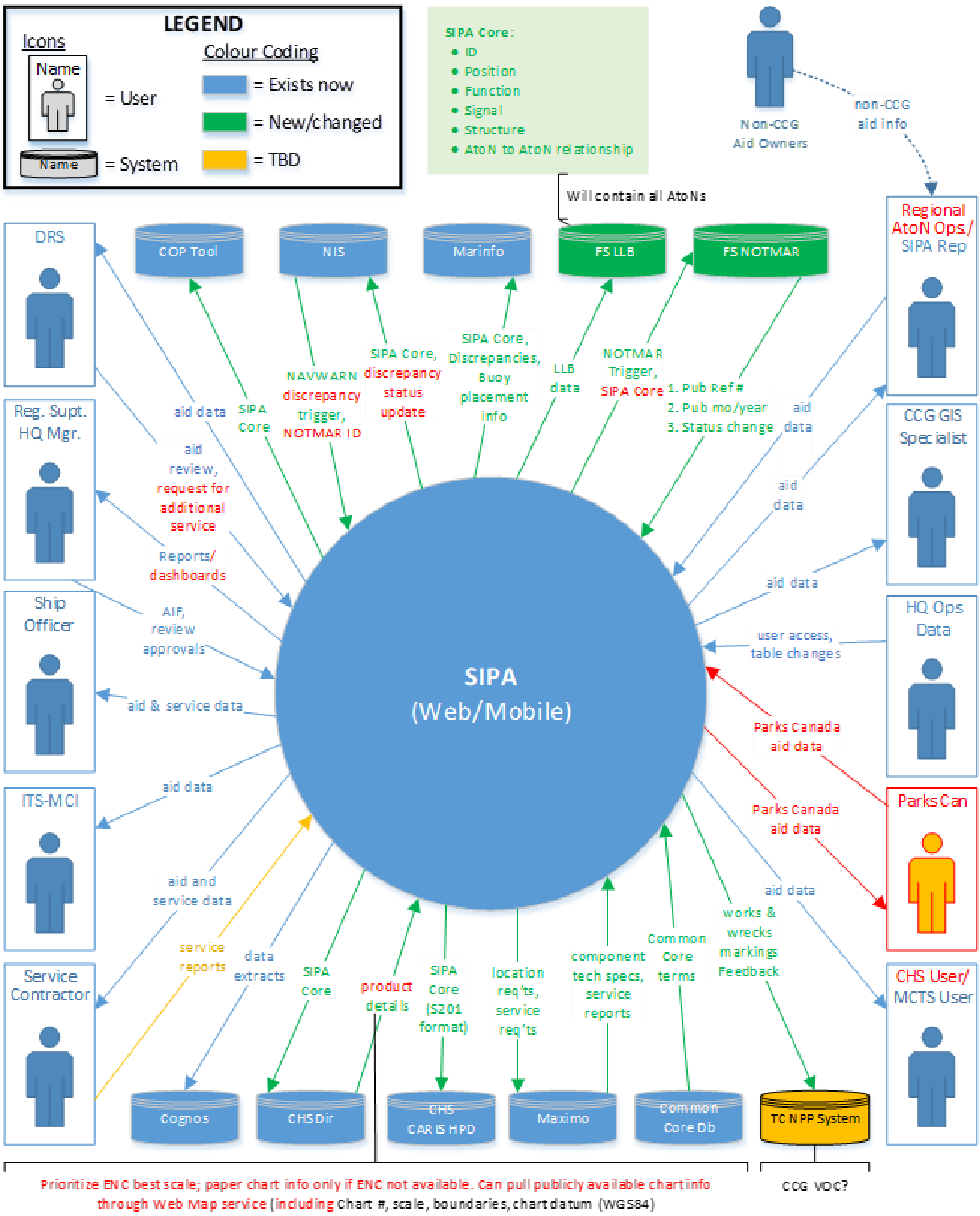

Figure 29 - Envisioned future state data flows

The business analysis also reviewed the data model and user interface of SIPA. This was documented in Entity Relationship Diagrams (ERDs) to express how the current information is stored and modelled in relation to the various functions of the system. Moreover, the ERDs helps document the current processes for data management and serve as a means to ensure all relevant parts of the current system are considered when developing the future state system. The example ERD below, shows the highest level entity, the Aid and its relationship with lower level entities; most of these also had their own ERDs created.

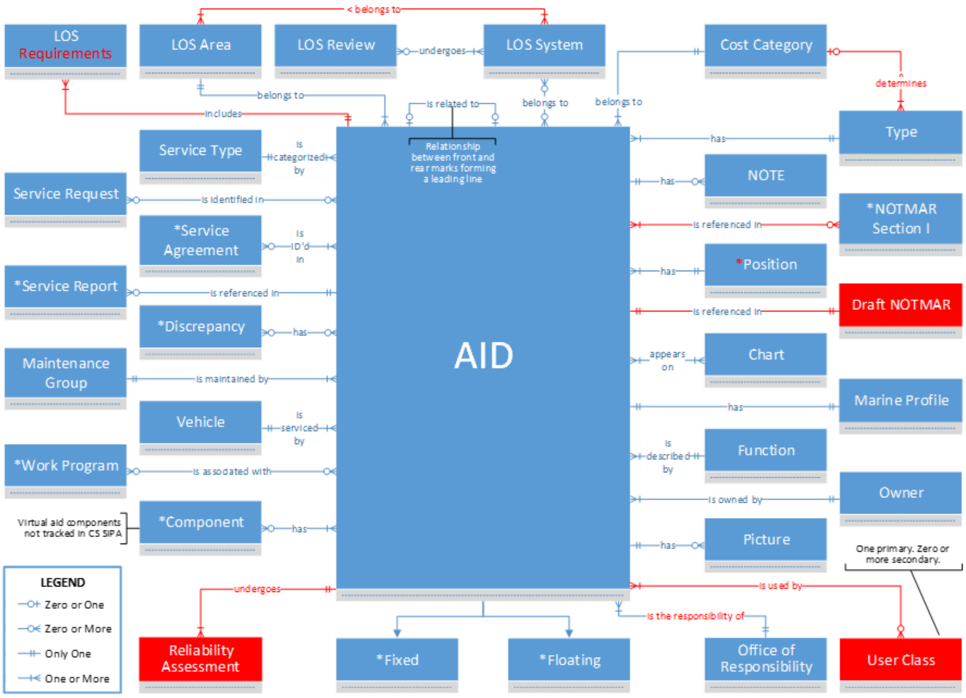

Figure 30 - Current state Aid Entity Relationship Diagram (ERD)

The ERDs are being used to document the various classes and attributes needed to hold the various pieces of information. These various classes and attributes are mapped against the S-201 data model. This work is being done using Microsoft Excel spreadsheets and is currently in progress.

The comparison with S-201 highlighted numerous revisions and alterations required to the data model in order to remain compliant with S-201 and the S-100 framework. In general, the changes are minor and impact how information is captured or modelled, while the general principles remained relatively unchanged. Some aspects of S-201 have been more challenging in that the general paradigm is to view an AtoN as a structure with optional equipment or as an electronic aid, while the Canadian system has been to view an AtoN as a signal achieved by a structure with optional equipment that delivers the requested signal. Terminology between the Canadian AtoN system and S-201 has, in some circumstances, been different and this has been noted as a challenge to be addressed by training. The future state highest level entity ERD is seen in draft form below and has considered the impact of S-201.

Throughout this process, gaps were identified in the S-201 data model and these were captured and submitted to IALA for discussion and implementation into future versions of the product specification. One example was greater details about the mooring components of floating AtoNs, which was implemented in Edition 1.1.0 of S-201.

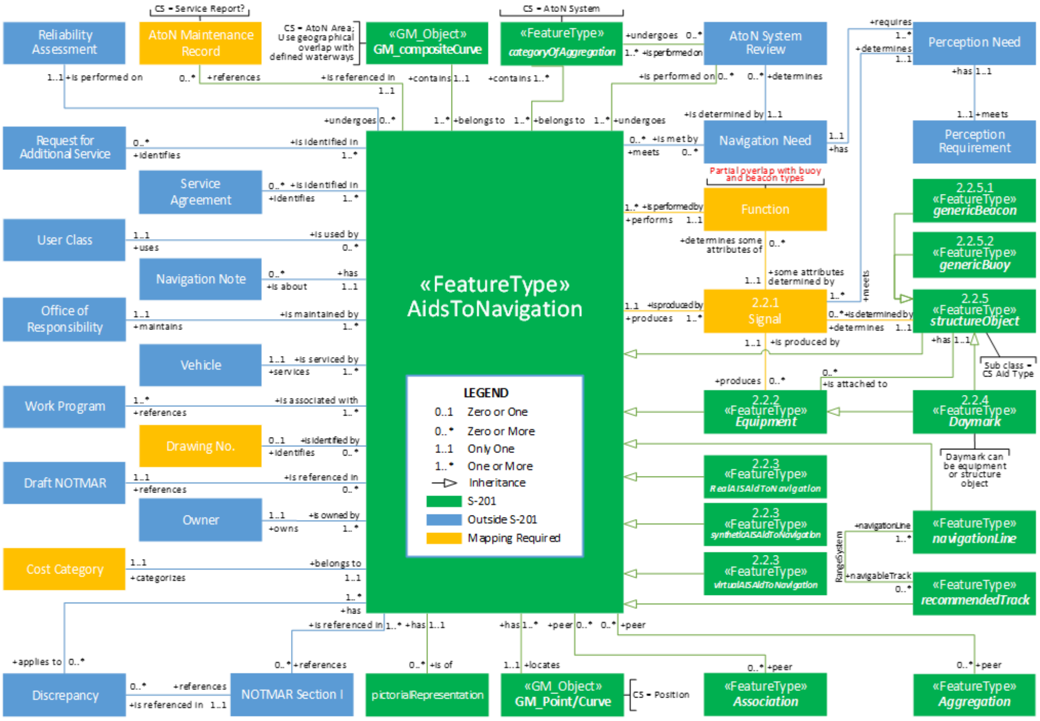

Figure 31 – Draft future state Aids to Navigation Entity Relationship Diagram (ERD)

In-parallel, use cases for the various system functions are being captured and mapped to the ERDs to document user interface requirements. Since the user interface is the front-facing part of the new system, special care is needed to make the system as efficient as possible. Some challenges to address include transitioning from current user interface, conveying AtoN information in the larger e-Navigation context to the regular user and finding a mobile solution that should be accessible on smaller displays.

The user interface of the current state system consists mainly of a web interface (see Figure 4) on the CCG intranet with tables, panes and queries. Additionally, the SIPA database is often queried using IBM Cognos Analytics for generating reports and other outputs for decision making.

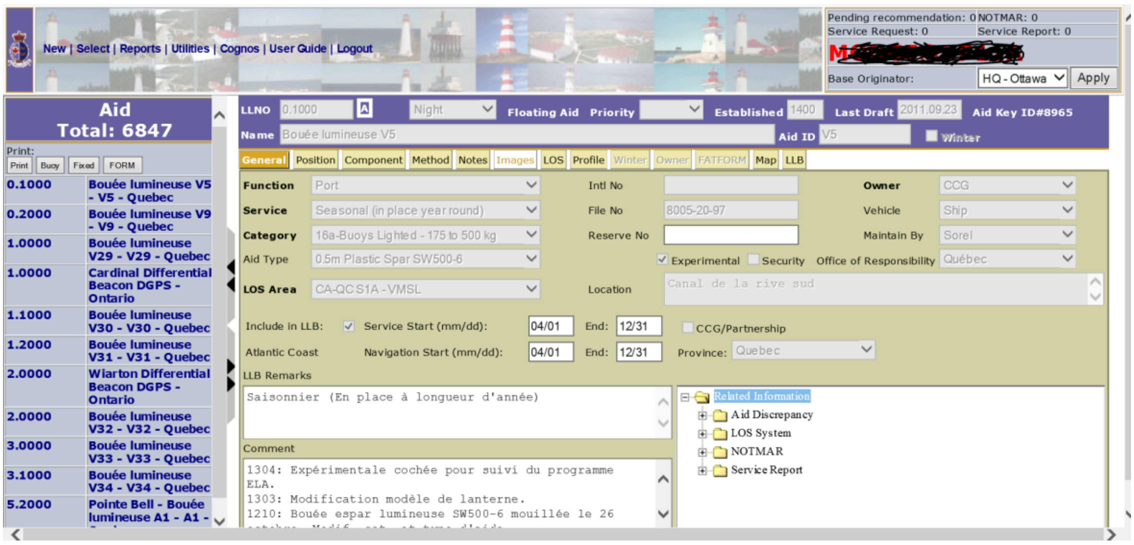

Figure 32 - SIPA Web Interface

A mobile solution is needed to ensure system access from remote locations, such as onboard ships. Given the expected smaller screen size, less comfortable work environment and potentially unstable connections to the main system, the mobile solution may require additional adaptations. Such adaptations may include larger buttons, less screen details and multiple modes to focus on particular sets of information. Extra validation of the input information may also be required. Creating such an environment has presented itself as a significant challenge. The mitigation has been to define a set of requirements that includes APIs to the relevant databases, which in turn will be folded into standing offers issued to industry, meaning that any provider of Electronic Charting Systems (ECS) or similar, will have to meet these requirements as part of the procurement process. Recent technology and service developments in the Low Earth Orbit satellite constellations are expected to significantly improve the options available to achieve an efficient exchange of information between shore and ship. There is still some work to be done on this approach, so time will show if it is more successful that creating a self-developed solution.

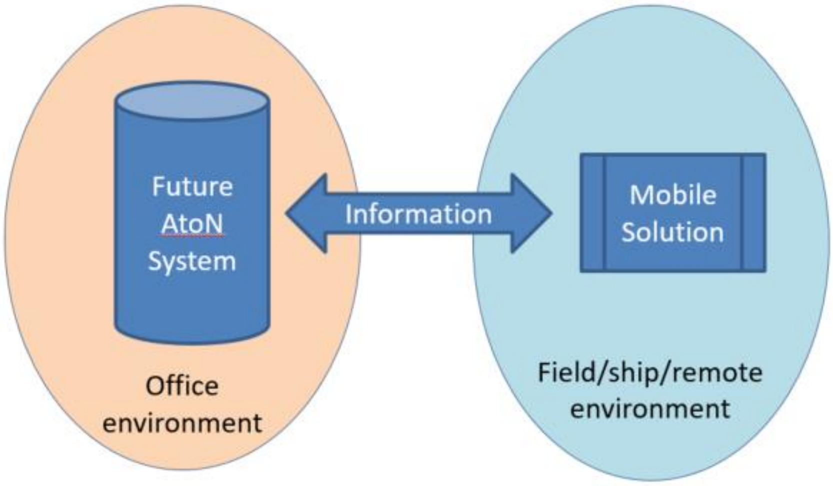

Figure 33 - High level vision of future system with the mobile connection

4.2 National data capture/business rules

In parallel to the business analysis, work has started on improving the national data capture/business rules. Due to the age of SIPA and the slightly different needs in each of the Coast Guard regions, the data in SIPA has some regional styles that make it more difficult to integrate with other systems. To investigate the seriousness of these regional styles on data migration, a small project was issued to a contractor to validate the conversion process as suggested in the 2017 report and test it with actual data. The results show that although it is possible to extract data from SIPA and convert it into something that resembles S-201 data, there is a need for significant data cleaning before a large-scale conversion is possible.

It is therefore necessary to enact a set of common, national business rules to harmonize data, improve data quality, and enable smoother data exchange transition to new system. A follow up project is planned to implement common rules on the entire SIPA database, but the sensitive nature of some of the content, such as contact information and service contracts, along with possible impacts on current business processes require careful planning before such a project can be launched.

4.3 Phase 2 – Identifying Solutions

With the business analysis was completed, the project is currently in its second phase, to identify and apply the solution. This phase is challenging as there are many competing user needs to balanced when finding a common solution.

The high-level vision for the future state system is an interface that fully supports a GIS view of the data to improve the user comprehension of the AtoN situation with better context and visualization of the input information. It will also prepare the users for a future where S-125 Marine Aids to Navigation [4] datasets may be an output of the system. Context will be improved by adding Electronic Navigational Charts (ENC) and topographic maps as a background, or by adding satellite or aerial photography. Additionally, further context could also include enabling inputs like AIS historic tracks, navigational warnings, notice to mariners and nautical publications.

In the GIS-aligned user interface, there is a vision to focus on using position to derive much information such as waterway name, Aid name, CCG region and so forth by connecting the system with updatable national datasets and databases, such as MAXIMO, the asset management system, to improve data quality and interoperability between different government entities.

There are limited providers of technology solutions with sufficient knowledge of the S-100 Framework and the AtoN service domain. The relatively new methodology introduced by S-100 along with a limited international customer base limits available solution providers. This makes it unlikely that any commercial-off-the-shelf (COTS) solution will be readily available, leaving only a fully bespoke or partial COTS with customization as the most likely options. There are considerable risks to the project when considering these issues, but it is expected that alignment with S-100 and S-201 will yield a system with significant longevity and flexibility that will align well with emerging international standards like S-125. Sufficient testing of possible solutions will be done and will likely consist of current super users verifying that daily operation processes are supported and function sufficiently.

CCG is currently looking at a solution that utilizes COTS components to integrate with bespoke interfaces and APIs. Figure 7 below shows the leading system solution architecture and highlights that the plan calls for a bespoke web-based user interface that pulls from different databases. A significant benefit of such a solution is that it allows the COTS components to be utilized where their strength is, and gives CCG control of the user environment to meet national standards and terminology, such as Canada's bilingual requirements, while still giving the benefits of COTS solutions to build on the strengths of these. This approach should provide for an expandable environment to build on as the CCG experience with S-100 and e-Navigation continues.

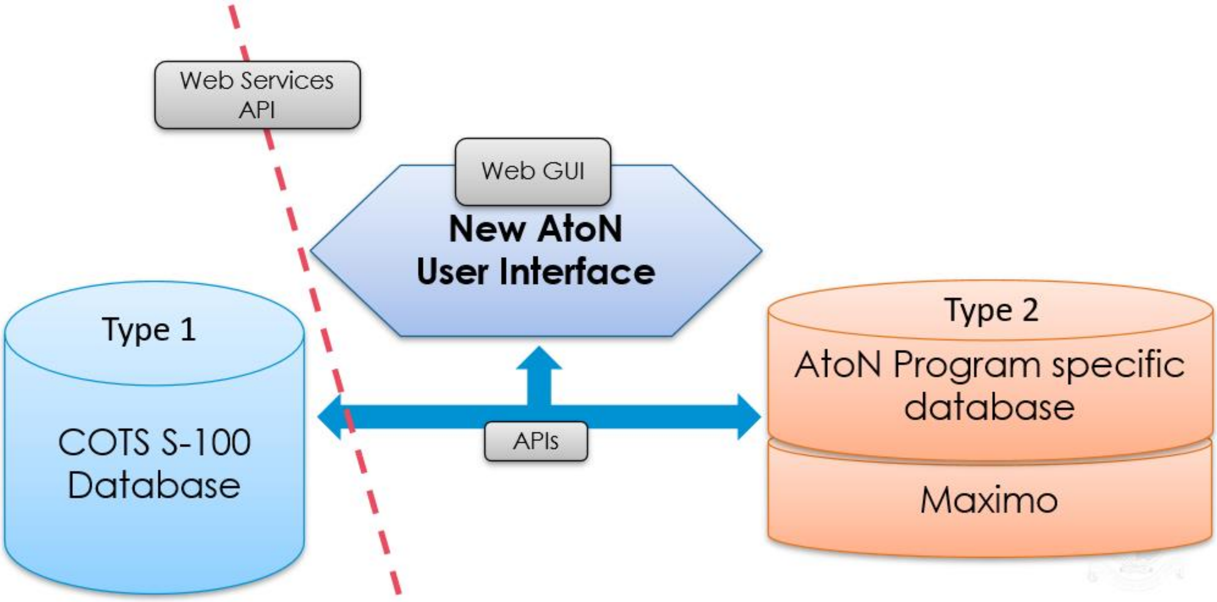

Figure 34 - Leading AtoN System solution proposal

4.4 Phase 3 – System Implementation and rollout strategy

Phase 3 of the project includes beginning to implement the identified solution and migrating the data into the new system. In parallel, a training to familiarize staff with the new S-100 and S-201 compatible system and new terms and definitions and also to provide proper system familiarization to the various user groups.

The alignment between ENC and S-201 may allow revisiting existing ENC training materials.

It is expected that system roll out will start initially with super users to beta test functions such as data input, visualization, data modification, data validation, data extract and queries. Verifying correct interaction with other systems will also take place at this time. Maintaining the data integrity and quality built up in Phase 2 will be a key activity in the migration to the new system when transferring historical data, and when adding new data to ensure successful integration with other systems.

A roll out to the general users is expected to follow based on priority of use. Staff that design and review the Canadian AtoN system will likely be first priority, followed by staff working with internal systems that integrate with the new AtoN system, such as notice to mariners and navigational warnings and finally, the rollout will include external users like Canadian Hydrographic Service.

4.5 Impact on staff and contractors

Rolling out a system of this magnitude will have significant impacts on staff. Communication and training will be essential to a successful rollout. Communication will focus on why a replacement is needed, what the replacement will look like, and design considerations that leads to the new system. Canada is a bilingual country with equality afforded to English and French and that must be considered. COTS tools investigated have been found to be English-only user interfaces, and therefore options are being considered as show by the web GUI in Figure 7. In parallel, significant training of staff in the S-100 world and new terminology will be necessary. This training will need to be multi-level and depend on the staff function in relation to the new system. Since significant customization is expected, it is important to also train internal development teams to be able to meet new requirements as needs and requirements evolve. It will be necessary to train support staff to help the average users and to train the operational staff and external users.

5 CONCLUSION

Canadian Coast Guard has embarked on an ambitious journey to renew its Aids to Navigation System, SIPA. The project has faced significant challenges and although it still consists of three phases, unforeseen changes has given the project a bumpy start. The project is currently in its second phase, identifying solutions where requirements captured and specified are being evaluated against options for a system design. Alignment with relevant IALA specifications is an essential motivator and is leading the direction of the solution definition. Communication with users and stakeholder, although often challenging as the project progresses, is an important consideration for successful implementation.

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AUTHOR BIOGRAPHY

Eivind Mong joined the Canadian Coast Guard in 2017 after having worked for nearly 20 years in the maritime industry. He is currently the Senior Adviser for e-Navigation and is actively working on implementing e-Navigation solutions in Canada. Mr. Mong is also the chair for the IHO Nautical Information Provision Working Group and leads the S-124 Project Team of the World Wide Navigational Warning Service Sub-Committee.

SESSIONS 7 AND 107 – COMMUNICATION AND CYBER SECURITY

S7.1 The Big Five - Safari in the world of risks for Cyber Security (066)

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ABSTRACT

Cyber security is becoming increasingly important in the context of the digitization and automation of our administrations and in shipping. Also, against the background of the data and information explosion and the increasing networking of machines, sensors and processes, we cannot afford to be lenient on this topic. Therefore, cybersecurity must be implemented as a management system from the beginning on and in the right places in our administrations. Otherwise, the implementation of individual security requirements for technical maritime systems is not going to work in the long term. The aim of this report is to show the risks / influences as well as the effects on this management level. That is why we go on safari to discover the Big Five.

There we can see them (each in analogy to the Big Five of the animal world related to cyber security management - what is to be done and what can happen if it is not done):

- Lion: Leadership responsibility (role model, integration, control, objectives, improvement)
- Leopard: Resources (time, money, personnel)
- Elephant: Responsibilities and security organization
- Buffalo: Staff (awareness raising, induction, motivation)
- Rhino: Security process (PDCA, concept, guidelines)

KEYWORDS: cyber security, management system, leadership responsibility, security process, security organization, digital maritime world

1 INTRODUCTION

What does a safari have to do with cyber security?

Maybe that is the first question that comes to mind when reading the title. In African hunting history, the Big Five represents the animals that were most difficult and dangerous to hunt.

In analogy to cyber security, five essential points can also be derived there that have enormous threat potential. I hope that if we go on safari we can find them and analyse the threats and opportunities.

In times of digitization, automation and artificial intelligence, cyber security is increasingly becoming a key factor. An increasing flood of data and information with the networking of machines, sensors and processes has also arrived in shipping and in our maritime domain in general. With all the new technologies and dependencies on data and infrastructure come the threats und vulnerabilities. Therefore, administrations must be prepared for the digital world. Ready to ward off all the risks, which live in the digital world, getting bigger and smarter.

In this context, every administration must implement a management system for cyber security. Cyber security as a part of information security and that leads us to an Information Security Management System (ISMS).

If we too live in this digital maritime world and want to offer services, an ISMS is the only way to be successful.

The aim of this paper is to show the risks and influences as well as the effects on this management system. The safari deals with the both questions

- what to do and
- what can happen if it is not done.

In the following, let us go on safari and explore the Big Five. I hope we can see them and know how to deal with the danger. With this in mind, each animal of the Big Five represents a management topic for cyber security.

Then we start the Safari.

2 THE LION

The lion is the king and with the king, everything is possible or even impossible. We need the king, a mighty, great lion to fight for his herd.

With a look to the management system, the lion could stand for the leadership in our administrations. The leader has the responsibility, the responsibility for everyone and everything, also for the management system for cyber security. The leader must want cyber security and show that the topic is very important. All employees look up to their leaders and closely observe their actions.

In addition to the top manager, every person in a leading position in the administrations must demonstrate that cyber security is very important and that we want live the processes in the context of cyber security.

Therefore, every manager must be a role model, otherwise you cannot demand from your staff that they live the processes and act in the interests of cyber security.

It is a management task and the task must be integrated into all processes in our administrations. Consideration of cyber security should be the standard, the normal way, and be embedded in all steps to fulfil our legal obligations.

To become the standard, we need objectives for cyber security and these objectives need to align with the business objectives.

The topic must not be questioned every time. Otherwise, we might forget the processes or develop a mentality that other functions might take precedence.

When the leadership implements the processes, the management is responsible for control and improvement. They have to show they care, even if they have delegated the doing of these both steps (control and improvement) to other roles.

Thus, the lion is so powerful that it could kill any effort. Therefore, there is a risk from start that cyber security is doomed to fail unless leadership takes the responsibility.

3 THE LEOPARD

The leopard crawls and is very well camouflaged, it is silent but also deadly.

It is very similar with our resources.

It is not enough that the leadership wants a management system for cyber security and formulates great objectives. In order to achieve the objectives, we naturally need resources. This means enough time for our personnel for the management system and for the operational level (the doing) of an ISMS. Nobody can do the task additionally. They need free time slots and that is often only possible with more staff and well-qualified staff.

In the field of cyber security, we need experts at the management level for the requirements and processes but also for the technical implementation at the operational level.

However, experts cost a little bit. So on the one hand we need money, for example to outsource tasks and on the other hand to train our own employees. We also have to pay our employees fair salaries to keep them, because the job market is like the jungle with the leopard.

There are so many deals lurking to hunt these cyber security experts.

4 THE ELEPHANT

The next animal on our tour is a big one and a real heavyweight. The elephant. Maybe not as aggressive as the other animals before, but colossal - in the sense of fundamental.

This could represent the organization and responsibilities in the management system.

The responsibilities in the administrations must be clarified. Which organizational unit does what and is responsible for what. There are many interferences to consider. We need the processes and every process has to have an owner who is responsible for all aspects of the process including the implementation of security measures.

The security organization must be implemented with several security roles and power. In this case, the security organization must match to the normal organization.

The role of a Chief Information Security Officer (CISO) is mandatory and supports the management.

Therefore, the role must be independent from the rest of the organization.

The role advises the management and makes recommendations. The role is not responsible for the doing (implementation of security measures), but for the security process.

The role holder must have an overview of all different perspectives in all areas of cybersecurity.

Depending on the organization, the security organization must be selected, which means that multiple roles may need to be implemented for CISO or for Information Security Coordinators (ISC).

Just as an elephant sometimes seems rather slow, the implementation of cyber security would also be sluggish because cooperation without defined responsibilities would not work.

5 THE BUFFALO

The buffalo in normal life is a herd animal, which does the same as all other buffalo around it.

On our safari tour, we also find a buffalo and in our administrations, this could stand for the staff.

In this regard, there are several points that we need to aware of.

All employees are basically good, but we have to make them aware of all the risks in the digitization and cyberspace.

The staff could be a big gate to penetrate our administrations.

Permanent sensitization is therefore absolutely necessary.

Each person is also responsible for the security measures to be observed by him or her. For example, closing doors or windows or keeping the passwords secret.

Therefore, we need a good induction and cyber security awareness needs to be a part of that.

But we not only need rules, we also need to make clear the benefits of security measures. With these benefits, we can probably increase the motivation of our employees.

Another motivation could be the lion that we saw on our first stop. When a buffalo herd sees a lion, they may be motivated to do something, for example to run.

So if the leaders from management stand behind this topic and lead the way, maybe the staff will be motivated to do the same.

6 THE RHINO

The last stop is for the rhino with its large and pointed horn resembling a weapon.

In cyber security, we also need a weapon, an instrument to achieve the objectives.

No animals will attack a rhino because of the risk of injuries.

Against this background, we could say that with the fifth animal, the rhino, the risks of the other four animals are minimized.

The instrument is the security process and includes the management, the staff, the resources and the responsibilities.

The focus is on the PDCA-cycle with the phases Planning, Doing, Checking and Acting. It is a permanent cycle without any end. When the cycle is finished, the next one starts automatically.

In order to implement cyber security, we need many requirements and appropriate security measures at the operational level.

These requirements and measures must be comprehensible, transparent and, of course, appropriate for the entire staff and external service providers.

For this, we need concepts and guidelines for our administrations.

Without guidelines or a documented security process, it is very difficult to achieve a homogenous level of security.

The danger is that everyone does it for themselves and in different ways.

Similar to the rhino, which is considered a loner and prefers to be on its own.

7 CONCLUSION

The safari shows that there are many different risks when we see the Big Five.

Therefore, we must be prepared that nothing happens to our administrations and us.

The tour shows not only the risks, but also the opportunities. The steps are explained for each individual stop what our administrations have to do.

The topic seems as old as the myth of the Big Five, but we must be aware of its importance every day.

The threats are there and some of our business processes are very vulnerable.

In the future, and especially in the age of digitization, shipping will take place in a digital world.

Some of us need to wake up to make our infrastructures resilient to threats, because the world of threats never sleeps.

So the attackers do not sleep either, especially in these times that we are currently experiencing in the world.

Staying with the wildlife parable…. For other levels of cyber security (like actual IT infrastructure or applications), there are much smaller animals aside from the Big Five that are even more aggressive or deadly.

One of our maxims must therefore be the integration of an ISMS as lived practice and as a matter of course in order to survive in the digital maritime domain and to master future challenges.

AUTHOR BIOGRAPHY

Alan Jacobsen was born in 1983, and in 2003, he joined the Federal Armed Forces. As an IT-Officer in the signal troop, he studied Electrical Engineering at the University of the Federal Armed Forces in Hamburg and received his diploma in 2010. In 2012, he joined the Federal Waterways and Shipping Agency and initially worked as an IT Security Officer for the Maritime Traffic Technology System. During this time, he graduated with a master's degree in business administration at the Private University of Applied Sciences in Göttingen in 2014. There he dealt intensively with the topic of business continuity management.

In 2020, he was appointed to the Information Security Officer for Traffic Technology and Deputy Head of the Department for Principles of Traffic Technology. There he was also responsible for information security of the

VTS centres in the maritime domain and the river headquarters of the inland waterways as a part of critical infrastructures. Since 2021, he is the Head of the Department for Principles of Traffic Technology, which is also responsible for the topic of information security for traffic technology.

S7.2 Communication coverage extension through rely technology in marine AtoN environment (189)

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ABSTRACT

Rapid developments such as the Internet of Things (IoT) and Long Term Evolution (LTE) are transforming the maritime industry and related research. Unlike on land, communication at sea has difficulties that communication quality may deteriorate and communication range is shortened due to movement of ships and buoys by ocean waves. Accordingly, issues relate to improving communication quality and expanding communication coverage at sea are emerging. In this paper, we propose a two-hop wireless communication system that leverages the motion of ocean waves to enhance maritime communication coverage. By utilizing buoys as amplify-and-forward (AF) relays, our approach adapts to the dynamic marine environment to confirm communication performance. Our proposed system explores the effects of wave dynamics on beamforming and beamwidth selection by modeling the mathematical motion of ocean waves. We conduct a comprehensive analysis of the received beam gain under various sea conditions and propose beamwidth for buoy-based relays. Through simulations, proper beamwidth selection can substantially enhance the performance of buoy-based relays, enabling more robust and efficient maritime communication. This research contributes to the ongoing efforts to advance the field of maritime wireless communication by demonstrating the potential benefits of exploiting ocean wave models and beamforming techniques. Our work provides a solid foundation for the development of more effective and reliable wireless communication systems for various marine applications, such as safety, monitoring, and navigation. Furthermore, the proposed approach can be extended to other challenging communication environments, offering a versatile solution for enhancing wireless connectivity in diverse scenarios.

KEYWORDS: Marine A to N environment, channel modelling, Amplify-and-forward (AF) relay, beamforming

1 INTRODUCTION

Maritime wireless communication plays a pivotal role in a wide range of marine applications, such as safety, monitoring, navigation, remote sensing, and data collection from ocean-based sensors. As our reliance on these applications grows, the demand for reliable and efficient communication systems that can overcome the unique challenges posed by the ocean environment becomes increasingly critical [1]. However, the performance of conventional wireless communication techniques in marine settings is significantly impacted by factors such as wave dynamics, signal attenuation, path loss, interference, and the time-varying nature of the propagation channel [2]. Researchers have been exploring innovative approaches to enhance the performance of maritime wireless systems. Some of these approaches include relay-assisted communication, adaptive beamforming, network coding, cooperative communication, and the utilization of multiple-input multiple-output (MIMO) technology [3]. The main goal of these strategies is to improve the signal-to-noise ratio (SNR), extend coverage, and enhance the overall performance of wireless systems in challenging marine environments. One promising approach for improving maritime wireless communication is the use of relay-assisted communication. Two-hop communication using buoys as relays has emerged as a viable solution to extend coverage, improve the SNR, and enhance the overall performance of wireless systems in marine environments [4]. Among the various relaying schemes, amplify-and-forward (AF) has gained popularity due to its simplicity, low processing overhead, and compatibility with various modulation and coding schemes [5]. In this work, we propose a two-hop wireless communication system using buoys as AF relays, considering the mathematical motion of ocean waves. We confirm an analytical model to capture the impact of wave dynamics on beamwidth selection, aiming to confirm the received beam gain and coverage under various sea conditions. We provide insights on how to effectively use the beamwidth in response to be changing wave conditions. To evaluate the performance of our proposed system, we conduct extensive simulations in diverse ocean environments. Our results show significant improvements in coverage, reliability, and overall system performance compared to traditional maritime wireless communication techniques. Furthermore, this study contributes to the ongoing efforts to advance the field of maritime wireless communication by demonstrating the potential benefits of exploiting ocean wave models and adaptive beamforming techniques. Our work provides a solid foundation for the development of more effective and reliable wireless communication systems for various marine applications. The remainder of the paper is organized as follows: Section II presents an overview of existing maritime communication technologies and related work; Section III describes our proposed methodology; Section IV details our experimental setup and results; and Section V concludes the paper.

2 SYSTEM MODEL

In this section, we consider the downlink of a maritime scenario including a single base station (BS), Relay Node (RN) and a certain number of maritime users, as depicted in Fig.1. oth the BS and RN are equipped with multiple antennas. Additionally, since maritime users often gather on ships, we assume that users on the same vessel receive identical multimedia services. Ships can receive and store these signals, which are then transmitted to users on board via WiFi. Consequently, maritime users aboard the same ship can be referred to as vessel-based users, each outfitted with a single antenna.

2.1 Channel model

In our communication model, the near-shore communication channel from a cellular tower to ships is expected to have a dominant line-of-sight (LOS) path, with less reflection from the sea surface. However, the second hop offshore communication channel may experience significant reflection from the sea surface, resulting in severe multipath effects. To account for this, we have devised an empirical loss Rician fading model to describe the first hop near-shore channel, as detailed in [6].

$$\boldsymbol{h} = d^{-\alpha/2}\boldsymbol{h}_{LoS}{}^{f} \quad (1)$$

where the communication distance is denoted by d, and the path loss exponent is represented by α. The small-scale channel fading coefficients are denoted by $\boldsymbol{h}_{LoS}{}^{f}$. To account for the reflection of the off-shore channel from the sea surface, we employ a modified two-ray reflection model subject to Rayleigh fading, as described in [7]. This model allows us to capture the multipath effects caused by reflection and account for the resulting channel fading. Then we have

$$\boldsymbol{H} = \frac{\lambda}{4\pi d}\sin\left(\frac{2\pi \mathrm{h_t h_r}}{\lambda d}\right)\boldsymbol{H}_{\boldsymbol{2-ray}}^{f} \qquad (2)$$

where $\lambda, d, \mathrm{h}_t, \mathrm{h}_r$ denote the carrier wavelength, the communication, transmitter and receiver antenna

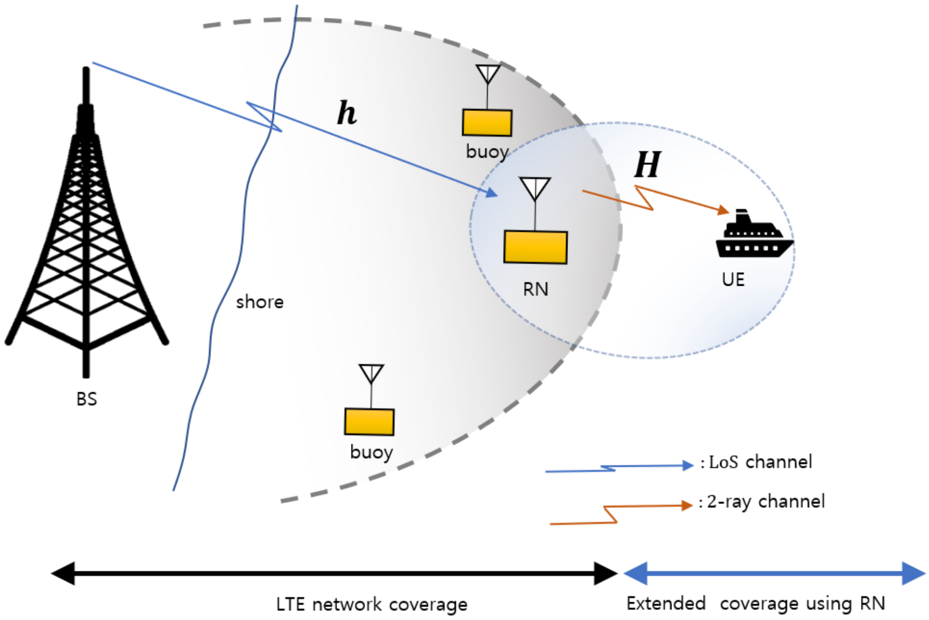


Figure 35: System architecture in maritime communication

height, respectively, while ${\boldsymbol{H_{2-ray}}}^f$ represents the small scale fading coefficients.

2.2 Ocean elevation

Understanding the complex mechanisms of fluid dynamics in ocean waves and the variations in surface elevation in highly dynamic oceanic environments is a challenging task. As a result, it is crucial to investigate the statistical modelling of how sea water surface elevation varies over time with greater precision. In this paper, we consider Bretschneider spectrum, also known as ISSC [8] is the spectrum model recommended for open-ocean wave conditions given by [9]

$$S(\omega) = \frac{5}{16}\frac{H_S^2\omega_p^4}{\omega^5} exp\left(-\frac{5}{4}\left(\frac{\omega_p}{\omega}\right)^4\right) \quad m^2/(rad/s) \quad (3)$$

In the spectral model expressed as Equation (3), H_S, ω_p represent the height (m) of the wave and peak angular frequency (rad/s), respectively. Here, peak period is $T_p = 2\pi/\omega_p$. A wave is composed of a multitude of frequencies (N_f) , and can be expressed as the sum of all frequency components, as demonstrated in Equation (4)[10].

$$\eta(x,t) = \sum_{i=1}^{N_f} a_i \cos(2\pi f_i t + k_i x + \alpha_i) \quad (4)$$

where a_i, $k_i = w_i^2/g$, α_i are amplitude, wave number, and phase for the i-th frequency f_i, respectively. Moreover, the amplitude of every frequency component can be computed using the formula presented in [11].

$$\mu_i = \sqrt{2 * S(\omega_i) * \Delta\omega} \quad (5)$$

$\Delta\omega$ is the frequency interval of the spectrum $S_\eta(\omega_i)$. Amplitude (a_i) is obtained by returning the values calculated using Equation (4) to values following the Rayleigh distribution [12].

2.3 Buoy angle

In [13], a varying angle is created between the sea level and the antenna over time. To approximate the angle θ (slope of the tangent) formed between the antenna and the vertical line of the sea level, an auxiliary tangent

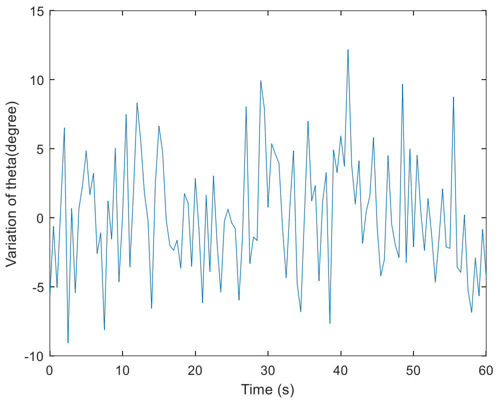


Figure 2: θ variation over time

can be drawn across point O with horizontal coordinates time x measured in meters, as explained in [13]. And then the time varying angle of buoy as follows

$$\theta = \tan^{-1}\left(\frac{\eta(x+1)-\eta(x-1)}{2}\right) \quad (6)$$

where $\eta(x)$ denotes the surface elevation, and as shown in Figure 2. The equation (6) involves the computation of the surface elevation $\eta(x)$ at the specific point O, followed by the calculation of the difference in elevation between the points to the left (x-1) and right (x+1) of O. Averaging these differences and applying a tangent function provides an approximate value of θ. By utilizing this method, we can monitor the variations in the angle over time and gain a better understanding of ocean wave behavior. Mathematical modelling of the moving angle of the buoy is used to construct a time-varying channel.

3 AMPLIFY-AND-FORWARD RELAY WITH ADAPTIVE BEAMWIDTH

In this paper, we consider a two-hop relay channel where the Source full-duplex relay node relay and UE. there is no direct (source destination) link, and the full CSI is available to the source and destination. The signal received by i-th relay is $y_i = h_i x_{i-1} + \xi_i, i \geq 1$, where $x_{i-1}$is the signal, transmitted by $i-1$-th relay, h_i is the i th hop channel (between (i-1) and i-th relays), and ξ_i is i-th relay AWGN noise. The signal transmitted by the relay in the AF mode is $x_i = \sqrt{K} y_i$, where K is its power gain. Thus, the input-output relationship of the whole 2-hop AF relay channel is [12]

$$\boldsymbol{Y} = \sqrt{K}\boldsymbol{H}_2\boldsymbol{F}\boldsymbol{H}_1^{+}\boldsymbol{x} + \sqrt{K}\boldsymbol{H}_2\boldsymbol{\xi}_1 + \xi_2 \quad (7)$$

where x and Y are the transmitted (BS) and received (Buoy) signal vectors, $\boldsymbol{H}$ is the hop channel, $\boldsymbol{F}$ is the by i th relay's receive beamforming matrix and $^{+}$ denotes Hermitian conjugation. To find the SNR at the destination in (7) can be expressed as

$$\gamma = \frac{|\boldsymbol{H}_2|^2\boldsymbol{F}\boldsymbol{H}_1^{+}\boldsymbol{R}_x\boldsymbol{H}_1}{\sigma_N^2} \quad (8)$$

where $\boldsymbol{R}_x = E\{xx^{+}\}$ is the covariance matrix of the source transmitted signal and σ_N^2 is the rely noise and UE noise part. The AF relay capacity error-free data transmission in the AF protocol, can now be succinctly expressed in (8) as

$$C = log(1+\gamma)\,[bit/s/Hz] \quad (9)$$

The capacity at the destination is obtained by setting the relay positions differently through the following capacity equation (9)

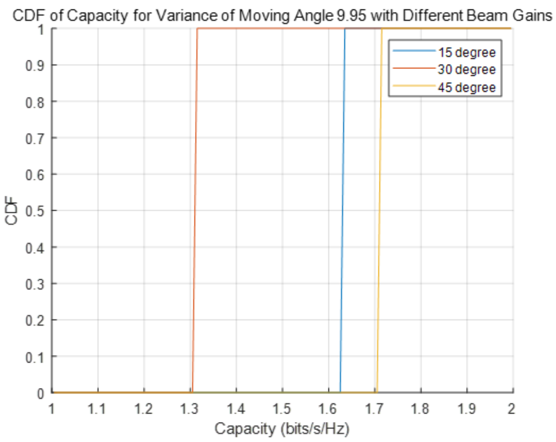
4 SIMULATION

In this section, the beam width performance of the relay is expressed numerically. As shown in Figure 1, we consider a maritime communication system network using 4 antennas for BS and Relay and a 2-hop AF relay network for UE using a single antenna. System parameters are summarized in Table 1. Assume that the first hop channel from BS to relay is a LoS single path channel and the second hop channel is a two-ray channel. The buoy's angle and path loss were considered in the waterway. The performance of an Amplify-and-Forward (AF) relay system using dual beamforming differently deployed between a base station and a destination is verified.

Parameters	Values
Center Frequency	2 GHz
Bandwidth	10 MHz
BS antenna Height	30 m
Relay antenna height	2, 3 m
UE antenna height	5 m
Beamwidth	15°, 30°, 45°
BS power	46 dBm
Relay power	23 dBm
Sea state level	Level 3
Ocean wave period	10 sec
Distance BS – Relay1	10 km
Distance Relay1 – Relay2 – UE	5 km

Table. 1. Simulation parameter

Using the simulation in Figure 3, the CDF according to the capacity to check the outage probability for various beam widths in the relay and the resulting outage capacity were confirmed in Figure 4.



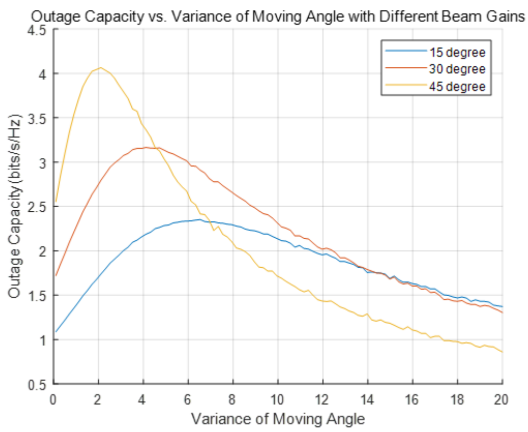


Figure 3: CDF according to the capacity

Figure 4: outage capacity

The simulation results are presented in Figures 3, 4, and 5. Figure 3 shows the CDF of the capacity and outage probability for various beam widths at the relay when relay moving angle variance is 9.95 degree. And this result confirmed that a 30-degree beamwidth is the most effective because variance is 9.95 degree. Figure 4 displays the resulting outage capacity. Based on these simulation results, it is confirmed that using a narrow beamwidth beamforming is preferable when the variance of the angle at which the buoy moves is small, while a wide beamwidth beamforming is more effective when the variance of the angle is high. Figure 5 shows the capacity results for different SNRs and beam widths in a time-varying channel with very low wave motion. It is observed that a narrow beamwidth beamforming is preferable when the variance of the angle at which the buoy moves is small, while a wide beamwidth beamforming is more effective when the variance of the angle is high. Furthermore, it was observed that, depending on the SNR, when the variance of the angle at which the buoy moves is small, the signal can be received entirely within a 15-degree beam, resulting in better performance. Through these results, the case of the beam width is well selected according to the sea state, it is possible to have gains in energy efficiency according to the beam width when using the same transmission power.

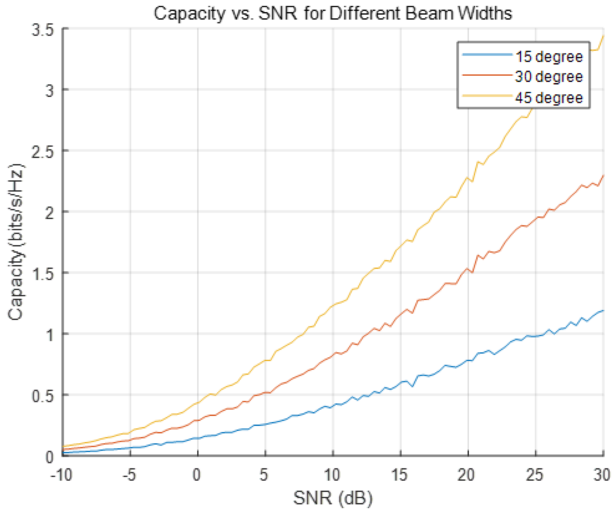


Figure 5: θ variation over time

5 CONCLUSION

In this study, we present a novel approach to model and evaluate the performance of wireless communication channels in maritime environments, with a focus on the impact of sea state levels. Our methodology involves mathematical modelling of ocean wave elevation using the Bretschneider spectral model to determine buoy angles and Time-varying channel modelling that considers the effect of sea state due to ocean waves. his method provides valuable insights into wireless signal behavior in marine environments, aiding in the design of effective communication systems for these settings. Our findings can help communication equipment for reliable communication between offshore and shore-based facilities. I n addition, we analyse the capacity in relation to target location and relay beamwidth, particularly for 2-hop AF relay systems. We demonstrate that adaptive beamforming techniques can achieve higher capacity and energy efficiency in near-shore communication systems by adjusting the beamwidth based on sea state. This leads to the potential for maintaining capacity while reducing power consumption. Overall, our study contributes significantly to the development of robust communication frameworks for oceanic channels, emphasizing the importance of considering sea state levels and adaptive beamforming techniques for optimal performance.

6 ACKNOWLEDGEMENTS

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S7.3 Harmonized IoT for Marine Lanterns (174)

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ABSTRACT

Marine Aids to Navigation (AtoN) have often been early adopters of new technologies. Since the 1980s, remote monitoring of marine signal lanterns has been available as a tool to track the availability of AtoN and predict maintenance needs. Remote Control has also been implemented in some applications. Today, there are various solutions available on the market based on Satellite Communication, GSM mobile networks, Point-to-Point short-range radio communication, as well as AIS transponders.

However, current communication topologies often have a low reporting frequency due to the limitations of data communication costs or energy constraints. Status reports are typically only transmitted when lights turn on in the evening and turn off in the morning, with additional ad hoc reports transmitted when an issue is detected by the station (e.g., position, energy or light operation related). Additionally, many current conventional communication systems have a limitation in the number of communication sessions they can manage, so reporting frequency is not only limited by outstation constraints.

As a result, the owner of the asset always has outdated information and no real-time situational awareness. They may also not be able to detect a malfunction of an AtoN in a timely manner. Due to the lack of industrial standards, each vendor operates a proprietary protocol and system, making it difficult for the owner of assets to mix devices in the field.

In this paper, we will demonstrate how modern and true IoT (Internet of Things) technology can be implemented to overcome all the current limitations and issues. We will demonstrate that we are able to resolve two of the main issues in existing remote monitoring technologies;

1. Implementing a new, open, secure and standardized non-propriety communication protocol used by a huge number of existing IoT devices, and

2. Utilizing modern IoT platforms like LTE-M and LoRaWAN achieving communication close to real time without driving data costs and energy consumption

This new method enables the Marine Signal lanterns to enter the real IoT era we have seen moving quickly into other industrial fields.

KEYWORDS: IoT, connected visual aids, harmonized protocol, remote monitoring and control

1 STANDARDIZED PROTOCOL

There are various communication protocols used in IoT and IIoT (Industrial IoT). The most appropriate protocol for a particular case depends on factors such as data rate, security, power consumption, compatibility, and complexity.

For the Visual AtoN IoT harmonization, the MQTT (Message Queuing Telemetry Transport) protocol is proposed as the best suited protocol. This protocol is optimal for small low-power applications and is one of the most commonly used communication protocols. It can be implemented in ultra low-power microcontroller applications, and on the server side, the MQTT broker is straightforward to establish and integrates well with an already established remote monitoring system.

1.1 MQTT

MQTT is a lightweight publish/subscribe messaging protocol designed for use in low-bandwidth, high-latency, or unreliable network environments. It was originally developed by IBM in the late 1990s and has since become an open standard maintained by the OASIS consortium.

The MQTT protocol operates on top of TCP/IP and uses a publish/subscribe messaging model, where publishers send messages to a broker, which then distributes those messages to interested subscribers. The broker acts as an intermediary between publishers and subscribers, allowing messages to be sent and received even if the publisher and subscriber are not connected at the same time.

Here is how the MQTT protocol works in more detail:

1. Clients: MQTT clients can be either publishers or subscribers. Publishers are responsible for sending messages to the broker, while subscribers are interested in receiving those messages.
2. Broker: The MQTT broker acts as a mediator between publishers and subscribers. It receives messages from publishers and then distributes them to subscribers that have expressed an interest in those messages.
3. Topics: Messages are sent and received on topics, which act as channels for communication. Topics are hierarchical in nature, allowing for the creation of a tree-like structure that can be used to organize messages by topic.
4. Quality of Service (QoS): MQTT supports three levels of Quality of Service (QoS) for message delivery: QoS 0, QoS 1, and QoS 2. QoS 0 provides at most once delivery, QoS 1 provides at least once delivery, and QoS 2 provides exactly once delivery.
5. Keep Alive: MQTT uses a Keep Alive mechanism to ensure that clients remain connected to the broker even if there is no data to transmit. Clients send periodic PINGREQ messages to the broker to indicate that they are still connected.
6. Last Will and Testament (LWT): MQTT supports a Last Will and Testament (LWT) feature that allows a client to specify a message that will be published by the broker in the event that the client becomes disconnected unexpectedly.

In summary, MQTT is a lightweight publish/subscribe messaging protocol that enables efficient communication between devices in low-bandwidth, high-latency, or unreliable network environments. It uses a broker to mediate communication between publishers and subscribers, and supports a range of QoS levels, Keep Alive mechanism, and LWT feature for reliable and fault-tolerant messaging.

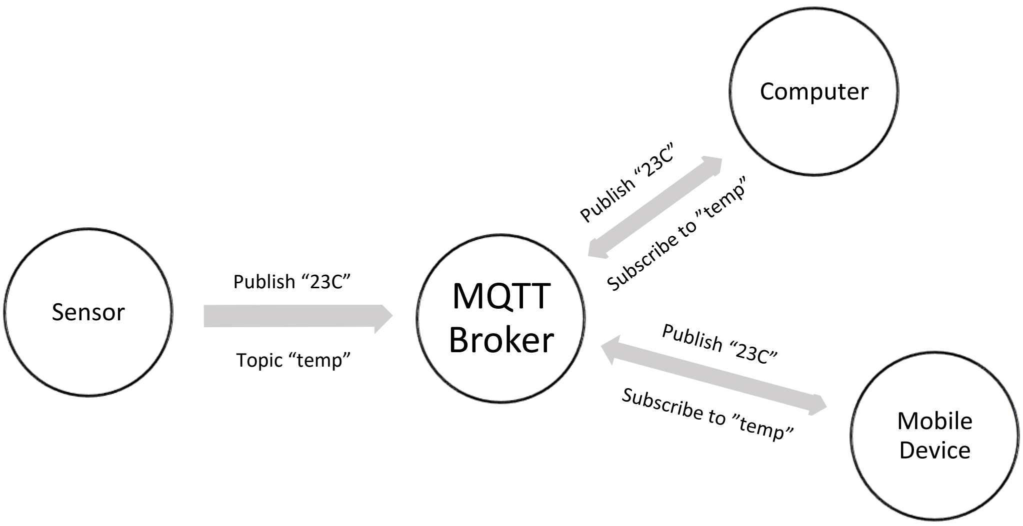

Figure 36: MQTT protocol

2 SECURITY

MQTT is a protocol that runs over TCP/IP and does not provide security measures itself, but it can be implemented with security measures to ensure secure communication between the client and the broker.

2.1 Encryption and authentication

MQTT does support the use of security measures such as SSL/TLS encryption, which provides a secure communication channel between the client and the broker. When SSL/TLS encryption is enabled, all data transmitted between the client and the broker is encrypted and cannot be intercepted by a third party.

Additionally, MQTT supports authentication mechanisms, such as username and password, to ensure that only authorized clients can connect to the broker. Access control lists (ACLs) can also be used to restrict the operations that clients can perform on the broker.

In this proposal, we recommend to restrict communication to only use TLS 1.2 or higher and the dedicated Secure-MQTT port 8883.

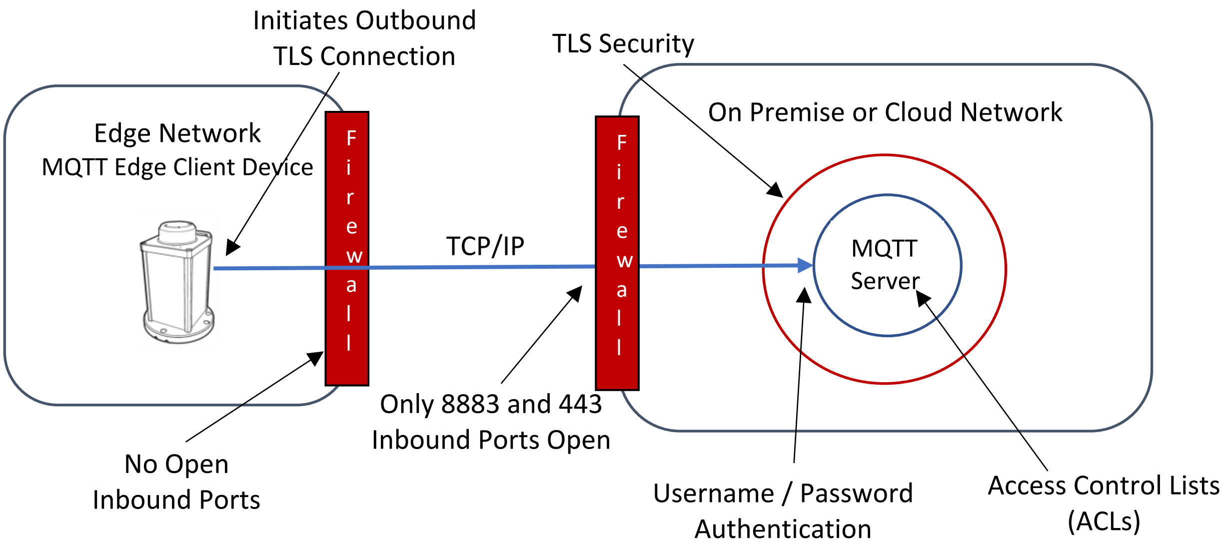

Figure 2: MQTT Security, Courtesy of Cirrus Link

2.2 One way or two way communication

For extremely critical infrastructure of Aids to Navigation (AtoN), or when remote commands are considered unnecessary, the implementation can be limited to only offer inbound messages from the remote AtoN. In such cases, the asset would not be capable of processing remote commands. This can be seen as analogous to the difference between AIS Type 1 and Type 3, where Type 1 does not include a receiver.

3 MESSAGE STRUCTURE

It is not enough to only standardize on using MQTT as the connectivity protocol. In order to reach full compatibility between different providers it is necessary to use a common message structure in the payload. The proposed structure is based upon JSON (JavaScript Object Notation).

JSON is a lightweight data interchange format that is easy to read and write for humans, and relatively easy to parse and generate for machines. The main reasons to use JSON, is that JSON is a platform-independent data format, which means it can be used with any programming language or platform.

JSON is a well-established format that is widely used for data-interchange, with support for parsing and generating JSON built into many programming languages and frameworks.

The following example shows a possible JSON representation describing a person.

```
{
  "firstName": "John",
  "lastName": "Smith",
  "isAlive": true,
  "age": 27,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "phoneNumbers": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
      "type": "office",
      "number": "646 555-4567"
    }
  ],
  "children": [
    "Catherine",
    "Thomas",
    "Trevor"
  ],
  "spouse": null
}
```

Figure 3: Example of JSON syntax, https://en.wikipedia.org/wiki/JSON

Please find the complete proposed communication protocol in Appendix A, Draft Visual AtoN MQTT Protocol.

4 WORKING WITH DIFFERENT COMMUNICATION PLATFORMS

In cases where the AtoN is connected using TCP/IP, MQTT can be implemented in the AtoN itself with direct MQTT communication to the Broker. The new GSM standard for IoT devices, LTE-M (Long Term Evolution for Machines), is perhaps the most suitable for this purpose. Low cost and low-power LTE-M modules capable of native encrypted MQTT are already widely available.

Offshore, or in other places where internet connection is not an option, there are many indirect possibilities using a proprietary network with an added MQTT gateway to relay the messages to the MQTT IoT platform. Examples of this are iridium, inmarsat, Globalstar and LoRaWAN / Sigfox to name a few.

It´s not necessary to build such integration from scratch. There are both on premises and cloud based systems available for fast integration. An example of a solution with LoRaWAN to MQTT using HiveMQ broker is shown in the Figure 4 below.

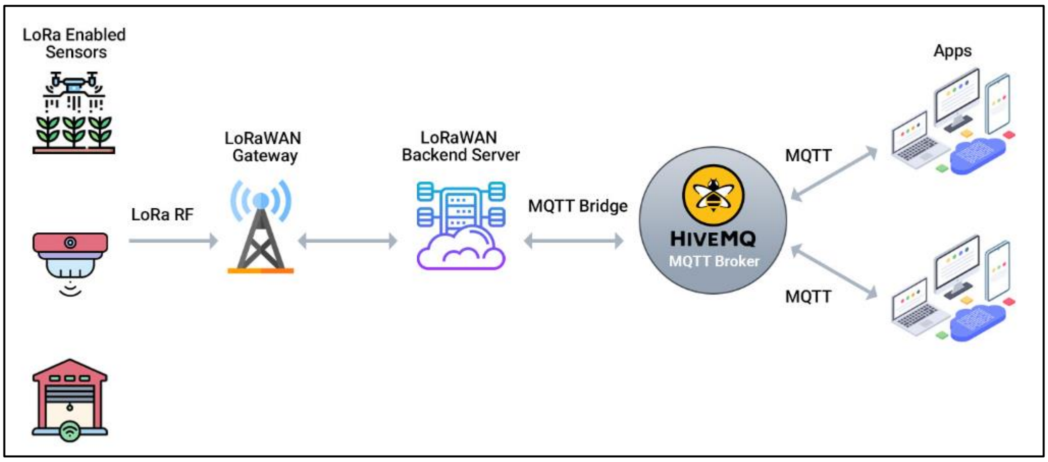

Figure 4: LoRaWAN MQTT Broker, HiveMQ GmBH

https://www.hivemq.com/blog/lorawan-and-mqtt-integrations-for-iot-applications-design/

5 CONCLUSIONS

MQTT is a lightweight publish/subscribe messaging protocol that enables efficient and frequent communication between devices in low-bandwidth, high-latency, or unreliable network environments. It supports SSL/TLS encryption enabling secure and authenticated communication. Used in conjunction with JSON, which is a platform-independent data format, it can be used with any programming language or platform.

Both MQTT and JSON are non-propriety and royalty free. Many open source platforms and libraries are available to support easy integration/adaptation.

IALA is invited to adopt this protocol and message structure as the standard IALA Visual AtoN Protocol (IVAP) to use so that members with a mixed network from various Industrial Members have the ability to monitor them in a single platform.

6 APPENDIX A, DRAFT VISUAL ATON MQTT PROTOCOL

6.1 Topic names

Each topic contain least four fields and optional device name:

1. First level topic name describe topic purpose, e.g. telematics topic, information topic, etc. First level topic names are described below.
2. Second and third level topic contain location or region, eg. estonia/tallinn
3. Fourth level topic contain site name, eg. soderskar-lighthouse
4. Fifth level contain device name or identificator

First level topic names:

1. 'tele' – telemetry information. Device issued automatic monitoring data.

Example:
tele/<location1>/<location2>/<site name>
tele/<location1>/<location2>/<site name><device x>

2. 'info' – device information. Device ID, capabilities. Etc.

Example:
info/<location1>/<location2>/<site name>
info/<location1>/<location2>/<site name>/res
info/<location1>/<location2>/<site name><device x>
info/<location1>/<location2>/<site name><device x>/res

3. 'cmd' – command, can trigger telemetry response

Example:
cmd/<location1>/<location2>/<site name>
cmd/<location1>/<location2>/<site name>/res
cmd/<location1>/<location2>/<site name><device x>
cmd/<location1>/<location2>/<site name><device x>/res

4. 'parameter' – get or set parameter(s)

Example:
parameter/<location1>/<location2>/<site name>
parameter/<location1>/<location2>/<site name>/res
parameter/<location1>/<location2>/<site name><device x>
parameter/<location1>/<location2>/<site name><device x>/res

5. 'direct' – device specific data that can be used for implement custom protocols inside device, like Modbus.

Example:
direct/<location1>/<location2>/<site name>
direct/<location1>/<location2>/<site name>/res
OR
direct/<location1>/<location2>/<site name><device x>
direct/<location1>/<location2>/<site name><device x>/res

Subscribe example:

1. Subscribe to all telemetry messages

tele/#

2. Subscribe to all telemetry messages in region named ’Country1’

tele/country1/#

3. Subscribe to all telemetry messages in region named ’country1/north-territory’

tele/country1/north-territory/#

4. Subscribe to telemetry messages which come from ’Lighthouse1’ in ’country1/north- territory’ region

tele/country1/north-territory/Lighthouse1/

5. Subscribe to telemetry messages which issued by telematics module, and flasher1 and flasher2

tele/country1/north-territory/Lighthouse1/telematics
tele/country1/north-territory/Lighthouse1/flasher1
tele/country1/north-territory/Lighthouse1/flasher2

6.2 Communication sequence

Every connection should subscribe to following topics:

- Command (’cmd’ topic)
- Parameter

6.2.1 Telemetry information

- Device connect to broker and send:
  - Telemetry packet. Depending on configuration this may be repeated during session
- Device disconnect from broker

6.2.2 Info

- Device connect to broker, and send following data
  - Subscribe for topics
  - Telemetry packet
  - Server ask info
  - Device send info topic
  - Server send done
- Device disconnect from broker

6.2.3 Set parameters

- Device connect to broker, and send following data
  - Subscribe for topics
  - Telemetry packet
  - Server ask parameter
  - Device send parameter

- ◦ Device update parameter
- ◦ Server send done
- Device disconnect from broker

6.3 Payload format

Payload have two different formats: unencrypted JSON format, and encrypted format.

	Byte 0	Byte 1	Byte n
JSON	'{'	Unencrypted JSON data	
Encrypted data	'E'	Unused, should be 0	Encrypted binary data

When unencrypted JSON data is used in MQTT payload, only plain JSON messages transmitted, no data is added. JSON data should be follow format published in https://www.json.org/json-en.html.

When payload is encrypted, then first byte must be 'E' (ASCII 0x45) and second byte is reserved and should have value 0x00. All subsequent bytes are encrypted JSON data. Unencrypted payload must be multiple of 16 (AES requirement), it is recommended to fill unused bytes with random data after terminating 0x00 in JSON string.

6.4 Payload data

6.4.1 General payload data rules

1. Payload is in JSON format (https://www.json.org/json-en.html).
2. Property names are only ASCII.
3. Maximum property name length is 32 characters.
4. In property names are allowed only lower case letters ('a' – 'z') and numbers. '-' (minus) is used to separate words in property names.
5. Property values are UTF-8 encoded strings.
6. Not recommended property name is "class".
7. User defined properties are allowed, but must follow above listed limits.
8. All optional properties can be omitted or have null value when data is invalid. Non-optional properties should have default value in case of invalid data.

6.4.2 Topic 'tele' – status information

Minimal JSON message for generic device:

```
{
	"session-id": "session-1",
	"status": "ready",
	"uptime": 20
}
```

6.4.2.1 Session ID

- This property is mandatory
- Property name: ’session-id’
- Description: can be monotonic counter, e.g. timer or session counter
- Example: "session-id": "session-820923084792"

6.4.2.2 Status

- This property is mandatory
- Property name: ’status’
- Allowed values: init, ready, alert, suspend
    - init – least one component to initialize, default value
    - ready – system is fully functional, e.g. lantern is switched on
    - alert – alarm condition detected, e.g. low battery
    - suspend – when system is switched off but it is functional, e.g. storage state. This field is not required on devices which does not have suspend state

6.4.2.3 Uptime

- This property is mandatory
- Property name: ’uptime’
- Seconds from last boot. Default value is 0.
- Example: "uptime": 211

6.4.2.4 Time

- Required only on devices with RTC clock
- Property name: ’time’
- Description: device UTC time, default value is 0
- Allowed values: seconds from January 1st, 1970 at UTC (UNIX time). Only positive values allowed.
- Example: "time": 1673564596

6.4.2.5 Alert status

- Only required when device status is ’alert’
- Property name: ’alert’
- Description: list of alert statuses. If device operates normally and don’t have any alerts, then this property may be omitted or set value to ’none’. Possible values:

- none, default value
- light-fail
- low-battery
- gnss-error
- off-location
- overheated
- etc...

- Example, two alerts: "alert": ["low-battery", "off-location"]

6.4.2.6 Beacon status

- Mandatory only on beacons. ’type’ field in info message should be ’beacon’.
- Property name: ’beacon-status’
- Allowed values:
  - on-main-character – main or night character
  - on-alternative-character – alternative or day character
  - off – not flashing, default value
- Example: "beacon-status": "on-main-character"

6.4.2.7 Device temperature

- Only on devices which have temperature sensor.
- Property name: ’temperature’
- Contains following sub properties:
  - ’last’ – last read temperature
  - ’max’ – maximum temperature in last 24 hours, optional
  - ’min’ – minimum temperature in last 24 hours, optional
  - ’avg’ – average temperature in last 24 hours, optional
- Allowed values: floating point value
- Example, valid temperature: "temperature": {"last": 21.0, "max": 25, "min": 19, "avg": 22}

6.4.2.8 Battery voltage

- Only on devices which can measure battery voltage
- Property name: ’voltage’
- Contains following sub properties:

- ’average’ – last battery voltage, averaged over one flash cycle
- ’loaded’’ – last measured battery voltage under load condition, optional
- ’unloaded’’ – last measured battery voltage under no-load condition, optional
- ’max’ – maximum battery voltage under no-load condition in last 24 hour, optional
- ’min’ – minimum battery voltage under load condition in last 24 hours, optional

- Allowed values: positive floating point value
- Example, valid battery voltage: "voltage": {"average": 12.3, "loaded": 12.1, "unloaded": 12.5, "max": 13.3, "min": 11.5}

6.4.2.9 Location

- Only on devices with GNSS receiver
- Property name: ’position’
- Description: JSON array of floating point values with last GNSS position, exact method how this value is computed is implementation defined
- Allowed values: degrees for latitude -90.0/90.0, and for longitude -180.0/180.0
- Example: "position": [60.0, 110.0]

6.4.2.10 Deviation

- Only on devices with GNSS receiver
- Property name: ’position-deviation’
- Description: Floating point value of deviation in meters from GNSS fixed position. Exact method how this value is computed is implementation defined
- Allowed values: positive floating point value
- Example: "position-deviation": 10.0

6.4.2.11 Last GNSS fix time

- Only on devices with GNSS receiver
- Property name: ’position-time’
- Description: Floating point value of UTC time derived from GNSS.
- Allowed values: seconds from January 1st, 1970 at UTC (UNIX time). Only positive values allowed.
- Example: "position-time": 1673564596

6.4.2.12 GNSS quality indicator

- Only on devices with GNSS receiver
- Property name: ’position-quality’

- Description: Floating point value of CSQ value
- Allowed values: only positive floating point values allowed
- Example: "position-quality": 1.1

6.4.2.13 Ambient light level measured by the light sensor

- Only on devices that can measure ambient light level.
- Property name: ’ambient-light-level’
- Description: Ambient light level measured in lux
- Allowed values: only positive floating point values allowed
- Example: "ambient-light-level": 30

6.4.2.14 Network statistics

- Optional. If present must contain all sub properties
- Property name: ’network-statistics’
- Description: contains nested statistics information
- Allowed values: positive value, default value is 0
- Example: "network-statistics": {"succeeded-server-connections": 2, "failed-server-connections": 0, "succeeded-network-logins": 2, "failed-network-logins": 2}

Amount of succeeded server connections

- Property name: ’succeeded-server-connections’
- Description: number connections between server and broker that have valid end.
- Allowed values: positive value, default value is 0
- Example: "succeeded-server-connections": 2

Amount of failed connections

- Optional. All network statistics data should be present in together: ’succeeded-server-connections’, ’failed-server-connections’, ’succeeded-network-logins’ and ’failed-network-logins’.
- Property name: ’failed-server-connections’
- Description: number connections between server and broker that have no valid end.
- Allowed values: positive value, default value is 0
- Example: "failed-server-connections": 0

Amount of succeeded network logins

- Optional. All network statistics data should be present in together: ’succeeded-server-connections’, ’failed-server-connections’, ’succeeded-network-logins’ and ’failed-network-logins’.
- Property name: ’succeeded-network-logins’
- Description: number of succeeded network logins
- Allowed values: positive value, default value is 0
- Example: "succeeded-network-logins": 2

Amount of failed network logins

- Optional. All network statistics data should be present in together: ’succeeded-server-connections’, ’failed-server-connections’, ’succeeded-network-logins’ and ’failed-network-logins’.
- Property name: ’failed-network-logins’
- Description: number of failed network logins
- Allowed values: positive value, default value is 0
- Example: "failed-network-logins": 2

6.4.2.15 Last reset source

- Optional
- Property name: ’last-reset-source’
- Description: number of resets starting from production
- Allowed values:
  - por – power on reset
  - wdr – watchdog reset
  - rst – reset from external reset signal (HW signal)
  - bor – brown-out reset
  - usr – reset triggered by command, e.g. SMS reset command
  - other – all other reset sources
- Example: "last-reset-source": "wdt"

6.4.2.16 Reset count

- Optional and only when last reset source is present. This property have nested properties with reset names defined in Last Reset sources.
- Property name: 'reset-count'
- Allowed values: positive value, default value is 0
- Example: "reset-count": {"por":30, "wdr":1}

6.4.3 Topic 'info'

Info is triggered by 'cmd' topic '"send": "info"'

6.4.3.1 Protocol version

- This property is mandatory.
- Property name: 'protocol-version'
- Integer to describe protocol version. Currently supported value is 1.
- Example: "protocol-version": 1

6.4.3.2 Type

- This property is mandatory
- Property name: 'type'
- Description: device type class
  - 'group' – logical container for device group
  - 'beacon' – for beacons
- Example: "type": "beacon"

6.4.3.3 System information

- This property is mandatory. This information can be used to set up optimal set/get transmission packet sizes.
- Property name: 'sys-info'
- Description: system parameters
  - 'rx-buf' – size of rx buffer in bytes, -1 means infinite
  - 'tx-buf' – size of tx buffer in bytes, -1 means infinite
- Example: "sys-info": [{"rx-buf": 512}, {"tx-buf": 512}]

6.4.3.4 Serial number

- This property is mandatory for non group devices
- Property name: ’serial-nr’
- Description: device serial number, this number may contain product code also, if product code and serial number are not related then ’product-code’ property show product code

6.4.3.5 Product code

- Required only when serial number does not have product information
- Property name: ’product-code’
- Description: device product code

6.4.3.6 Firmware version

- This property is mandatory for non-group devices
- Property name: ’firmware-version’
- Description: device firmware version

6.4.3.7 Component info

- Only for device which have components with own version
- Property name: ’component-info’
- Description: device component version list, like onboard GNSS receiver.
- Example: "component-info": [{"gnss-version":"1.0"}, {"gnss-type":"NEO M8N"}]

6.4.3.8 Limits

- Optional property. Not required to list all parameters.
- Property name: ’limits’
- Description: returns list of device limit values, for example maximum allowed light intensity, maximum battery voltage, etc. Limit values and value names must match with same configuration parameters.
- Example: "limits": [{"light-intensity":1000}, {"low-voltage-level":6.0}]

6.4.4 Topic ’cmd’

This topic is for server initiated actions.

6.4.4.1 Send

- Required
- Property name: ’send’
- Description: send requested topic
- Allowed values:
  - tele – for telematics
  - info – for information
- Example: "send": "info"

6.4.4.2 Reset

- Property name: ’reset’
- Description: reset device or parameter
- Allowed values:
  - null, empty string or ’reset’– reset device (required)
  - parameters – reset all parameters (optional)
  - <parameter-name> – reset parameter name to default (optional)
- Example: "reset": null

6.4.4.3 Done

- Required
- Property name: ’done’
- Description: this is hint from server, that server has been completed all tasks and controller if free to disconnect from broker. It depends on client configuration if it disconnects immediately or send telematics packets. If server send packet after ’done’ message then for disconnect is needed re-send ’done’ message. If server does not send ’done’ message then controller can disconnect if last message from server was more than X seconds ago.
- Allowed values: any string
- Example: "done": "ok"

6.4.4.4 Light on demand

- Optional
- Property name: ’light-on-demand’
- Description: start light on demand, parameters describe how many seconds is light on demand mode is active. Device returns normal operation after this time is elapsed. This command allows to specify optional intensity for light on demand operation.
- Contains following sub properties:
- ’timeout’ – last battery voltage, averaged over one flash cycle
  - -1 – light on demand is active until switched off
  - 0 – light on demand switched off
  - 1...2147483648 – seconds active
- ’intensity’ – effective intensity in cd, optional
- Example: "light-on-demand": {"timeout": 3600, "intensity": 300}
- Light activated for one hour with 300 cd effective intensity

6.4.4.5 Fix position

- Optional
- Property name: ’fix-position’
- Description: start or stop GNSS position fix
- Allowed values:
  - start – start positon fix
  - stop – stop position fix
- Example: "fix-position": "start"

6.4.5 Topics ’parameter’

Set or get configuration parameter. All get commands must have ’res-topic’ property. All topic queries have parameter value null.

Get

```
{
      ”res-topic”: ”get/locationa/locationb/site/device1/res”,
      ”time”: null
      ”light-intensity”: null
}
```

Response to get/locationa/locationb/site/device1/res

```
{
    "session-id": "session-1",
    "time": 1677677908
    "light-intensity": 34
}
```

Set

```
{
    "res-topic": "get/locationa/locationb/site/device1/res",
    "time": 1677679999
    "light-intensity": 30
}
```

6.4.5.1 Date and time

- Property name: 'time'
- Description: set or get time
- Allowed values:
  - null – query from server
  - any positive number – set or get result

6.4.5.2 Light intensity

- Property name: 'light-intensity'
- Description: set or get effective light intensity in candelas.
- Allowed values:
  - null – query from server
  - any positive number to max allowed value – light intensity in candelas

Note: Max allowed 'light-intensity' is retrieved with the 'info' Topic.

6.4.5.3 Ambient light threshold

- Property name: 'ambient-light-threshold
- Description: set or get ambient light threshold levels in lux. Minimum ambient light level triggering beacon activation.
- Allowed values:
  - null – query from server
  - any positive number – light level in lux

6.4.5.4 Maximum allowed distance from fix position

- Property name: 'distance-from-fix'
- Description: set or get distance from fix position
- Allowed values:
  - null – query from server
  - any positive floating point number – distance from fix

6.4.5.5 Latitude and longitude of fix position

- Property name: 'fix-position'
- Description: set or get latitude and longitude of fix position. Array, where first value is latitude and second value longitude. Positive values indicate Northern latitudes and Eastern longitudes.
- Allowed values:
  - null – query from server
  - degrees for latitude -90.0/90.0, and for longitude -180.0/180.0

6.4.5.6 Telemetry

- Property name: 'telemetry'
- Description: common property for telemetry
- Allowed sub properties
  - report-mode – telemetry report mode
  - report-period – telemetry report period

Telemetry report mode

- Property name: 'report-mode'
- Description: set or get telemetry report mode
- Allowed values:
  - null – query from server
  - off – telemetry data is sent only after query with 'cmd'
  - utc-fixed – UTC fixed mode, for example 00:00, 00:05, 00:10, ... To spread simultaneous sessions, can be added delay to this period. Delay length is implementation defined, for example delay seconds can be calculated from device serial number.
  - interval – interval mode, for example every 3 minutes, not fixed to UTC
  - on-failure – only when error condition is detected

Telemetry report period

- Property name: 'report-period'
- Description: set or get telemetry report period
- Allowed values:
    - null – query from server
    - 0 – disable telemetry period, telemetry is sent only after query
    - any positive number – telemetry period in seconds

APN

- Property name: 'apn'
- Description: set or get APN
- Allowed values
    - null – query from server
    - string – APN name

APN user

- Property name: 'apn-user'
- Description: set or get APN
- Allowed values
    - null – query from server
    - string – APN user name

APN password

- Property name: 'apn-password'
- Description: set or get APN
- Allowed values
    - null – query from server
    - string – APN password

Broker address

- Property name: 'broker-address'
- Description: set or get broker address. Currently used address will not be changed.
- Allowed values
    - null – query from server
    - list of addresses with port, may contain current address

6.4.5.7 Low voltage level

- Property name: ’low-voltage-level’
- Description: set or get low voltage level
- Allowed values:
  - null – query from server
  - any positive floating point number – voltage level

6.4.5.8 GNSS

- Property name: ’gnss’
- Description: common property for GNSS
- Allowed sub properties
  - base – GNSS wakeup base
  - interval – interval of GNSS time and position checkup
  - duration – duration of GNSS time and position checkup
  - sync – flash code synchronization base

GNSS base

- Property name: ’base’
- Description: select GNSS wakeup base
- Allowed values:
  - async – not synchronized with other threads (this is default)
  - pre-telematics – always before telematics (optional). In this mode GNSS start ’duration’ seconds before telematics and after task is completed then start telematics. If interval is set then GNSS started before telematics and repeated with interval. If telemetry is disabled, then this option does not have any effect.
  - utc – synchronized with UTC (optional)

GNSS interval

- Property name: ’interval’
- Description: set or get time interval for GNSS time and position checkup
- Allowed values:
  - null – query from server
  - 0 – disable GNSS time and position periodical checkup
  - any positive number – interval in seconds

GNSS duration

- Property name: ’duration’
- Description: set or get duration for GNSS time and position checkup
- Allowed values:
    - null – query from server
    - 0 – disable GNSS time and position checkup
    - any positive number – duration in seconds

GNSS sync

- Property name: ’sync’
- Description: set or get GNSS-guided synchronization of flash code
- Allowed values:
    - off – GNSS sync disabled
    - on – GNSS sync is enabled, this is equal with ’utc’
    - utc – UTC based GNSS sync (start of flash adjusted to UTC 00:00:00)
    - gps – GPS time based GNSS sync (start of flash adjusted to GPS 00:00:00)

6.4.5.9 Beacon flash character

- Property name: ’flash-code’
- Description: set or get beacon flash character
- Allowed values:
    - null – flashing is disabled
    - "flash-code": {"main": [{"on":ms}, {"off":ms}, ...], "secondary" : [{"on":ms}, {"off":ms}, ...]}

6.4.6 Topic ’direct’

Direct commands to device. For example Modbus packets.

- Only single device
- Must contain ’res-topic’ and ’data’ properties
    - ’res-topic’ property describe response topic name
    - ’data’ property contains data in device specific format
- Example: {"res-topic”: ”direct/locationa/locationb/site/device1/res", "data": "10AB"}

Useful references:

- https://github.com/kokke/tiny-ECDH-c
- https://stackoverflow.com/questions/6032675/diffie-hellman-test-vectors
- https://www.techiedelight.com/c-program-demonstrate-diffie-hellman-algorithm/
- https://www.oryx-embedded.com/doc/dh_8c_source.html
- https://github.com/parthendo/thrain
- https://github.com/terlan98/Diffie-Hellman-and-AES
- https://github.com/ojan2021/AES_and_DiffieHellman_Implementation
- https://www.programmingboss.com/2015/11/diffie-hellman-key-exchange-algorithm.html
- https://datatracker.ietf.org/doc/html/draft-irtf-cfrg-augpake-08

AUTHOR BIOGRAPHY

Mr. Lindberg has key competence in embedded electronics for low power applications. He has been involved in development of visual aids to navigation and remote monitoring since he joined Sabik in 1997, and has a comprehensive understanding of this special application area. He has been in charge of the Sabik´s product development team since 2010. He has been a member of the IAIA Engineering committee since 2006.

S7.4 Robust, Secure and Reliable Digital Platforms for AtoN Connectivity (116)

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ABSTRACT

Considering historical AtoN systems, maintenance practices and the latest digital techniques this presentation will outline the steps to build a secure, reliable and robust digital platform for monitoring and maintaining AtoN assets. Covering minimum encryption standards, PII, roles and associations and onsite inspection reporting through future trends and developments to implementing customer feedback and innovative technology.

KEYWORDS: AtoN Systems, Maintenance, Monitoring, Asset Management, Cybersecurity

RESUMEN DEL ARTÍCULO

Teniendo en cuenta los sistemas históricos de AtoN, las prácticas de mantenimiento y las últimas técnicas digitales, esta presentación describirá los pasos para construir una plataforma digital segura, confiable y sólida para monitorear y mantener los activos de AtoN. Cubriendo los estándares mínimos de encriptación, PII, roles y asociaciones e informes de inspección en el sitio a través de tendencias y desarrollos futuros para implementar comentarios de los clientes y tecnología innovadora.

PALABRAS CLAVE: Sistemas AtoN, Mantenimiento, Monitoreo, Gestión de Activos, Ciberseguridad

RÉSUMÉ DE L'ARTICLE

En tenant compte des systèmes AtoN historiques, des pratiques de maintenance et des dernières techniques numériques, cette présentation décrira les étapes pour construire une plate-forme numérique sécurisée, fiable et robuste pour la surveillance et la maintenance des actifs AtoN. Couvrant les normes de cryptage minimales, les PII, les rôles et les associations et les rapports d'inspection sur site à travers les tendances et les développements futurs pour la mise en œuvre des commentaires des clients et des technologies innovantes.

MOTS CLÉS : Systèmes AtoN, Maintenance, Monitoring, Asset Management, Cybersécurité

1 INTRODUCTION

Aids to Navigation (AtoN) systems are critical for safe navigation of vessels. AtoN assets such as buoys, beacons, and lighthouses need to be monitored and maintained regularly to ensure their functionality and reliability. The historical AtoN systems and maintenance practices were manual and labor-intensive, resulting in increased operational costs and risks. However, the latest digital techniques can significantly improve the maintenance and monitoring of AtoN assets. This paper outlines the steps to build a secure, reliable, and robust digital platform for monitoring and maintaining AtoN assets.

2 ATON SYSTEMS

An AtoN typically consists of a platform or structure, such as a lighthouse or buoy. The signals that they provide can either be visual (a light) or non-visual (an AIS) or a combination of both. These signals require some kind of electrical power to provide the signal and are housed within the structure. Combining the above elements forms a system that has strengths and weaknesses. The weakest part of the system requires the most attention. Whether that be an incandescent light source that needs replacing often or chain made of poor steel that wears out prematurely. These elements often dictate the maintenance regime. However, modern technology in the use of LEDs and synthetic moorings can drastically extend the maintenance period.

3 MAINTENANCE

Traditional maintenance is undertaken on a scheduled basis. As an example, an incandescent lamp has a nominal lifetime of 2,500hrs. This equates to approximately six months of operation at which point the lamp would need to be replaced so scheduled maintenance is conducted every six months to coincide with the lamp replacement. Condition-based maintenance relies on everything working as it should be or in other words, if it isn't broken, don't touch it! This approach often leads to Reactive maintenance whereby a fault is reported, and it is required to be fixed immediately. Using Predictive maintenance techniques can lead to significant cost reductions in unplanned visits and extended maintenance periods. This requires monitoring of asset data, looking at data trends and planning against that data.

4 THE INTERNATIONAL ASSOCOATION OF MARINE AIDS TO NAVIGATION AND LIGHTHOUSE AUTHORTIES (IALA)

IALA is a non-profit, international technical association. Established in 1957, it gathers together Marine Aids to Navigation authorities, manufacturers, consultants, and, scientific and training institutes from all parts of the world and offers them the opportunity to exchange and compare their experiences and achievements.

IALA encourages its members to work together in a common effort to harmonize Marine Aids to Navigation worldwide and to ensure that the movements of vessels are safe, expeditious, and cost-effective while protecting the environment. Taking into account the needs of mariners, developments in technology, and the requirements and constraints of aids to navigation authorities, a number of technical committees have been established bringing together experts from around the world. The work of the committees is aimed at developing common best practices through the publication of IALA Standards, Recommendations, Guidelines, and Model courses.

An example of an IALA recommendation would be: R0130 – Categorization and Availability Objectives for Short Range Aids to Navigation where each category is defined given an availability objective. The most vital Aids to Navigation should be available to the mariner for 99.8% of the time. Availability figures can be determined by a robust monitoring system.

5 MONITORING

There are many ways to monitor an AtoN. An observer can be used to inform the service provider of any outages. This may be achievable in a small network of AtoN, but not very practical in a large system. For offshore AtoN, the RF spectrum has been used to locally monitor the system and then transmit to shore where it would be forwarded to a central location via the PSTN network. As technology has converged from OT networks to IT networks, the data can be transmitted directly to the data center for processing. The modern default system for monitoring is via satellite communications. Once thought prohibitive due to cost, it is now cost compatible to telecoms. It is very reliable and provides pole-to-pole coverage.

To build a secure, reliable, and robust digital platform for monitoring and maintaining AtoN assets, certain steps need to be taken. The platform should meet minimum encryption standards to protect against cyber-attacks and data breaches. As a minimum use AES-256 for encryption and SHA-256 for Hashing. A good example of a cyber security standard that is relevant to AtoN is the International Electrotechnical Commission (IEC) 62443, which provides guidelines for securing industrial automation and control systems. The IEC 62443 standard provides a framework for establishing a comprehensive cyber security management system, which includes risk assessment, security policy development, and implementation of appropriate security controls. The platform should also ensure the protection of personally identifiable information (PII) of users. Roles and associations should be clearly defined to ensure that only authorized personnel can access the platform. Onsite inspection reporting should be automated to reduce the risk of error and operational inefficiencies. The platform should also be scalable to accommodate future trends and developments.

Many AtoN systems are based on legacy technologies, which can be difficult to integrate with modern digital platforms. To achieve seamless integration, it is essential that the digital platform is designed with a flexible architecture including an Application Programming Interface (API) key that can be easily integrated with legacy systems.

6 ATON ASSET MANAGEMENT

Managing AtoN assets is essential for ensuring the safety of mariners and protecting the environment. An effective AtoN asset management system should enable authorities to monitor and maintain AtoN assets remotely and efficiently. The system should provide accurate and up-to-date data on the status of all AtoN assets in one easy-to-use platform. The AtoN asset management system should be able to accept multiple data inputs, such as battery voltage, charge current, character, intensity, and status. It should also be able to generate configurable alarms, such as off-station, low battery, and lantern failure, to alert authorities of any potential issues. Effective AtoN asset management should also involve regular inspections and audits of the AtoN assets to identify any issues that may not be captured by remote monitoring. These inspections should be scheduled based on the level of risk posed by the AtoN asset and the likelihood of failure.

7 FUTURE TRENDS AND DEVELOPMENTS

Future trends and developments in AtoN systems include the use of unmanned aerial vehicles (UAVs), autonomous vessels, and artificial intelligence (AI). UAVs can be used to inspect AtoN assets, reducing the need for manual intervention. Autonomous vessels can be used to deploy and maintain AtoN assets, reducing operational costs and risks. AI can be used to analyze the performance data of AtoN assets and predict failures before they occur.

8 CONCLUSIONS

In conclusion, the latest digital techniques can significantly improve the monitoring and maintenance of AtoN assets. To build a secure, reliable, and robust digital platform for monitoring and maintaining AtoN assets, certain steps need to be taken. The platform should meet minimum encryption standards, protect PII, clearly define roles and associations, automate onsite inspection reporting, and be scalable.

AUTHOR BIOGRAPHY

Malcolm Nicholson is a seasoned professional in the field of Marine Aids to Navigation (AtoN) with over twenty-five years of experience. He began his career with the Northern Lighthouse Board, where he gained fundamental knowledge and experience. Later, he joined the UK General Lighthouse Authorities and served as the Principal Development Engineer (Visual Signaling).

Today, Malcolm is Sealite's Global Product Manager, where he is responsible for managing and developing the extensive range of Marine AtoN products. He represents Sealite internationally and is currently the Chairman of Working Group 1 for the Engineering Committee and is the IMC’s representative to the Policy Advisory Panel. Malcolm's expertise and accomplishments have also earned him the distinction of being a Fellow of the Royal Institute of Navigation.

S7.5 Development of a GLA e-Navigation architecture (131)

Nikolaos Vastardis, Research and Innovation Engineer, Research and Development Directorate (GRAD)

ABSTRACT

e-Navigation services have the potential to support and expand a service provider's range of maritime Aids-to-Navigation (AtoN). The General Lighthouse Authorities of the UK and Ireland (GLA), through its research and development directorate (GRAD) has been working to support the Maritime Connectivity Platform (MCP) and has been developing its own prototype e-Navigation architecture. This paper will introduce the GLA's prototype e-Navigation architecture, explain the process used in its design and explain how it aligns to the MCP. The paper will provide an overview to the design and outline, which design decisions were made and why. It will also show how the architecture has been used to support an e-Navigation Service Demonstrator – where a Virtual AtoN (VAtoN) is presented to the mariner via a VDES transmission, initiated by an operator located some distance away. This approach is novel, timely and brings together the different aspects of e-Navigation, demonstrating how such services are developed and then demonstrated in a real-life scenario, helping to develop an emerging e-Navigation architecture that aims to support future GLA e-Navigation services.

KEYWORDS: e-Navigation, Service, Architecture, Demonstrator, GLA, AtoN, S-125

RESUMEN DEL ARTICULO

Los servicios de e-Navegación tienen el potencial de apoyar y ampliar la gama de Ayudas a la Navegación marítima (AtoN) de un proveedor de servicios. Las Autoridades Generales de Faros del Reino Unido e Irlanda (GLA), a través de su Directorio de Investigación y Desarrollo (GRAD), han estado trabajando para apoyar la Plataforma de Conectividad Marítima (MCP) y han estado desarrollando su propia arquitectura de e-Navegación de prototipo. Este documento presentará la arquitectura de e-Navegación de prototipo de GLA, explicará el proceso utilizado en su diseño y explicará cómo se alinea con la MCP. El documento proporcionará una visión general del diseño y la descripción, explicando las decisiones de diseño que se tomaron y por qué. También mostrará cómo se ha utilizado la arquitectura para respaldar un Demostrador de Servicio de e-Navegación, donde una AtoN Virtual (VAtoN) se presenta al marinero a través de una transmisión VDES, iniciada por un operador ubicado a cierta distancia. Este enfoque es novedoso, oportuno y reúne los diferentes aspectos de la navegación electrónica, demostrando cómo se desarrollan dichos servicios y se demuestran en un escenario de la vida real, ayudando a desarrollar una arquitectura de e-Navegación emergente que tiene como objetivo apoyar los futuros servicios de e-Navegación de la GLA.

PALABRAS CLAVE: e-Navegación, Servicio, Arquitectura, Demostrador, GLA, AtoN, S-125

RESUME DE L'ARTICLE

Les services de e-Navigation ont le potentiel de soutenir et d'étendre la gamme d'Aides à la Navigation maritime (AtoN) d'un fournisseur de services. Les Autorités Générales de Phare du Royaume-Uni et de l'Irlande (GLA), par le biais de leur Direction de la Recherche et du Développement (GRAD), ont travaillé pour soutenir la Plateforme de Connectivité Maritime (MCP) et ont développé leur propre architecture de prototype de e-Navigation. Cet article présentera l'architecture de e-Navigation de prototype de la GLA, expliquera le processus utilisé dans sa conception et expliquera comment elle s'aligne sur la MCP. L'article donnera un aperçu de la conception et de la présentation, expliquant les décisions de conception qui ont été prises et pourquoi. Il montrera également comment l'architecture a été utilisée pour soutenir un Démonstrateur de Service de e-Navigation, où une AtoN Virtuelle (VAtoN) est présentée au marin via une transmission VDES, initiée par un opérateur situé à une certaine distance. Cette approche est nouvelle, opportune et rassemble les différents aspects de la navigation électronique, démontrant comment de tels services sont développés et ensuite démontrés dans un scénario réel, contribuant ainsi au développement d'une architecture de e-Navigation émergente visant à soutenir les futurs services de e-Navigation de la GLA.

MOTS CLÉS: e-Navigation, Service, Architecture, Démonstrateur, GLA, AtoN, S-125

1 INTRODUCTION

The e-Navigation concept was developed by the International Maritime Organization (IMO) to improve the safety and efficiency of navigation in the maritime domain through the integration of technology and information. The concept is based on the idea of a "digital infrastructure" for navigation, where information and services can be shared seamlessly across different systems and stakeholders. The goal is to enhance situational awareness, reduce the risk of accidents, optimize routes and operations, and support environmental protection. Some of the specific technologies and services that are part of the e-Navigation concept include Electronic Chart Display and Information Systems (ECDIS), Automatic Identification Systems (AIS), Vessel Traffic Services (VTS), and weather and oceanographic data services. It is currently being implemented globally, with different regions and countries taking different approaches based on their specific needs and circumstances.

The General Lighthouse Authorities of UK and Ireland (GLA), as the three agencies primarily responsible for the provision of Aids to Navigation (AtoN) in the area, in line with the IMO initiative, are also planning the implementation of e-Navigation to improve the digital services provided to their users. This initially required a risk and cost-benefit analysis of selected e-Navigation applications and the associated infrastructure. This process identified a number of potential use-cases, with the provision of Virtual AtoN (VAtoN) being considered as one of the most noteworthy ones.

This paper introduces the GLA's prototype e-Navigation architecture, discusses how it aligns with the Maritime Connectivity Platform (MCP), and demonstrates how it can be used to implement an integrated e-Navigation service for the provision of VAtoN over AIS/VDES. The paper is structured as follows: Section 2 presents a review of the relevant background and literature. Section 3 outlines the design decisions that were made and why, and provides an overview of the whole design. Section 4 then presents the individual components of the architecture in more detail, while Section 5 showcases how the architecture was used to support an e-Navigation Service Demonstrator test-bed, where a VAtoN is presented to the mariner over AIS/VDES transmissions, initiated by an operator located some distance away. Finally, Section 6 concludes the paper.

2 BACKGROUND

The maritime domain is facing a number of challenges, mainly due to increasing demand, which may in turn increase the risk of an accident or loss of life. These challenges require technological solutions and e-Navigation is one such solution. To this end, IMO adopted a specific strategy for e-Navigation (IMO, 2009), which it defined as "*the harmonised collection, integration, exchange, presentation and analysis of maritime information on-board and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment*". A presentation of the overarching e-Navigation architecture, as envisaged by the IMO, is presented in Figure 37. Certain details are deliberately encapsulated in a "black box" fashion in order to demonstrate how the major entities of the e-Navigation architecture connect and cooperate, hence "overarching". In addition, IMO has provided a list of Maritime Services (MS) (IMO, 2019), which can be defined as services that are provided to ships or to the maritime industry as a whole, such as search and rescue, vessel traffic management and environmental protection. On the other hand, Technical Services (TS) are services that support the operation of maritime services, such as communication systems, navigational aids and software applications.

In response, the International Association of Lighthouse Authorities (IALA) published a number of guidelines such as G1113 (IALA) and G1114 (IALA), which establish the relevant principles for the design and implementation of harmonised shore-based technical system architectures and propose a set of best practices to be followed. In these, the terms Common Shore-Based System (CSS) and Common Shore-based System Architecture (CSSA) were introduced to describe the shore-based technical system of the IMO's overarching architecture. Especially the latter guideline, provides a very clear description on how a CSSA should be structured, and categorises the technical services of the architecture as follows:

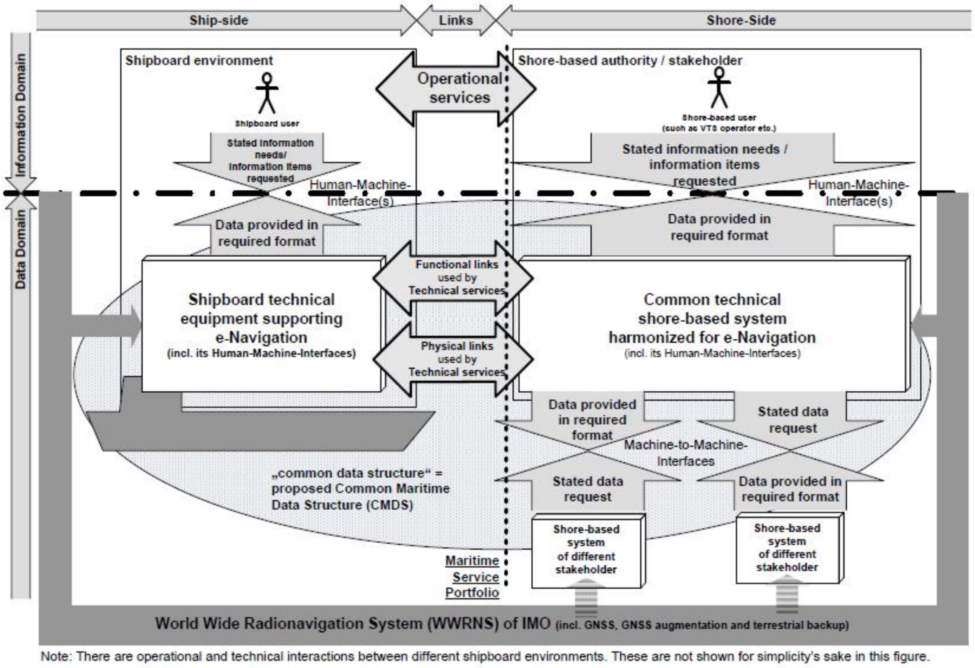

Figure 37: The IMO-defined overarching e-Navigation architecture.

1. **The Data Collection and Data Transfer Services (DCT)**: A group of technical services interfacing the shore-based system via the physical links to traffic objects' electronic systems, to the waterways and to the natural environment.
2. **The Value Added Data Processing Services (VAD):** A group of individual technical services. Their main task is to add value to (raw) data by processing, combination, comparison etc.
3. **The User Interaction Service (UIA)**: An individual technical service specialised to provide the Human-Machine-Interface (HMI) to the primary users of the CSS.
4. **The Gateway Service (GWY):** Another individual technical service specialised in data exchange shore-to-shore. It interfaces mainly to external systems of third parties.

The CSSA is based on a Service-Oriented Architecture (SOA), a design also supported by other publications (Hahn, Bolles, Fränzle, Fröschle, & Park, 2016). According to Wolf (Wolf, 2017), SOA services are built and provided as part of a business process, but can also be reused in new and different ways to create new functionality and processes.

To ensure the secure communication between ship and CSSA, the International Electrotechnical Commission (IEC), in coordination with IALA, compiled a set of system architecture and operational requirements for e-Navigation into a standard better known as SECOM (IEC, 2022). This provides mechanisms for secure data exchange, as well as a TS interface design that is in accordance with the service guidelines and templates defined by IALA. Although SECOM is just a conceptual standard, the Maritime Connectivity Platform (MCP) (MCP, 2023) provides an actual implementation of a decentralised framework that supports SECOM.

3 THE GLA E-NAVIGATION ARCHITECTURE

The GLA follow the developments on e-Navigation closely, contributing through their role as an IALA member whenever possible. As part of their efforts, a prototype GLA e-Navigation Service Architecture is being developed by the GLA Research and Development Directorate (GRAD), to be used as the basis for the provision of the future GLA e-Navigation services. This section presents the key points of the design process and an overview of the current architecture. A special mention is made to the relationship with the MCP, which is utilised to align the architecture with the security and discoverability requirements dictated by SECOM.

3.1 Design Process

GRAD, in consultation with the involved stakeholders, initially performed an analysis of selected e-Navigation applications and the associated infrastructure, aimed at identifying risks, costs, benefits and the priority for a set of selected use-cases. As a result, a multi-year project was initiated, to determine the requirements, architecture and eventual design of the software and hardware platform for the delivery of future GLA e-Navigation services to the maritime community. The first step of the initiated project was to elicit the requirements from the selected use-cases, which were categorised into two levels:

1. The infrastructure level: Use-cases of the GLA service infrastructure, the implementation of which will follow the selected architecture. These are based on MS already provided by the GLAs, or novel MS required to be developed.
2. The application level: Use-cases identified in the requirements analysis of the specific MS to be developed.

At the same time, work commenced on the business process analysis, which is considered to be interlinked with the requirements gathering. In order for an e-Navigation service to provide the desired functionality and output result, it was first necessary to identify:

1. The roles of the stakeholders of the service.
2. The information that is required to be exchanged between stakeholders of the service.
3. Under what conditions that information should be exchanged.

Even after just one iteration of the requirements gathering and business process analysis, it becomes possible to start thinking about the architecture design. In the context of the IMO's e-Navigation concept, this of course had to also take into account the principles described in the previous Section 2, focusing mainly on the CSSA.

It has already been mentioned that the CSSA is based on SOA. A pure-SOA approach however was found to be a bit cumbersome for the GLA operations, as it usually requires the entire IT landscape being compatible, resulting in high investment costs (Wolf, 2017). In the context of e-Navigation, this could become a serious problem, since different components of the system are designed by independent teams/manufacturers. Instead, a more flexible microservice architecture was opted for. This is based on a break-down of the larger functional blocks into small independent services, each responsible for performing its own orchestration, maintaining its own data and communicating through lightweight mechanisms such as HTTP/HTTPS. It should be pointed out that SOA and the microservice architecture are not necessarily that different. Sometimes, microservices are even considered as an extension or a more fine-grained version of SOA (Lewis & Fowler, 2014).

The next and final step of the design process was the identification of the required microservices and their respective implementation. This was performed with the goal of demonstrating a service for the provision of VAtoN, specifically over AIS/VDES. The general e-Navigation architecture was also considered, particularly in terms of security, extendibility and scalability. As such, and in accordance with IALA Guideline G1114, the following services were identified:

1. **A Data Collection and Data Transfer Service (DCT)** interfacing with the shore-based AIS/VDES system to send the specified VAtoN information.
2. **A Value Added Data Processing Service (VAD)**, that stores and distributes the Virtual (but not excluding non-virtual ones) AtoN messages. An additional service was also implemented to enable a geospatially-aware publish-subscribe data exchange operation.

3. **The User Interaction Service (UIA)** specialised to provide the Human-Machine-Interface (HMI) to the primary users of the CSSA.
4. **The Gateway Service (GWY)** to interface to external systems of third parties.

3.2 MCP Connectivity

As mentioned in Section 2, SECOM was proposed by the IEC to provide a set of requirements for secure data exchange, as well as a technical service interface design. Since the GLA are committed at providing secure and reliable services, the MCP was selected and an ideal candidate to support the e-Navigation Service Architecture operation. The MCP, and more specifically its Maritime Identity Registry (MIR) component, is utilised to support the secure and reliable exchange of information through the use of existing/emerging standards such as Maritime Resource Names (MRN), OpenID Connect and X.509 certificates (MCP, 2023).

Due to the nature of the microservice architecture however, where each microservice is responsible for performing its own orchestration, each of the identified microservices would have to individually communicate with the MCP to perform all the necessary security operations. To simplify this requirement, a single additional microservice was introduced into the architecture in order to assume responsibility for all SECOM security functions. This can be contacted by all other internal microservices to generate SECOM signatures through the use of the appropriate X.509 certificates, and also verify the authenticity of the received messages, through the received signatures. This approach, not only greatly reduced the implementation workload, but also allows the possibility of employing any other alternative framework, without the need for additional software changes on the other architecture components.

One more MCP component, also dictated by SECOM, is the Maritime Service Registry (MSR). This can be seen as a sophisticated “yellow pages” phone book of maritime services, that can be searched for, using a number of different criteria (MCP, 2023). The MSR allows the GLA e-Navigation services to be registered and become discoverable by authorised users, through the use of the IALA G1128 Guideline (IALA, 2021). Service and client registrations are also mandated to support the SECOM subscription operation. SECOM subscriptions however, could potentially be replaced by the MCP third and final component, the Maritime Messaging Service (MMS) which is currently under development.

3.3 Architecture Overview

Having identified most of the required microservices, we can now proceed with the presentation of a general overview of the GLA e-Navigation Service Architecture, seen in Figure 38.

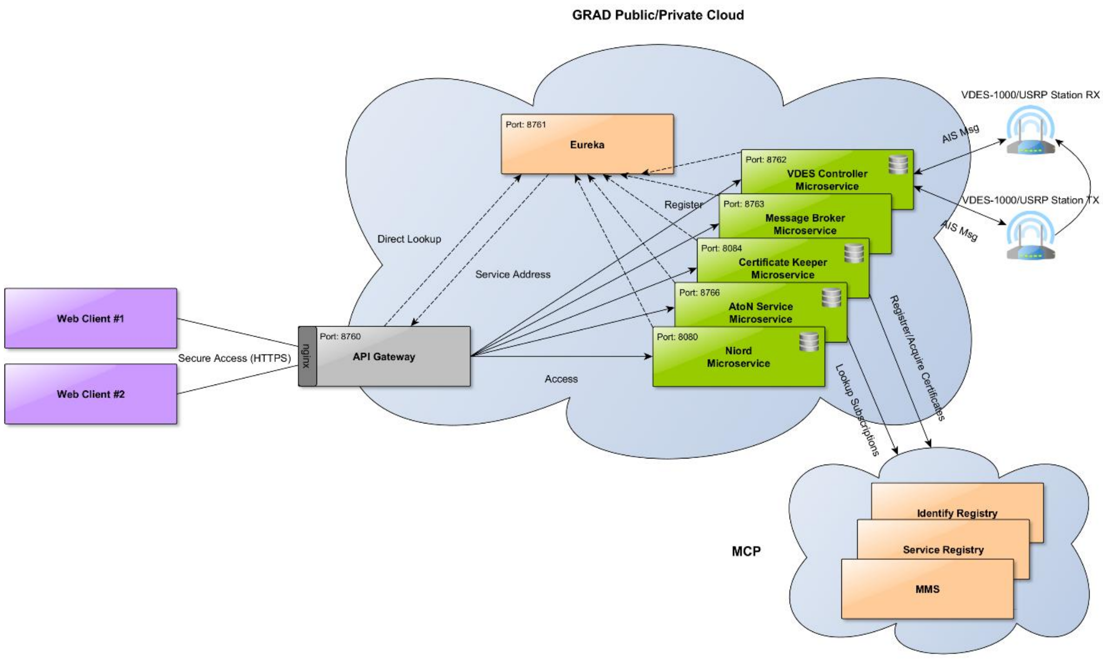

Figure 38: The GLA e-Navigation Service Architecture overview.

The DCT ("VDES Controller", "Message Broker"), VAD ("AtoN Service") and UIA ("Niord") services are all evident in Figure 38. In addition the "API Gateway" component implements the G1114 GWY service. The integration with the MCP is also demonstrated by the link originating from the "Certificate Keeper" microservice. An additional component present in the figure that hasn't been mentioned previously is the internal "Eureka" service registry. This is another microservice component, only for internal use, that allows the microservices present to be discovered and communicate with each other without the need to establish static connections. In addition it allows for a very flexible monitoring of the system and optionally a shared configuration repository.

Figure 38 also illustrates that the "API Gateway" becomes available to the clients via a dedicated web server (nginx). This setup allows the architecture to expose a different SSL certificate (not generated via the MCP) and also permits higher flexibility where different e-Navigation systems could be served in parallel.

Microservices are typically cloud-native, which means that they can easily be deployed in a hosted cloud environment. This allows the architecture be scalable in order to dynamically support a large number of requests. Scaling in this context refers to the ability of the architecture to increase its capacity and performance. In cloud environments, horizontal scaling in particular allows applications to run in multiple independent instances, which are perceived by the end-users as a single entity. Consequently, the microservices displayed in Figure 38 are also included in a cloud environment, which can be public or private, depending on the service provision requirements.

It has to be noted at this point, that since microservices are quite specialised in terms of their functionality, they should not be confused with the notion of an MS or a TS, in the context of e-Navigation. A relatively large number of individual microservices will normally have to communicate with each other, in order to provide the full functionality of an MS, or even a more elemental TS.

4 GLA E-NAVIGATION ARCHITECTURE COMPONENTS

All microservices of the GLA Service Architecture presented in the previous section have actually been implemented, and constitute the established GRAD e-Navigation Service Demonstrator test-bed. The latest Springboot 3 (VMware, 2022) framework was used for this purpose, as it already supports a significant amount of the required functionality. The remainder of this section briefly presents the list of developed microservices and provides some further implementation-specific information on their respective functionalities.

4.1 Eureka

This is the internal component the handles the service discovery and facilitates the microservice inter-communication. It should not be confused with a MCP MSR component, as it is only focused on the discoverability of the internal e-Navigation Service Architecture microservices. It is based on the Netflix Eureka (Netflix Eureka Project, 2022) service implementation which allows the registered microservices to be contacted via a simple name identifier. It removes the requirement for microservices to be aware of each other's addresses (IP, URL) beforehand, and also supports the system scaling operation by allowing multiple instances of each microservice to be used according to a selected load-balancing strategy.

4.2 API Gateway

As required by the relevant IALA guidelines, all available services are externally accessible through the GWY component called "API Gateway". Its main purpose is to provide access to the platform in a secure way (e.g. through HTTPS), protect the system availability (e.g. through load-balancing and rate-limiting of the incoming requests), and finally route the incoming requests to the appropriate service. To achieve this, it collaborates closely with Eureka, as it is required to know the address of the microservice it will route the incoming requests to. One more key feature is the verification of the incoming SECOM requests. These are mandated to use TLS/SSL certificates, which are first verified by the API Gateway, before gaining access to the internal microservices. If no certificate is present or it is not valid, the API Gateway will require authentication via the OAuth 2.0 (Hardt, 2012) standard. In the current implementation, a separate Keycloak (Red Hat, 2023) OpenID Connect (OpenID Foundation, 2014) server is used to provide this functionality.

4.3 Message Broker

IALA Guideline G1114 makes reference to a Maritime Messaging Service amongst its value-added data processing services. In the current implementation, the "Message Broker" assumes this role and facilitates a geospatially-aware publish-subscribe communication pattern (through the use of the GeoMesa (Geomesa Project, 2022) library), where the senders of messages (publishers) do not program the messages to be send directly to a specific receiver (consumers). Instead, publishers submit the messages to a specific topic, so that all authorised services interested in that topic and the affected geographical location will receive them. The topics can be defined as a character string representation of the message type such as "aton" or "aton/virtual". The latter topic format can be used to provide a more fine-grained topic categorisation.

4.4 Niord

As per the G-1114, there is a need for a UIA service. In the current implementation, this is provided by the Nautical Information Directory (Niord), a system able to produce and publish Navigational Warnings (*NW*) and Notices to Mariners T&P (*NM*). It was originally developed as part of the EfficienSea2 EU (EfficienSea2 Project, 2018) project and subsequently implemented as a production system for the Danish Maritime Authority (DMA). For the needs of the current project however, the original code was ported onto the latest Red-Hat Quarkus (Red Hat, 2023) and Angular (Google, 2022) frameworks. In addition the capability was added to generate AtoN information, which can then be encoded into the IHO S-125 data format. Any update on the AtoN information is communicated to the "Message Broker" microservice, so that all other microservices that have subscribed to receive updates will be notified. It has to be noted here that although Niord is a very useful component of the demonstrator test-bed, it is a not a core component of the architecture and any other NW/NM/AtoN management system could be used instead, at least as long as it is able to generate S-100 (IHO, 2022) compliant data.

4.5 AtoN Service

This is the core service supporting the provision of AtoN information. It follows the SECOM standard and it is implemented in accordance with the "Technical Specification for the Provision of AtoN Information Service to End-users" guideline being developed by IALA. It stores all the published AtoN messages generated by Niord (including VAtoN), allows clients to retrieve them based on various search criteria, and supports geo-spatial queries. It currently employs a premature version of the IHO S-125 data format, since the final data product specification is not yet published. The "AtoN Service" monitors the AtoN information published to the "Message Broker" and updates its list of defined datasets when applicable. It also supports the SECOM subscription operation, so that it can notify client services whenever dataset updates become available.

4.6 VDES Controller

As stated in Section 3, the GLA identified the provision of VAtoN as one of the top priority use-cases for their future e-Navigation applications. The use-case requirements stated that the transmission must be performed over AIS/VDES, therefore the architecture should include a component that provides this capability. Consequently, the "VDES Controller" microservice was introduced, which is capable of interfacing with VDES modules like the CML Microcircuits VDES1000, using a set of predefined UDP/IP ports. The application is therefore able to transmit messages using the TSA/VDM (Transmit Slot Assignment/VHF Data-link Message) and the BBM (Broadcast Binary Message) sentence protocols. "VDES Controller" can receive the current VAtoN information by either polling or subscribing to the "AtoN Service" microservice, and translates it to the appropriate transmission format. For testing purposes, the service is also able to send AIS messages using the Ettus E320 software-defined radio USRP platform in a similar manner.

4.7 Certificate Keeper

Subsection 3.2 already stated that an additional microservice is required to interface with the MCP. The "Certificate Keeper" microservice has been designed explicitly for that purpose. It interfaces with the MCP MIR securely using the TLS/SSL protocol, and is able to generate a new MCP X.509 certificate for each of the architecture elements, including the services, the users and of course the advertised VAtoN. The generated certificates along with their public/private key pairs are cached in a local microservice database, so that it is easier to generate signatures for the transmitted messages, as well as verify incoming messages based on the provided signatures. The microservice has an additional feature, where it can be used as a stand-alone application on the client side, in order to provide an easier and more robust way to verify the messages originating from the CSSA, especially in cases of intermittent connectivity.

5 E-NAVIGATION SERVICE DEMONSTRATOR - VATON TRANSMISSION

From the initial phases of the GLA e-Navigation Service Architecture design process, the goal of being able to transmit a VAtoN was identified. The purpose of a VAtoN System is to provide a near-instantaneous warning to the mariner of a new danger, such as a wreck, obstruction or floating debris. Therefore the responsiveness of the system, even in real-world distributed scenario was crucial.

GRAD, in collaboration with the Commissioners of Irish Lights (CIL – also a member of the GLA), established the e-Navigation Service Demonstrator test-bed where the CSSA is implemented following the proposed GLA e-Navigation Service Architecture and is located in the GRAD Radio Navigation Laboratory in Harwich, UK. The VAtoN transmission node on the other hand is located in Dublin, Ireland, and comprises of a VDES1000 module, controlled by an additional "VDES Controller" microservice also present in the same physical location. Connectivity with GRAD is achieved over the public internet, secured via a dedicated VPN link.

The test transmission was initiated by generating a new VAtoN entry in Niord. Subsequently the "AtoN Service" was notified and updated the corresponding CIL S-125 dataset. Finally, the "VDES Controller" located in Dublin was informed of the new VAtoN via polling and initiated the AIS transmission. As expected, the whole operation took less than a few seconds. Figure 39 confirms the successful transmission, as this was subsequently picked up by a local AIS receiver.

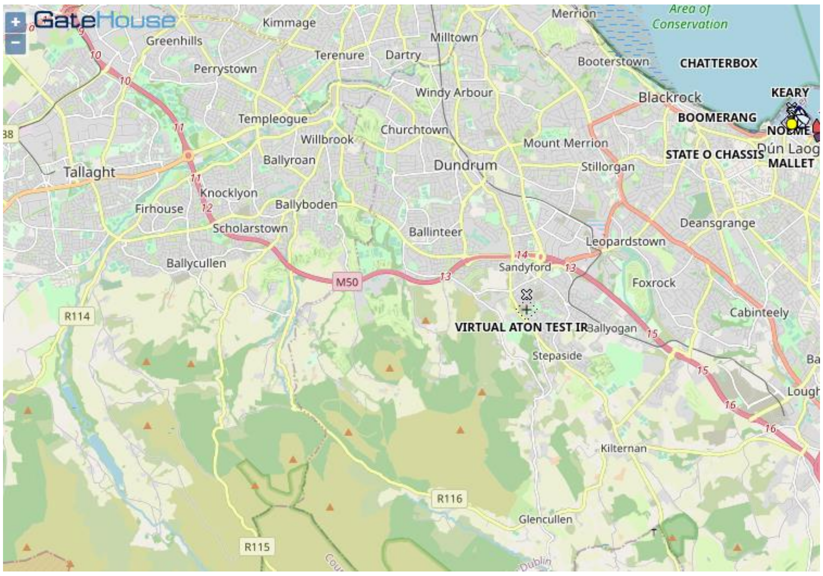

Figure 39: The GLA VAtoN test transmission demonstration, as captured by an AIS receiver.

To our knowledge, this is the first successful experiment of this kind, using the latest e-Navigation and security standards, and demonstrates the flexibility and efficiency of the new proposed system architecture. It is also planned to expand the e-Navigation Service Demonstrator test-bed to cover more areas in the UK and Ireland.

6 CONCLUSION

This paper introduces a novel e-Navigation architecture that was designed and developed by the GLA to form the basis for the provision of their future e-Navigation applications. It describes the design process followed, justifies the reasoning behind the key design decisions made, and provides an overview of the architecture as a whole and a brief description of its individual components. A special reference is made to the MCP, as the platform utilised to support the secure data exchange following the SECOM standard. The proposed architecture was subsequently implemented in the GRAD Radio Navigation Laboratory, and is currently operational, as illustrated by the successful VAtoN transmission performed over Ireland in collaboration with CIL. The approach presented aspires to incorporate all relevant IMO, IHO, IALA end IEC guidelines, recommendations and standards in the context of e-Navigation, and it is intended to be used as a prototype for developing e-Navigation applications not only by the GLA, but by the whole maritime community.

7 ACKNOWLEDGEMENTS

The author would like to thank all GLA colleagues that assisted in the design and implementation of the described architecture. Special thanks to Jan Safar, Gareth Wimpenny, Chris Hargreaves (GRAD) and Roger Valentine (CIL).

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Nikolaos Vastardis is a Research and Innovation Engineer at the Research and Development Directorate (GRAD) of the General Lighthouse Authorities of UK and Ireland (GLA), where he has been working for the past three years. He specializes in software development and system design, bringing to the table over 10 years of experience in the field.

Nikolaos holds a Master of Science in Networks and Telecommunications, which he received in 2008, and a PhD in the field of Delay Tolerant Networks, awarded in 2014. Before joining the General Lighthouse Authorities, he worked as a software developer on a number of academic and industry posts, including a number of years leading a team in the development of a successful aviation MRO solution.

His current research interests include e-Navigation, the S-100 framework, and scalable software designs. Nikolaos is dedicated to pushing the boundaries of technology in his field, and is always exploring new ways to bring innovation and efficiency to his work.

S107.1 Wireless technology in Aids to Navigation (186)

José Antonio Martinez Tanco, CEO, Mediterráneo Señales marítimas S.L.

ABSTRACT

Digital connectivity technologies have progressed faster than any other breakthrough in history, reaching over half of the world's population in just two decades and changing civilizations. In AtoN, long and mid-range digital technologies such as AIS, remote monitoring and control, satellite communications, and fiber optic internet; are widely used and established as a way to exchange and provide safety, status, and navigational information. On the other hand, short-range wireless technologies (such as WI-FI and Bluetooth) are not developed to their full potential. In its current technology state, Bluetooth can substitute cabling in a variety of AtoN applications and combined with smart modular systems can drastically improve the user experience and versatility of lanterns and electronic AtoN equipment. Wi-fi is originally intended as a replacement for high-speed cabling for general local area network access in work areas, and in AtoN environments, combined with smart units, can drastically improve maintenance ease and modularity.

These solutions should be developed and integrated into future developments, as is reliability and versatility are superior to current solutions. This is illustrated by the new developments in smart compact lantern systems and by the usage of directional WI-FI point-to-point connections in lighthouses monitoring applications.

(No paper submitted)

AUTHOR BIOGRAPHY

Toni Martínez is an electronic engineer with a solid background in the maritime Aids to Navigation industry. He started his professional career in 1989, developing control panels for the automation of lighthouses and beacons. Throughout 34 years he has held different positions related to Aids to Navigation sector as Project Manager, Production Manager and Head of After-Sales Services, being involved in many international beaconing projects.

In 2006 he decided to launch his own company as co-founder of Mediterráneo Señales Marítimas S.L., a company specialised in aids to navigation products and services with a worldwide presence. Currently, he is the CEO of the company, providing guidance on strategy, significant value, and expertise to the different departments of the company.

S107.2 Resilience against AtoN failure and how to recover from cyber incidents and attacks (044)

Martijn Ebben, Cyber Security and Risk Officer, Port of Rotterdam, Netherlands

ABSTRACT

The maritime community is increasingly dependent on digital services and techniques. The consequences of cyber incidents and attacks are evident, especially when autonomous shipping is implemented an no human is around to intervene. Prevention and resilience are key, but statistically every organisation will be hit by a coincidental or deliberate cyber-attack someday nevertheless. This should be acknowledged by every AtoN administrator and plans on recovery from cyber-attacks should have been made. This is digital crisis management and business continuity planning and it is less technical than you might think.

Martijn Ebben will give you valuable suggestions on resiliency to cyber incidents, and in terms of recovery, where to start and what the minimum requirements for your plans and check lists are.

Key points:

1. VTS Cyber Security
2. Awareness
3. Best practices and tools
4. Prevention

(No paper submitted)

AUTHOR BIOGRAPHY

Martijn is Cyber Security & Risk Officer at the Port of Rotterdam, responsible for strategic and operational cyber security for the VTS, VHF, sensors and AtoN systems in the port. He is responsible for policy, enforcement and implementation of the cyber security strategy and is involved in all projects and day-to-day operational management of the VTS systems. The Port of Rotterdam has a team of 8 Security Officers that all have a specific business focus.

Martijn has a background in system and security engineering and networking and has been working in the port for seven years after holding several operational and management positions in network security. He is a contributing member in several IALA committees.

S107.3 IMT technologies-based Maritime Evolution with the case study of public warning service (218)

Hyounhee Koo, CEO SyncTechno, Republic of Korea

ABSTRACT

IMT technologies-based Maritime Evolution with the case study of public warning service

(No paper submitted)

AUTHOR BIOGRAPHY

Hyounhee Koo is the CEO of SyncTechno Inc., a research and development firm that specializes in projects and businesses related to local and global standardization activities. The company is focused on developing software technologies and global standards in the fields of public safety and the maritime domain. Ms. Koo has been involved in 3GPP standardization since 2003 and served as the rapporteur of 3GPP Release 16 stage 1 work item MARCOM (Maritime Communication Services over 3GPP systems) from 2016 to 2018. Her efforts resulted in the official inclusion of the maritime sector in the scope of 3GPP standardization.

In 2019 Hyounhee was appointed as the 3GPP liaison person for the global collaboration between 3GPP and IALA, where she has contributed to the development of IMT technologies applicable to the digital transformation of the maritime sector. She is also involved in the development of ITU-R report for the introduction of IMT usage applicable to autonomous surface ships, virtual AtoN, smart ports, maritime safety, and other relevant areas. Furthermore, Ms. Koo is involved in 3GPP standard activities related to public safety, including warning services.

Prior to her current role, Hyounhee worked for LG Electronics and Samsung Electronics in the field of mobile communications, including 3GPP standard activities. She graduated from the Graduate School of Seoul National University with a master's degree in Electrical Engineering and Computer Science in early 2002.

SESSIONS 8 AND 108 – SERVICE PROVISION IN AN AUTONOMOUS WORLD

S8.1 What makes an AtoN 'MASS-compatible'? (058)

Jan-Hendrik Oltmann, Senior Strategic Adviser, Federal Waterways and Shipping Administration, Kiellinie 247, 24106 Kiel, Germany, Jan-Hendrik.Oltmann@wsv.bund.de

ABSTRACT

With the advent of Autonomous Vessels (AVs) – the maritime subset of which is called Maritime Autonomous Surface Ships (MASS) by the International Maritime Organization (IMO) – the question arises what their impact on the domain of Aids-to-Navigation (AtoNs) might be. Their very name implies that they are supposed to be able to gain and maintain their orientation and route while navigating a waterway by themselves without any externally provided aid. It could be argued, however, that AVs would still require AtoNs for assistance in their navigation in a similar way as AtoNs are required by a human bridge team who also operates their vessel 'autonomously' of some kind – at least as seen from the outside. If the latter holds true, AVs would just only require a different technical setup of AtoNs provided to them as opposed to AtoNs provided to human bridge teams, i. e. 'AV compatible' AtoNs. This paper considers options for AtoN administrations to deal with the challenges caused by the advent of AVs as a contribution for further discussion.

KEYWORDS: AtoN-assisted Autonomous Vessel; AV-supportive Aids-to-Navigation; AV-adapted Aids-to-Navigation; adaptive AtoN; remotely operated vessel; 'smart' vessel; 'smartness-induced' accidents; PNT data processing; generic shipboard navigational system architecture; invisible high-precision vessel track; waterway infrastructure site architecture; 'smart hectometre stone'; high-bandwidth visual light communications; swarm collection of data.

1 INTRODUCTION

Some of the findings of an IALA workshop on 'Marine Aids to Navigation in the autonomous world' in 2021 constitute the starting point for the present topic 'What makes an AtoN MASS-compatible?' as follows (emphasis added):

- 'Marine Aids to Navigation will continue to be essential infrastructure for all degrees of maritime autonomy on vessels and will continue to be required to support safe, efficient and pollution free transits. This includes identifying options for position, navigation and timing (PNT). This may lead to the development of adaptive AtoN to support different degrees of autonomous vessels' ([1], finding No. 5).
- 'MASS will require a robust and resilient communication 'system of systems' to support complex and vital communication needs, allowing communication between ships, remote control centres, VTS, AtoNs and other elements that may be required in a MASS operating environment' ([1], finding No. 6).
- 'All developments in the provision of AtoN to support MASS must consider their role in a mixed maritime environment which includes both conventional vessels and MASS, and be fully compatible with both' ([1], finding No. 8).

These findings either expressively state or imply the following claims, which in turn prompt critical questions:

- It is claimed, that AtoN infrastructure will be **required** in the future for AVs (besides being still required for traditionally operated vessels). *Is this really a substantiated statement or just an optimistic self-assurance?*
- It is stated, that the co-operative nature of any AVs' operations prompts stringent requirements, including robustness and resilience, for their communication with all entities involved. The **communications between AVs and AtoNs** are of particular interest here. *Would those communications be visual or (digital) radio communications or both maybe even?*
- It is stated, that AtoNs may also be an option to **fulfil AVs' PNT requirements**, the prerequisite of which is that these AtoNs would be meaningful for AVs at all. Hence, *what would be the requirements for an AtoN providing PNT to an AV, which – by very definition – would be operating entirely electronically?*
- It is stated, that 'developments in the provision of AtoN' must address a **mixed target fleet** of both traditionally operated, automated vessels (to whatever intermediate degree of automation), and AVs.
  - The 'provision of AtoN' could be fulfilled by a single AtoN service comprising only a new variety of AtoN, that is 'automation-supportive', 'AV-compatible', and 'traditional', all at the same time. *How would such an AtoN appear? What would be its visual and electronic interfaces towards an automated vessel and even to an AV? What degrees of shipboard automation would the same AtoN be capable to support?*
  - Or, could the mixed target fleet requirement only be fulfilled by an AtoN service portfolio of different, partly new AtoN services? *How would an AtoN service portfolio look like that comprises different varieties of AtoN services that operate concurrently with each individual AtoN service only addressing a certain portion of the mixed target fleet, only?*
- The design goal of an **'Adaptive AtoN'** has been postulated. In engineering, 'adaptive' is understood as being capable of adapting functionality *at run-time.* Here, 'adaptive' would imply an 'Adaptive AtoN' to support at run-time the different degrees of automation in vessels addressed, up to the AV proper. *What would be the consequential run-time sensitive design requirements for that 'Adaptive AtoN'?*

It is the goal of this paper to answer at least some of the above questions within the limitations of a paper like this, while hinting to potential solutions for the remaining questions.

2 IMPLICATIONS OF TERMINOLOGY – NOT JUST NUISANCES

When it comes to automated vessels and AVs, terminology is very important, but also not yet universally consolidated. For the scope here, the following topics need to be addressed first.

2.1 Autonomous Vessel terminology and 'Degree of automation' vs. 'degree of autonomy'

There have been developed different terminology domains and – in the recognition of the need to capture the implications of the above 'mixed fleet' – a variety of 'degree of automation' or 'degree of autonomy' scales. For example, the International Organization for Standardization (ISO) has published intermediate terminology definitions recently [2]; different organizations relevant for shipping have defined different scales for either 'degree of automation' (Central Commission for the Navigation of the Rhine (CCNR) [3]) or 'degree of autonomy' (International Maritime Organization (IMO) [4]; Lloyd's Register [5]; Sheridan [6]). In a philosophical sense, strictly speaking, there is no such thing as a 'degree of autonomy', since the entity under consideration – here: a vessel – either is autonomous of whatever relevant constraints, or not; there is however possible and meaningful any degree of automation operative within that entity, culminating eventually in in its 'autonomy'.[1]

Here, I prefer 'degree of automation' with 'autonomy' as its final stage.

2.2 Maritime and inland waterway domains and the 'mixed target fleet'

This paper is entitled 'What makes an AtoN MASS-compatible?' Maritime Autonomous Surface Ship (MASS) is a technical term defined by IMO to precisely distinguish vessels under consideration from, for example, sub-sea autonomous systems on one hand and from inland waterway vessels on the other hand. IALA's overarching remit comprises both the inland waterway and the maritime domains ([7], Article 2); hence, a more generic term than MASS would be needed. The most fundamental terms would be **Autonomous Vessel (AV)** – in the above sense of autonomy as the final stage of automation – and **Remotely Operated Vessel (ROV).** In addition, 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. The figure overleaf may be drawn to illustrate the 'mixed target fleet' in fundamental generic categories in accordance with the overarching architecture for e-navigation on the left hand side. On the right hand side, the relevant generic shore entities are shown such as waterway field infrastructure, including AtoNs, and all kinds of shore-based centres.

[1] Some of the proposed scales of 'degree of autonomy' resolve the issue to designate the autonomy of the entity in its above philosophical sense by introducing terms like 'fully autonomous' ([4], [5]), and thus the prudence of language – obviously perceived need for adding the prefix 'full' – reveals the issue at hand. At Sheridan levels of autonomy, the term 'autonomy' appears only at Level 10, while the term 'automatic execution' appears last at Level 6. The intermediate levels 7, 8, and 9, are neither labelled automatic nor autonomous, and it can be debated what is implied by 'computer executes action' in this regard ([6], 11).

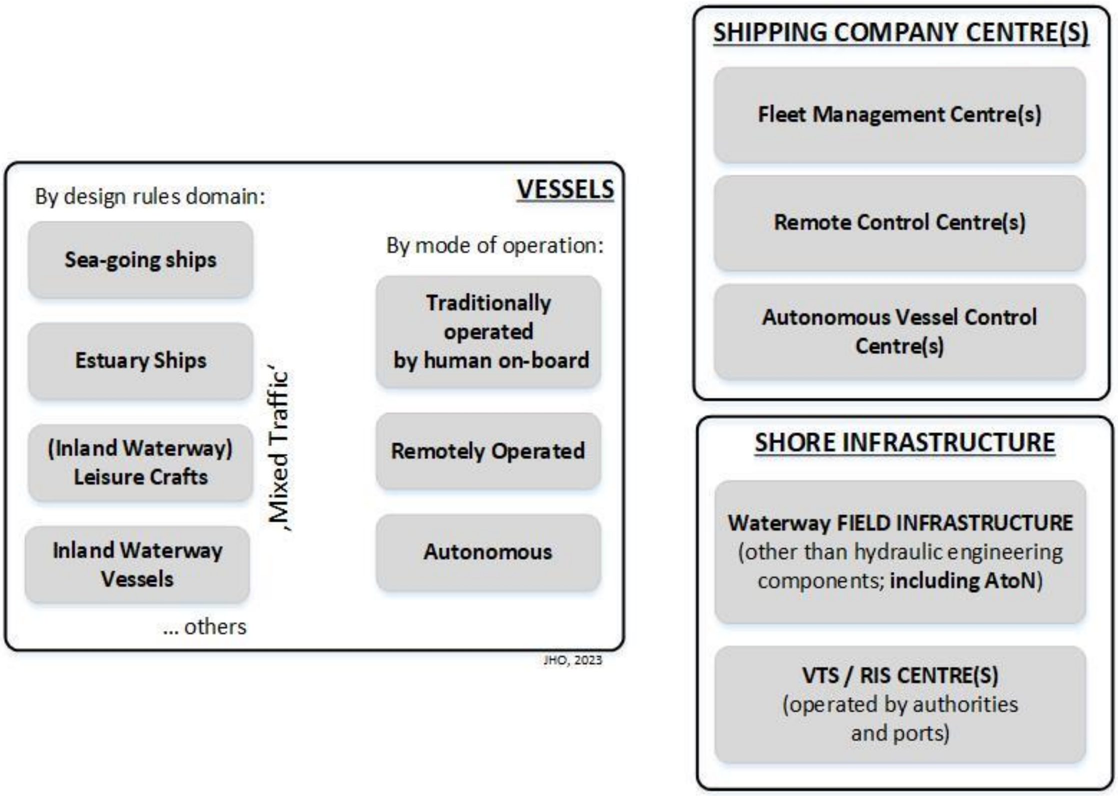

Figure 40: Overview of generic 'mixed target fleet' and different generic infrastructures and centres provided by shipping companies and shore authorities (Source: own creation)

- **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 *Remotely Operated Vessel (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[3] is irrelevant in regards to its navigating functions as long as they are performed remotely as the intended regular case.

[3] ISO defines 'uncrewed' as a 'ship with no crew onboard', while 'crew does not include passengers, special personnel etc.' ([2], 3.1.9).

- An *Autonomous Vessel (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.[4] 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. [5]

  ISO draws attention to the temporal or to the process character of AVs' autonomy: Autonomy is confined to a period and/or to a defined operational scope, that is called **Operational Envelope** ([2], 3.1.3, note 2, in conjunction with Annex B). 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 a crew on-board).

- **Generic shipping company centres:**
  - *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.
  - An *Autonomous Vessel Control Centre (AVCC)* is a shore-based centre that monitors and controls an AV 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. [6]

2.3 Navigational aids versus Aids-to-Navigation and the generic shipboard navigation system architecture

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, but with the advent of AVs intensity of debate will increase, as will be discussed further down below.

PNT data is particularly important for navigation, and therefore IMO has identified and described the **(shipboard) navigational aids relevant for PNT** in considerable generic detail: IMO's 'Guidelines for Shipborne Position, Navigation and Timing (PNT) data processing' (MSC.1/Circ.1575) [8] refer. These Guidelines discuss the integration of PNT related data derived from shipboard sensors to arrive at a consistent PNT data solution

[4] 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*' ([2], 3.1.3, emphasis added). Sheridan Level 10 defines autonomy in respect to a computer as 'Computer does everything autonomously*, ignores the human'* ([6], 11, emphasis added).

[5] Consequentially, this fundamental distinction may or even should be clearly stated by the vessel to the outside world by setting an appropriate flag visually and electronically dynamically at run-time, if the state 'autonomy' would imply any operational difference to other vessel traffic participants compared to any other degree of automation.

[6] The functions of the RCC and of the AVCC can be merged. This is indicated by ISO, by positioning the functionality of the 'Autonomous Remote Controller' into the RCC ([2], 3.2.5 and Figure A.1).

for navigational purposes; they also introduce a **generic shipboard navigation system architecture,** which is structured hierarchically in three functional layers in the vertical dimension. These are from bottom to top:

- *Sensor / Source Layer:* Here reside all shipboard sensors, the pre-processing entities for their data as well as the radio communication front ends to the physical radio links. This layer provides the technical interfacing to the physical and operational environment of the ship.
- *Data Processing Layer:* 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.
- *Operational Layer:* This layer provides the HMI to the bridge team to support their navigational task for traditionally operated vessels. When applied to an AV, the Operational Layer would contain the autonomous shipboard decision making functionality, the **'Autonomous Onboard Controller'** ([2], 3.2.4), and a dedicated HMI would no longer be required during regular operation.

It is important to note, that the above IMO Guidelines would be applicable to traditionally operated and AVs 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.

2.4 Notion of the 'autonomous ship system' and its context – moving towards co-operative nature

ISO has defined the term **'autonomous ship system'** to indicate that each AV needs to operate in an ecosystem comprising the 'support services' and the 'remote control services' ([2], Annex A) besides the AV itself. In addition, ISO embeds the autonomous ship system within a **'wider context'**. On the shore side, this wider context includes 'river services (locks, bridges), fairway services (tugs, anchorages), port services (mooring, cargo handling, supplies, inspections, reporting, checks), and pilot', and – relevant for the topic at hand here – **'fairway information** (MSI and **AtoN**) and traffic services (VTS, MRS, RIS)' ([2], Figure A.2, transcribed; emphasis added). The various **operational relationships** between the various components of the autonomous ship system itself and between the autonomous ship system and its wider context imply an increased required connectivity compared to the present situation. These **functional and physical links** need be established by a **variety of communication technologies**.7 The figure overleaf generically transforms the ISO statements into the overarching architecture for e-navigation. The position of the AtoN Service of a waterway authority would be part of the 'Common technical shore-based system for fairway & navigation applications' on the right hand shore-side of that figure ([9] and [10] refer).

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[7] Which do not need to be radio communication technologies exclusively; see further down below.

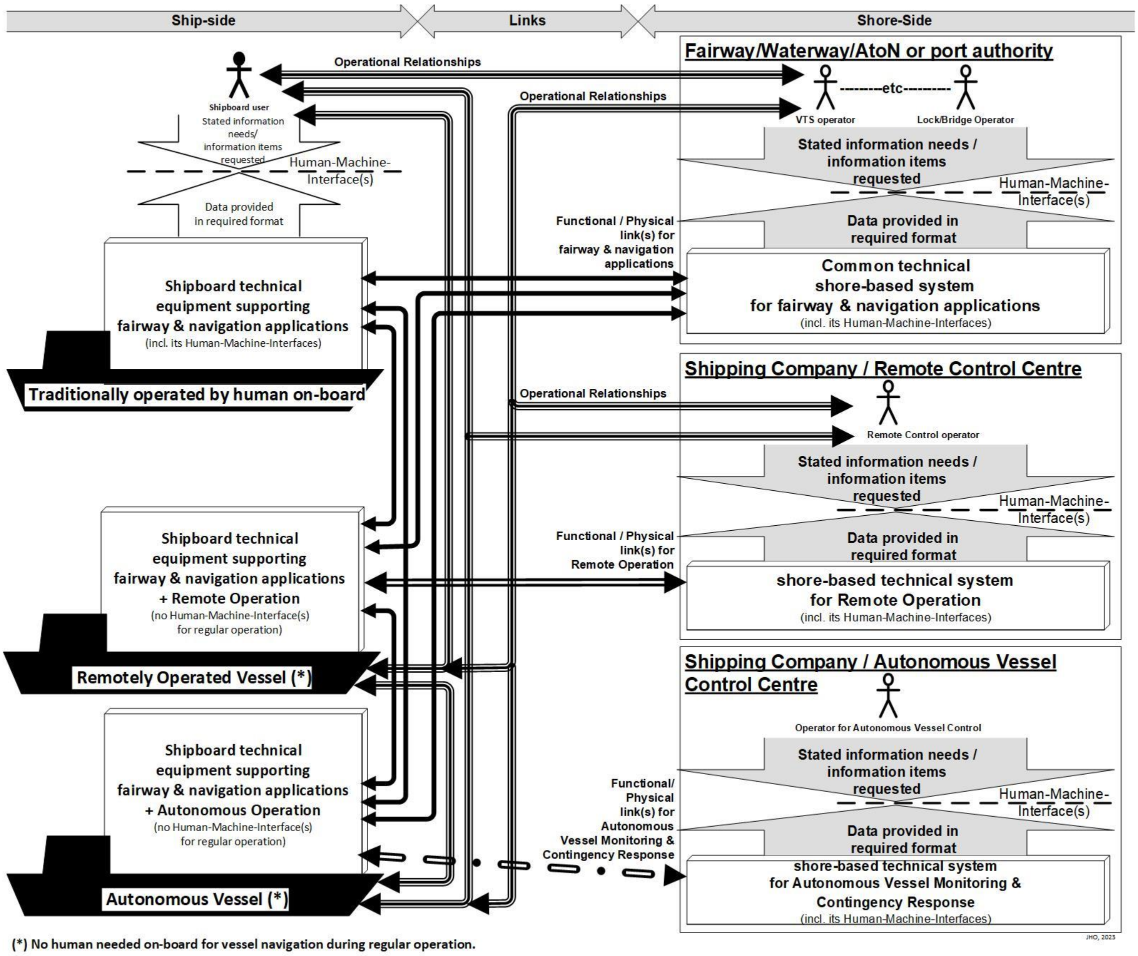

Figure 41: Generic operational relationships and resulting generic communications relationships (Source: own creation)

3 ‘AV-SUPPORTIVE’ ATONS -WHY SHOULD AN AV REQUIRE ANY AID FROM ATONS?

When observing current projects, test beds, and discussions regarding AVs and ROVs it seems, that attention mainly lies with the shipboard automation and the challenges for automation to arrive at autonomy. The pendula thus seems to have swung almost exclusively towards navigational aids supporting the decision making and execution functionality of the AV. The envisaged PNT Data Processing as embedded in the generic shipboard navigation system architecture as introduced above serves as an example here.

When considering the ‘AV-compatibility of an AtoN’ like in this paper, the point of view is from the outside towards the automated or even autonomous vessel, however. It exhibits to the onlooker a certain behaviour as a consistent entity – that is a ‘black box’ characteristic perceivable from the outside. So, what requirements originate from this ‘black box’ relevant for the future role of AtoNs for AVs?

There is one last term to be introduced here, a term that appears to be broadly used. That term is ‘**smart vessel**’. ‘Smart vessel’ seems to be a synonym for at least very highly automated vessels or even – or maybe only – AVs. Reading documents dealing with ‘smart vessels’ construed as AVs, the underlying assumption seems to be that ‘smart vessels’ and thereby AVs are required to be ‘smarter than humans’.[8] Which would also imply, that any AV would recognise at least the same data, information, guidance etc. of the world outside

[8] A ‘smart vessel’ was not incorporated in ISO’s comprehensive AV terminology definition work [2], although ISO hosts a dedicated working group on the topic labelled by that term. Maybe ‘smart vessel’ (or any correlate term for that matter) was not included in the ISO AV definitions, because of the obvious difficulties to define that term.

the AV that a human would recognise. This in turn, of course, explains why the focus of attention is on ('smart' or 'intelligent') sensory equipment of an AV in the 'smart vessel' camp. All of which are navigational aids!

According to ISO, AtoNs – on the other hand - 'are various physical or virtual devices that are installed to directly assist in the ship's navigation. It can be lighthouses, markers and buoys, or virtual AIS-based AtoN' ([2], A.2.2). While this introduction is formally correct, no real value of AtoN for the AV is apparent in that definition: AtoNs seem to be represented in the 'context of the autonomous ship system' only as entities that context just traditionally seems to contain and that therefore are to be mentioned. Despite that, one important truth needs to be captured from that definition, though, namely that **AtoNs are the – only – entity from the outside of the automated or even autonomous vessel that is capable of 'directly assisting' in its navigation**. This is important for any determination of a future role of AtoNs for AVs.

Going back to the AV as such, the question must be raised, whether the bias towards an AV being a 'smart vessel' and thus being 'intelligent' or 'smart' (in the common sense of those terms) is really helpful for the successful – meaning broadly accepted – introduction of AVs? This bias may even stand in the way of a graceful introduction of AVs. That is, because the definition of autonomy does not mean 'intelligent' by default; the definition of autonomy would allow for 'dull' (in common sense), too. Which prompts the following question: Are there maritime or inland waterway business cases, use cases, or applications that would benefit using only even 'less than smart' AVs? Of course, 'less than smart' is not an appropriate designation. A more appropriate designation will be found further down below.

While the identification or even specification of specific such applications is beyond the scope of this paper, the following use cases should be given to eventually identify them:

- **Reasonable expenditure constraint**: All AVs, including the anticipated 'smart' AVs, will remain 'less than smart' if *the required or even desired level of 'smartness' cannot be accomplished reliably* in the harsh environments of the maritime and/or inland waterway domains *within reasonable expenditure constraints*. This holds true for equipment in R&D stage, which tends to be costly, but potentially also for mass produced commercial products eventually.
- **Expenditure trade-offs between shipboard navigational aids and shore-based AtoNs in an economy of scale**: All AVs would be required to have whatever shipboard functionality in terms of the generic shipboard navigation system architecture with the Autonomous Onboard Controller on top. The specific functionality profile of these entities may be negotiated as follows, however: There may be an economical incentive to use many 'less than smart' AVs in combination with a smaller or even small set of shore-provided high-profile AtoNs *instead of* the same number of 'smart' AVs equipped with high-profile navigational aids in combination with present-state AtoNs. Even more so, if this trade-off may cover not only one kind of business case, use case or application at the same time.[9]
- **Shore-based AtoNs to pre-empt impositions due to 'smartness-induced' accidents**: Despite all good efforts, 'smartness-induced' accidents will happen – which is just a matter of time. Accident investigations and/or the public may potentially *conclude that sole reliance on (shipboard) navigational aids for AVs may not be acceptable (any more)*. Reverting to traditionally operated – meaning crewed – vessels might not be possible, however, due to reasons like the demographic change. One way to avoid this reverting to crewed vessels would be the co-operative system approach, *where (shore-based)* ***'AV-supportive' AtoNs*** *would support AVs' navigational aids – however 'smart' –* ***by default***. If the above reaction to 'smartness-

[9] This is ***not*** to advocate 'sub-standard' AVs. Quite the contrary. *All functionality that* ***is*** *implemented in an AV for* navigation *must adhere to the high quality standards likely in place in due course for navigational aids and must demonstrate their compliance, too,* by e.g. type approval procedures. Since both requirements will add to the expenditure of shipboard equipment of the AV, this even adds weight to this expenditure trade-off use case.

induced' accidents is to be anticipated as a 'sure event', *why not anticipate it and start with such a co-operative system approach from the outset?* Such an approach will likely also qualify as a risk mitigation measure in any Formal Safety Assessment.

- **AV operation outside Operational Envelope – falling back to remote operation:** Autonomous operation takes place only within an Operational Envelope, which contains a temporal dimension, too, as introduced above. When situations occur that renders the AV as being outside its pre-defined Operational Envelope, the AV will revert to a ROV as a first stage. *Operating the ROV under way by a human operator from the (remote) RCC could benefit from AV-supportive AtoNs in the proximity of the AV-reverted-to-ROV, too,* and potentially extend this mode of operation before re-crewing the AV or AV-reverted-to-ROV as a final stage.
- **Malfunction fall-back shore-support:** A shipboard navigational aids simply can fail, either at individual AVs or – even worse – system-wide for **common modes of failure.** While failure may lead to AVs leaving their Operational Envelopes as discussed above*, AV-supportive AtoNs may serve as shore-provided fall-back in order to* ***keep the AVs affected within their Operational Envelops,*** *otherwise impossible solely with just shipboard navigational aids.* This scenario does not depend on the unpredictable timing of the occurrence of any future 'smartness-induced' accident; rather, the need for fall-back as a shore-support can be recognised by a risk consideration at planning time already. This would also be the case, if the required or even desired level of 'smartness' can and will be accomplished reliably within reasonable expenditure constraints. Again, a co-operative system approach where AV-supportive AtoNs would support the remaining operational AVs' navigational aids may offer a solution before reverting to ROV or crewed operation.

Common to all characteristics for potential business cases, use cases, and applications is **the 'directly assisting' capability** of the AV-supportive AtoN made instrumental to AVs here. For the same reason, this renders also a better term than the 'less than smart' AV, as promised above, namely '**AtoN-Assisted' AV**. Using these terms, the co-operative system postulated above would thus reside on the following relationship:

Table 10: Fundamental relationship for AtoN supportive of AtoN-Assisted AVs

AtoN-assisted Autonomous Vessel	⇔	**AV-supportive Aid(s)-to-Navigation**

4 PRINCIPLE CAPABILITIES OF AV-SUPPORTIVE ATONS FOR ATON-ASSISTED AVS

From the preceding the following question follow suit: What would be the implications for AV-supportive AtoNs when being designed for support of AtoN-Assisted AVs? As part of the shore infrastructure, an AtoN, as the very name implies, is supposed to provide aid to the navigation of vessels in its coverage area or within range. AtoNs were traditionally deployed at critical locations along a coast, within an approach or along a waterway to benefit humans operating a vessel on the bridge at these locations – to be physically seen by the human master at the helm. In addition, there have been deployed AtoNs, that, upon being triggered by an appropriate electronic shipboard device carried by the vessel passing those locations, would send data by radio transmissions physically to that electronic shipboard devices to be displayed directly and immediately to the human master at the helm. All visual AtoNs would fall into the first category, while Racons would serve as an example for the second category ([9], figure 4 refers).

In addition, AtoN for the large area provision and therefore – by very definition not confined to any single critical location – of navigation-supportive data by radio transmissions have been deployed. Their radio transmissions are received and used by certain electronic shipboard devices, which in turn forward the abstract data received to other shipboard systems to be displayed eventually, but not necessary immediately, to the human master at the helm. Well-understood examples for this category would be PNT augmentation and/or backup provisions by terrestrial radio services; virtual AIS AtoNs may also serve as an example.

It is in principle the first two cases of traditional deployments **where transforming the underlying ideas of the traditional aids renders the new class of the AtoN-assisted AV**: Their functional requirements may be relaxed regarding the requirements to correctly and reliably analyse the AV's navigational environment in the visual domain similarly or even better than human capabilities. This can be achieved, if and when the traditional visual functionalities are amended by radio transmissions that emulate the visual functionalities by **direct** delivery at an appropriate shipboard radio receiver at their Sensor Layer in an appropriate machine-readable format (instead of the detour via the visual domain). In other words, the fundamental idea would be to emulate the combined functionalities of in particular leading lights and sector lights by providing **directional and highly beam-focussed short-range radio transmissions**. Together they would **create a shore-provided radio transmitted high-precision trajectory to the AtoN-Assisted AV through the approach or waterway, i.e. an 'invisible high-precision vessel track' or 'electronic tow path' provided from ashore.**

- NB: The AV's functionalities to autonomously and dynamically position and motion itself to whatever degree of precision would still be required.

Since these essentially short-range radio transmissions would preferably predominantly operate in the Short Range Devices (SRD) 10 or cellular land mobile frequency bands dedicated by the International Telecommunication Union (ITU), this would require and allow also using their mass market commercial off-the-shelve electronics for their radio front ends. Relaxed infrastructural requirements for supporting short-range radio transmissions sites (see discussion below) even would allow to increase the number of sites with the goal to provide bended and approximately curved trajectories than just straight lines or simple polygons.

- NB: Since uniquely identifiable, the spot locations marked by the short-range radio emissions could potentially be used for supporting shipboard PNT at the AtoN-assisted AV, by e.g. shipboard map matching applications or even short-range R-Mode implementations.
- NB: This is *not* a Racon functionality, although Racons come close to it. While Racons are located at locations critical for navigation, Racons are specifically designed to operate on the radar bands in such a way that their radar transmissions are directly displayed and therefore visible on the radar screen for the human at the helm in a human-readable signature, i.e. they directly serve the shipboard HMI. Racons require more sophisticated and therefore more expensive technology for their operation in the radar band(s) with also a limited market size.
- NB: This is *not* a virtual AtoN application by a shore-based AIS Service because the radio beacons envisaged are situated directly adjacent to navigation critical locations; as opposed to a large(r) area coverage provided by an AIS Service.
- NB: The motion dynamics of a buoy would regularly *disallow* them to be used as infrastructure sites for the envisaged directional short-range radio transmissions. Conversely, the envisaged short-range radio transmissions may put certain buoy positions into disposition.

While science fiction regularly employs this kind of invisible tracks for space station-guided automated landing of spacecraft, it is no 'rocket science'. A proven example of this approach since long is the well-established combination of the 'Autoland' functionality and the Instrument Landing System (ILS) in aviation, which allows for autonomous landing of an appropriately equipped airplane at an appropriately equipped airport under even severe weather conditions (refer to [12] and [13]).

The above variety of AV-supportive AtoNs do not need to be necessarily digital: High-precision can be achieved also just with analogue transmissions. However, progress in beam-forming technologies as developed specifically for latest digital land mobile radio communication technologies, such as IMT-2020 (aka '5G'), may

[10] This technical term is defined by ITU as an umbrella term and comprises a number of diverse short-range radio communication technologies. For further details, refer to e.g. [11].

be useful for AV-supportive AtoNs, in combination with bi-directional digital data communications via the same digital technology.

5 'AV-ADAPTED' ATONS TO SUPPORT SHIPBOARD AUTOMATION

While the preceding discussions focused on the AtoN-assisted AV, it is now necessary to address the traditionally operated vessels at an intermediate degree of automation and the truly 'smart' AV.

5.1 Benefits of AV-supportive AtoNs for all degrees of shipboard automation

Would the above AV-supportive AtoNs, i.e. the invisible high-precision vessel track feature, originally introduced for AtoN-assisted AVs benefit traditionally operated vessels with intermediate degree of automation or for truly 'smart' AVs, too? Both would not need the AV-supportive AtoNs for their navigation tasks in regular operations – strictly speaking. However, once implemented the AV-supportive AtoNs may provide required support for operation outside the 'smart' AV's Operational Envelope, for the RCC when operating an ROV remotely and generally as fall-back arrangements as indicated above. Traditionally operated vessels may benefit by the re-assurance provided potentially by the AV-supportive AtoNs as soon as their functionality would have crept into the appropriate HMI's at the helm.

5.2 Principle capabilities of an AV-Adapted AtoN

While the previous option would be just a spin-off, it is necessary now to take the potential assistance of AtoNs for traditionally operated vessel with intermediate degrees of automation and for truly 'smart' AVs into focus. This assistance to these vessels categories can be provided, if the traditionally human-focused AtoN would be amended by a machine-focused functionality, i.e. if the traditionally human-focused AtoN would become an **AV-Adapted AtoN**. This would mean that the traditional AtoN would be equipped with an additional Machine-to-Machine (M2M) interface directly communicating with shipboard peer equipment.

- NB: 'To be amended' as opposed to 'to be replaced' would be required in general due to the mixed traffic target fleet. Traditionally operated vessels would still require AtoNs with a HMI, namely visual aids. This does not exclude the deployment of AV-Adapted AtoNs solely equipped with M2M interfaces as required locally.
- NB: Increased automation and AVs both would allow and require increased data telegram communications, even as an operational key element, which was labelled **Nautical Datalink Communication (NDLC)** in a relevant project [14].
- NB: An AV-Adaptive AtoN becomes an **adaptive AtoN** (compare the IALA workshop findings in the introduction), if designed to be capable of changing its support for automated or AVs at run-time.

Table 11: Fundamental relationship for AtoN(s) adapted for vessels with different degree of automation

Traditionally operated vessel at intermediate automation degree
(optional: truly 'smart' AV)
(for supplementary and fall-back purposes, only: AtoN-assisted AV)
⇔
AV-Adapted Aid(s)-to-Navigation

5.3 AV-adapted and AV-supportive AtoNs as two functional types of AV-compatible AtoNs

Concluding, the preceding discussions have rendered **two functional types of AV-compatible AtoNs**, namely the **AV-supportive AtoNs** that were designed specifically for the needs of **AtoN-assisted AVs** and the **AV-adapted AtoNs** designed to support intermediate degrees of shipboard automation on traditionally operated vessels or truly 'smart' AVs. The AV-supportive AtoNs may be used by traditionally operated and truly 'smart' vessels alike, once implemented, of course.

6 GENERAL TECHNICAL CONSIDERATIONS REGARDING AV-COMPATIBLE ATONS

This section will consider some technical aspects for the AV-compatible AtoNs. They are applicable in principle to both AV-adapted AtoNs and AV-supportive AtoNs likewise, but the AV-supportive AtoN may be subject to additional requirements as given above regarding e.g. high-precision.

6.1 Introducing the Infrastructure Site Architecture

In vicinity of shore, the distances between the vessel and an AV-compatible AtoN can be considered sufficiently short range everywhere for any kind of direct data communications, which is short-range by default. To cover a variety of options, the consideration of a generic **Infrastructure Site Architecture** for the AV-compatible AtoNs might be helpful. It supports at least the following three different use cases:

- *co-operative position determination* of the vessel passing by the AV-compatible AtoN, which is also *electronically identified* in the process;
- *upload of data relevant for navigation from AV-compatible AtoN to vessel,* such as locally gained sensor data or remotely received data for broadcast to all passing vessel or remotely retrieved data for identified vessel, if sufficient time available for retrieval process;
- *download of vessel data to AV-compatible AtoN,* such as vessel sensor data at the time of passing of site or data stored by the vessel on-board equipment for a period prior to passing by.

The interaction of the AV-compatible AtoN with a vessel is illustrated by **Error! Reference source not found.** f ollowing figure.

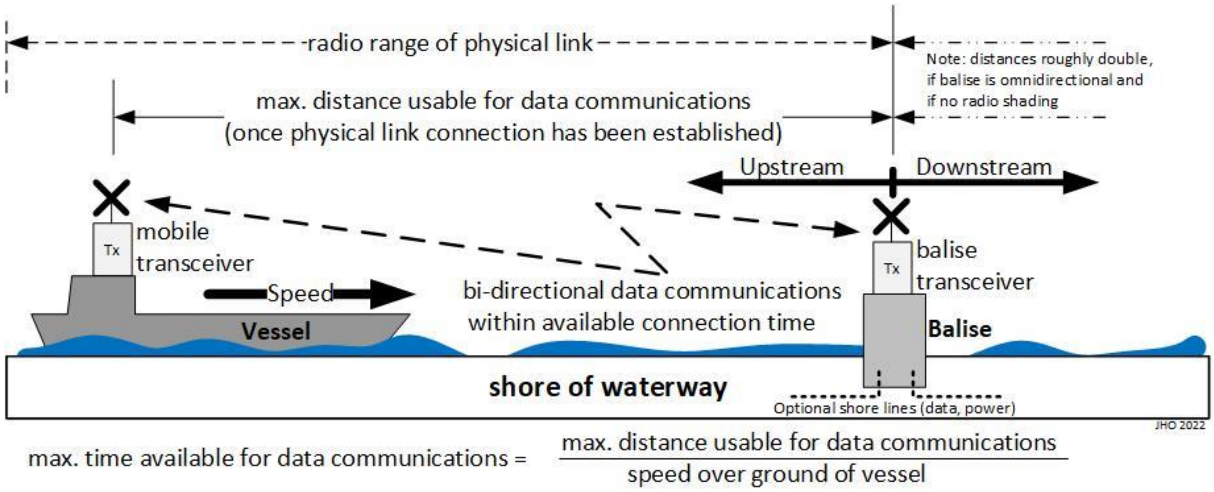

Figure 42: Working principle of interactions between vessel and AV-compatible AtoN (Source: own creation)

In order to give an indication for timing requirements when selecting any suitable communication technology to support the above use cases, the following example calculations for vessels of different speeds over ground at an example maximal distance usable for data communications are given.

Table 12: Example calculations for time available for data communications at infrastructure site/AtoN

Max. time available for data communications V2I [s] | [min]	Max. distance usable for data communications V2I [m]	Vessel speed over ground [km/h] | [m/s]
360 | 6	100	10 | 2,8
10 | 0,18	100	36 | 10

6.2 Physical links using High bandwidth Visual Light Communications (VLC)

Besides the physical links that use radio communication technologies as introduced above, **the use of light for high bandwidth data communications** may be interesting as a short-range communications means in general but in particular for adapting traditional visual AtoN to render AV-adapted AtoNs. ITU recently has conducted a survey on the emerging technology enabling ‘short distance broadband communication via visible light’ ([15], para. 5), which precisely expresses the idea. This is labelled ‘(near) visible light communication (VLC)’ or alternatively ‘Optical Wireless Communication’ ([15], para. 1). The latest developments regarding modulation of light for establishing high-bandwidth physical links are introduced there: ‘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.’ ([15], para. 3.1). Use cases of relevance here are identified as follows ([15], 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 (V2V) as Vessel-to-(AtoN) Infrastructure (V2I) 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. 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.)’ – e.g. for local VLC link in the bridge/wheelhouse.
- ‘Connected-cars and Autonomous Vehicles‘
- ’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, VLC may offer an emerging solution, even if it is only ‘one bit’ – namely the detection of presence of an (expected) object. But also V2V data exchange at short distances might be an option specifically in fairways with their regularly close encounters. Finally, the motivation to shift communications from a radio link to a visual link may be helpful also 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’ ([15], para. 3.4). Since a number of products and application domain projects employing VLC are given worldwide ([15], para. 5.4) and standardisation is under way already, it may be assumed that the VLC technology as such has reached the ‘testing prototype in user environment’ stage in a technology maturity model.

6.3 The ‘Smart Hectometre Stone’ as a basic variety of an AV-compatible AtoN for many locations

Considering a deployment of many instances of the same or similar such AV-compatible AtoNs would allow for **steady** direct communication with vessels during their (entire) voyage under land but in particular in waterways. Sites with a high affinity to that would be (existing) hectometre stones and/or other passive AtoN positions (signs), thus rendering ‘Smart Hectometre Stones’ and/or ‘Smart AtoNs’, and bridges thus rendering ‘Smart Bridges’. The figure overleaf gives an engineering sketch for the functional setup of such ‘smart’ infrastructure sites.

- NB: A ‘smart’ infrastructure site would lend itself as a contribution to Resilient PNT, if and when its precisely known position is used in combination with a precise time kept and being transmitted by any relevant radio or light communication technology or technologies. The deployment of many ‘Smart Hectometre Stones’ along relevant waterways may resolve the challenge of providing R-Mode indicated above.
- NB: The remoteness of the sites equipped, would require local energy generation and storage, if and when no fixed electricity line would be available. Alternatively, the substantial experience with integration of solar powered low-power electronics gained in the maritime domain could be used.
- NB: The degree of integration of electronics will likely further increase over time while size and energy consumption of individual components will decrease, thus allowing for more functionality to be integrated and/or the dimensions of the ‘Smart Hectometre Stone’ being reduced.

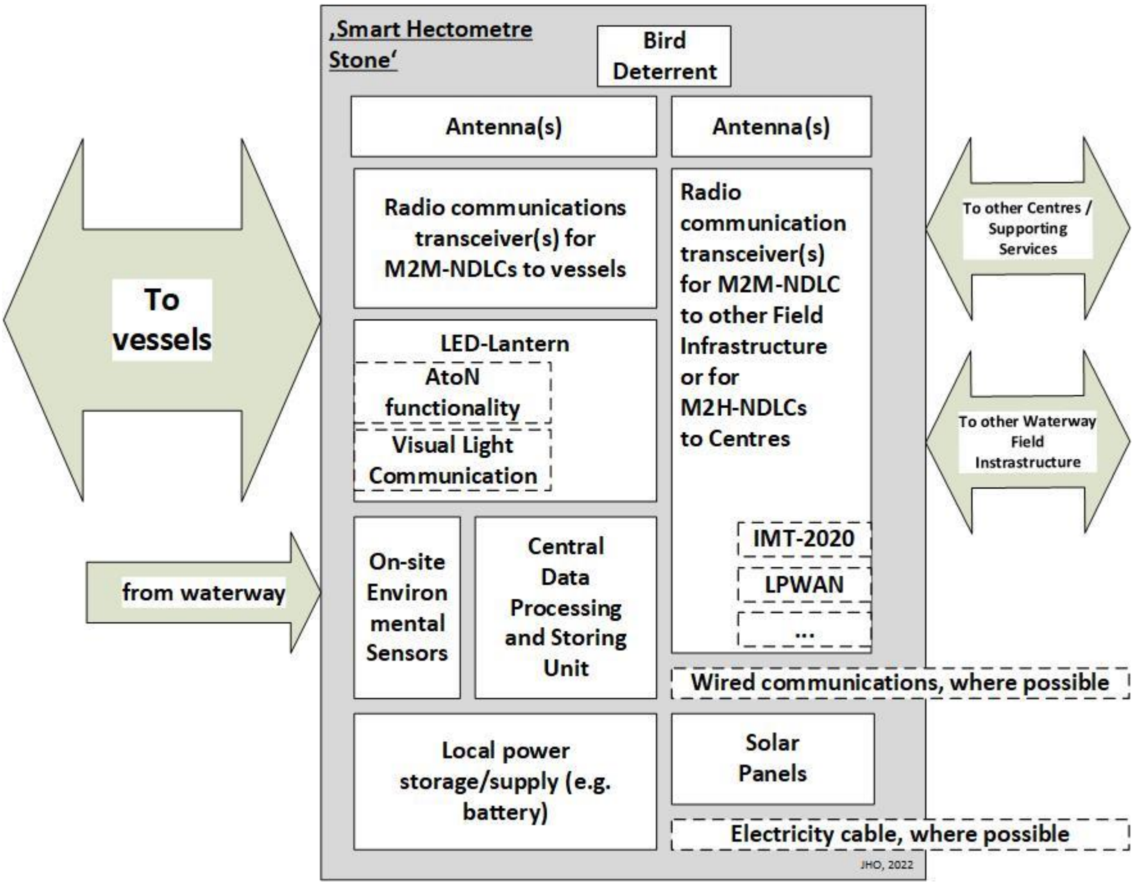

Figure 43: Functional block diagram of a ‘Smart Hectometre Stone’ (Source: own creation)

Legend to above figure:
M2M-NDLC = Machine-to-Machine-Nautical Datalink Communications (compare [14], paras 3.2 and 4.2);
IMT-2020 = International Mobile Telecommunication for 2020 and beyond (aka ‘5G’; compare [16]);
LPWAN = Low Power Wide Area Network (compare [17]).

6.4 Benefits for infrastructure/waterway providers

While deploying the AV-compatible AtoNs along an approach or a waterway may be a considerable investment, it may provide an option to arrive at a **new system or service mix** thus allowing to exploit the trade-off with other Aids-to-Navigation and/or VTS services. In addition, with increasing number of those AV-compatible AtoNs deployed, the potential benefit of **swarm collection of relevant waterway and environmental data** for operation and maintenance of the waterway itself will increase. Such data is gathered by the AVs on the waterway for their own reasons, anyway; to that end, the AV-compatible AtoNs need to have bi-directional radio communications.

7 CONCLUSIONS

From the discussions presented in this paper, it can be concluded that AtoN infrastructure will be needed in the future with increased numbers of AVs, (highly) automated, traditionally operated vessels operating both in coastal waters and in inland waterways. AtoN concepts must be amended compared with the present situation to become **AV-compatible AtoNs**. As one variety of those, the concept of an **AV-adapted AtoN** has been defined, that would be specifically geared towards traditionally operated vessels with mixed intermediate degrees of automation as well as for truly ‘smart’ AVs. Another variety of AV-compatible AtoNs were defined as **AV-supportive AtoNs** for certain applications benefitting from AVs, labelled **AtoN-assisted AVs**, which are dependent on those AV-supportive AtoNs for their navigation. Both AV-compatible AtoN varieties could co-exist. They would be designed to provide direct on-site shore-range data exchange AtoN with AV and vice versa in M2M communication while potentially maintaining a human-readable AtoN functionality to cater for the mixed target fleet. The data communication of both varieties could be done by short-range radio links and/or high-bandwidth visual links; potentially even being adaptive at run-time to different degrees of shipboard automation encountered. The AV-supportive AtoN infrastructure would provide a high-precision trajectory to the AtoN-assisted AV through the approach or waterway, i.e. an 'invisible high-precision vessel track' or 'electronic tow path'.

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S8.2 Preparing for the Future whilst serving the Present - Navigating the Regulatory Framework (178)

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ABSTRACT

The maritime world is going through a period of immense technological change with regards to navigational techniques together with the imminent introduction of autonomous shipping. The current challenge is to prepare for the future whilst still serving the present. Amongst issues to be considered is an assessment of how autonomous shipping can be operated safely and confidently. Once the necessary AtoN features for autonomous shipping have been identified, consideration must be given to how these features would fit in a navigational world as currently populated, with a view to resulting potential conflicts, contradictions or misguidance with AtoN systems as currently in existence. Once the preferred arrangement of AtoNs and associated support systems has been discussed and agreed by consensus, then attention must be given to not only technical feasibility but also the potentially more difficult aspect of negotiating the international regulatory framework that would permit not only installation of such a system but the safe and efficient operation of such a system. The ambition is to identify a global AtoN system that can be used by all classes of marine craft.

KEYWORDS: MASS; autonomous; regulatory; S-100

1 INTRODUCTION

The United Kingdom Hydrographic Office (UKHO) has provided marine geospatial information to mariners to support safe, compliant, and efficient navigation across the world for over 225 years.

Through those centuries navigation techniques and technology have continually evolved and so has the data to support it:

- From lead-line surveys to modern multibeam systems collecting hundreds of data points a second.
- From observing celestial bodies and constellations through the use of sextants to the full global GNSS positioning and timing functionality.
- From the human eyeball with the help of a telescope through RADAR developments to AIS transmissions.
- From the paper chart through first generation electronic charts to the S-100 Universal Hydrographic Data model being developed today.
- From few standards, little regulatory oversight through national regulation to the extensive international regulatory standards that oversee so much of the industry of today.

These are just a few of the many developments affecting the maritime environment, but we are now faced with a further potentially significant change: Maritime Autonomous Surface Ships (MASS).

2 MARTIME NAVIGATION LANDSCAPE

While focussing on the rapid and significant technology advances it is perhaps worth remembering the things that have not changed.

In a technology domain increasingly dominated by accessing a virtual world through synthetic reality, the oceans and seas remain a very physical, challenging, hostile and dynamic environment.

In an age when cyber security and dis-information, such as spoofing AIS or GNSS denial, are ever present threats, it is worth remembering the alleged (and disputed!) activities in the past of the 'wreckers' to extinguish legitimate lights and create false lights for unethical purposes.

Celestial and terrestrial navigation is still the ultimate fallback or contingency illustrated by the fact that the Royal Navy - a technologically advanced 'end-user' - still teaches traditional navigation techniques to its navigators.

Despite the rapid and dramatic technology advances, the vulnerabilities to digital technologies and their uneven implementation across the whole maritime community, means that very physical, static structures such as lighthouses are still a key part of the maritime landscape some 2,300 years after their introduction.

However, it is also evident that maritime navigation has, and continues, to change dramatically and at an increasing rate.

The one constant, through all the changes of the last few centuries, has been that the human has ultimately made the navigation decisions albeit increasingly helped by advancement in sensors, infrastructure, communications, and information.

The possibility of increasingly delegating the decision making to the system, ultimately to the point of removing the human from the process altogether in some instances from some vessels, is the revolutionary change we are faced with.

The drivers for increasing autonomy include:

- Increased safety.
- Increasing shortage of available seafarers to crew ships.
- Targets for de-carbonisation.
- Increased time/cost pressures & greater efficiency.

These are enabled by advances in:

- Digitalisation and the development of multi-function mobile platforms capable of fusing digital information.
- Artificial Intelligence (AI) and Machine Learning (ML).
- Increasing communications reach and bandwidth.
- The development of the e-navigation concept.

But bring the challenges of:

- Implementing technology in a safe and controlled way.
- Managing the different pace of technology change across the world.
- Developing the regulatory framework that is robust, consistent, and applicable to the existing and advancing technology but also flexible enough to cope with the pace of change.
- Providing coherence across national interests but also specific areas of expertise and specialism so that there is an holistic approach to the needs of maritime navigation in the 21st century.

3 REGULATORY CHALLENGES

It is generally recognised across many domains, that technology moves faster and is further advanced than the development of the regulations to enable, control and where necessary constrain their use. In a safety-critical domain this is an important issue and the difficulties encountered in this area may be illustrated by the extensive introduction of Electronic Charting Systems (ECS) over the past decades. The development of the associated standards for Electronic Chart Display and Information Systems (ECDIS), their associated official data standards and their eventual mandatory implementation was a process that took a number of years and had to account for many different offerings and solutions already extant on the market as well as new products.

The need for a robust regulatory framework, without stifling innovation and technical development, is not an easy balancing act.

The development of policy and legislation by various bodies at a national level and then under the overarching international organisations, where consensus must be built across multiple national approaches and interests, can rarely be a quick activity.

The regulatory framework needs to understand the impact and implications of implementing developing technology, but technology implementation is often held back by a restricted ability to test and operate under a restrictive and less flexible legal framework required by safety considerations.

Legislation for MASS is a complex, cross-domain problem space, illustrated by the fact that even consistent terminology and definitions are still under discussion across the international community.

As Maritime Autonomous Systems (MAS) are developed, it is important that the associated requirements and lessons learned are captured and shared globally. This will enable the necessary regulation and services, to safely support autonomous navigation, to be developed in an informed and effective way that meets the need of the technology the industry is developing.

The use of technology demonstrators, testbeds, and trial environments, where innovative design concepts can be flexibly introduced with a minimum of restrictions, would seem to be a key approach. The objective of these should be not only to test technical approaches but, as importantly, identify the requirements, issues and challenges that the regulatory framework needs to address to support the wider, international implementation of this technology.

To that end it is essential that, while elements of these environments may need to be synthetic or controlled, they interact as much and as realistically as possible with the 'real-world' to ensure that a proper assessment of the capability can be evaluated, along with its constraints, risks, and issues.

As these initiatives are done collaboratively across the international stage, they will generate the factual evidence for national members to bring to international bodies to provide the confidence and consensus to support the development of the regulatory framework.

Without this coherent approach there is a danger that the hard won international maritime navigation and safety standards, developed over the previous decades, will become more fractured and inconsistent as different coastal nations, flag states, classification societies and international bodies develop divergent and potentially contradictory approaches to the introduction of emerging technology.

Such an approach mitigates against the risk of developing technology and processes that remove or address one set of errors or inefficiencies merely to introduce another, less well understood set, of potential errors.

4 ENDURING REQUIREMENTS TO SUPPORT CURENT NAVIGATION TECHNIQUES

There is understandably much activity and concentration in preparing for the future in terms of technology, processes, and regulation.

However, more traditional navigation techniques reliant on human decision-making, using physical infrastructure and human-accessible information to maintain situational awareness and inform those decisions, will continue to be required for the foreseeable future for the following reasons:

- Current development paths in the autonomous space envisage continued human involvement to some degree in most of the use cases, whether physically on-board or via remote operations.

- In addition to that there will be classes of user, including those falling into lower regulatory remits (e.g. leisure; fishing) and those for whom the investment of more advanced technology and newer vessels will not be desirable or commercially viable, that will continue to rely on human-optimised methods of navigation. For example, half the fishing fleet of the UK is over 30 years old [1].
- Even in fully autonomous operations, with no human involvement or oversight, visual reference points that can be aligned to synthetic 'digital-twin' datasets are still important components to the navigation system. Traditional AtoN are an important maritime element to this and are likely to remain so as part of an overall navigation solution.

It is clear that an holistic system of navigation, including all of its aids (sensors, infrastructure, communications, information) needs to be devised that safely supports the human decision making process, which may have very limited technology support, as well as the most sophisticated model of autonomous operation.

5 COHERENCE

The 'Internet of Things' is a widely used and reasonably well understood concept allowing efficiency and seamless operation between disparate and previously stand-alone 'things' through defined, standardised protocols. Advances in internet connectivity at sea will increasingly deliver the 'Internet of Things' to vessels.

The various elements and components, that provide safety and effectiveness of navigation, equally need to be brought together in an interconnected and coherent way.

This already happens over significant parts of the domain for example in integrated bridge designs that fuse together information from various sensors. However, it must be equally true in the support systems and organisations involved with safe and effective navigation.

In the UK there are several organisations that work together to deliver the UK's Flag, Port and Coastal State responsibilities. Each maritime organisation has its own history and responsibility:

- Coastal State Responsibility
  - General Lighthouse Authorities (GLA) – deliver the UK's Coastal State responsibility for providing AtoN
    - Trinity House
    - Northern Lights Board
    - Commissioners Irish Lights
  - UK Hydrographic Office – assessment of hydrographic information and provision of navigational products and services (nautical charts & publications etc)
  - Maritime Coastguard Agency (MCA) – Providing Search & Rescue (SAR) coordination and other Coastal State policy including Vessel Traffic Management (VTM)
  - Royal National Lifeboat Institution (RNLI)
- Flag & Port Control
  - MCA – Provide legislation for, and inspection certification of, ships and seafarers. Enforce regulations and promote safety standards in shipping.

To these organisations we could add:

- Classification societies – ensuring vessel quality
- Industry - building vessels, navigation, and communications equipment
- Technology – designing software including AI advances

The challenge is to achieve regulatory harmony and consistency of across this diverse national landscape and then represent that onto the international stage through organisations such as IALA, IHO and IMO.

It is more important than ever that these entities work closely together so that the overall navigation 'solution' provided by the sum of its various parts remains coherent in policy, process, and information.

The cross-cutting nature of autonomy that affects every aspect of the maritime navigation domain reinforces the complexity of managing and regulating this technology. This is illustrated in the way in which the IMO MASS Regulatory Scoping Exercise (RSE) resulting in the IMO MASS Joint Working Group (JWG), the IALA MASS Task Force and the IHO MASS Project Team have been created to look across multiple WGs, activities and instruments in their respective organisations.

As a recognition of this requirement the IHO, under the Universal Hydrographic Data Model, designated S-100, has recognised the need to create coherent data standards across a range of maritime interests that go well beyond the data traditionally found on a nautical chart.

6 IHO S-100 UNIVERSAL DATA MODEL

To address the emerging requirements for hydrographic-related digital data and in recognition of the limitations of the first-generation electronic navigational charts, the IHO began to develop a standard that would provide the basis for a suite of maritime products and services aligned to modern geospatial standards.

Although the S-100 concept was devised before autonomous shipping has the profile that it has today – the first edition of S-100 was published 13 years ago – it is well placed to support the hydrographic data and navigation requirements of technically advanced autonomous systems. This would include the data used on-board vessels, as well as on systems outside of the vessel, to assure and support their safe operation.

As well as overcoming the limitations of the extant S-57 standard and aligning to modern geospatial standards, particular drivers for the S-100 development include:

- Enabling the standards developed under the S-100 framework to be more easily and quickly updated.
- Enable harmonisation and interoperability of data, products, and services across the maritime domain beyond that which would be traditionally found on a nautical chart.
- Enable the integration of more dynamic and time-critical datasets (e.g. real-time tidal information) to enhance the safety and operational effectiveness of maritime operations.

As a result, several maritime organisations are involved in the development of specifications under S-100, as illustrated in Figure 1, below.

Figure 1: Some of the organisations developing S-100 compliant specifications [2]

As with other organisations, IHO has recognised the importance of the emerging autonomous developments and the need for the S-100 standard to support these requirements as well as other navigation scenarios.

In 2021, IHO set up a MASS Project Team (MASS PT), chaired by UKHO, to identify and prioritise MASS navigation requirements and to analyse their impacts on the various S-1xx specifications under development.

While the S-100 standards are designed to be machine-readable and consumable in electronic format, many are still optimised to ultimately be displayed on a screen (i.e. on an Electronic Chart *Display* and Information System – ECDIS) for human interpretation and decision making. Displays are clearly redundant in an uncrewed navigation scenario and, even where navigation crew remain, the ability to push more and more of the routine decision making to computer systems are part of the drive for greater safety and efficiency in navigation.

The IHO MASS PT identified a number of gaps in the current specification development that would need to be addressed to make the data not only machine-readable but also machine-intelligible. As examples:

- Traffic-separation schemes need additional geometry and 'intelligence' encoded so that a computer understands their significance and the specified lane directions.
- Additional geometry and polygons encoded for number of features where the extent of those objects will be obvious to the human eye but not to the computer e.g. the explicit definition of buoyed channels.
- The considerable amount of text-rich information contained in Sailing Directions, chart notes and Radio Navigational Warnings that will need to be re-described in ways that are unambiguous to an autonomous system.
- There is no provision for the standardised encoding of 'Digital-Twin' models which have an important part to play in enabling on-board sensors to match the real-world observations with synthetic data held within their systems.

In addition, even where features have been modelled and adequately attributed, further considerations need to be made in relation to the way they are captured or encoded by a Hydrographic Office. Cartographic techniques have traditionally been used to make information more easily assimilated and understood by a human, such as:

- Scaled or generalised data (e.g. bathymetric contours; coastline; wrecks as point features rather than a polygon extent).
- De-cluttering of information (e.g. a textual note for a wind farm, rather than the position and detailed infrastructure for each element of it).
- Cartographic 'coherence' (e.g. moving a lighthouse so that it is positioned on the edge of a headland or pier).

These techniques are often unnecessary or even inappropriate for a computer and may lead to sub-optimal decisions.

The incorporation of these requirements into the future standards will greatly enhance the safety and effectiveness of autonomous navigation. The UKHO is involved in an experimental project with the Mayflower (the Mayflower vessel crossed the Atlantic in 2022 as an entirely crewless vessel [3]). This involves the use of a number of S-1xx datasets in the Plymouth Sound to simulate different vessel type's ingress and egress to the port. Early feedback has provided the evidence that, even in their current form, S-100-compliant datasets are a significant enhancement to autonomous operations compared to existing S-57 data.

However, with more dynamic updates of specifications and more organisations and maritime domains developing standards, producing data and services and utilising different delivery and transmission technology, there is a risk that, at the point of use on-board a vessel, data becomes incoherent. Diverse datasets that are duplicated, inconsistent, incompatible, or contradictory will not provide either the human or the computer with a helpful scenario on which to base decisions.

This has been recognised by IHO and one of the important initiatives is the S-98 (Data Product Interoperability in S-100 Navigation Systems) development. Although in its current state of development it does not cover the full suite of S-100 specifications it is an important element of the S-100 vision to ensure that the maritime navigation community has a logical and consistent approach to the implementation and delivery of data under the S-100 framework.

Table 1 - S-100 Product Specifications currently covered by the draft S-98

Specification No	Title
S-101	Electronic Navigational Chart (ENC)
S-102	Bathymetric Surface
S-104	Water Level Information for Surface Navigation
S-111	Surface currents
S-129	Under Keel Clearance Management

7 UK TESTBED AND TRIALS

In the UK a number of initiatives and trial areas have been established to drive forward the development, evaluation, testing and understanding of maritime autonomous systems and, for UKHO, to test the application of S-100-compatible data sets, these include Plymouth Smart Sound and the Solent area around Portsmouth and Southampton.

7.1 Plymouth Smart Sound

The Smart Sound has been designated as an area for designing, testing, and developing cutting edge products and services for the marine sector. Included in the initiative are:

- Testing environment and >1,000 sq. kilometres of authorised, de-conflicted water space.
- 5G high speed marine communications network.
- Future Autonomous at Sea Technologies (FAST).
- Interconnected remote operation centres.
- System of Systems capability with interconnected sub-surface, surface & aerial autonomous platforms.

This initiative brings together Government, academia, and industry.

Also in development is the Maritime Autonomy Assurance Testbed (MAAT). This partnership with a number of organisations including Lloyd’s Register and National Physics Laboratory, and in liaison with Singapore, aims to develop the capabilities to test, assure, and validate autonomous technologies with the aspiration to deliver a test and certification approach to assure the safety and reliability of MAS, including remotely operated systems, in the UK and internationally.

7.2 Solent

The area around Southampton and Portsmouth is also an active area of maritime autonomous development and testing. This includes:

- UK National Oceanographic Centre including its Marine Robotics Innovation Centre.
- Solent University Southampton including the Warsash MASS Research Centre.
- Royal Navy and the Defence Science and Technology Laboratory (dstl).
- Industry including, Ocean Infinity, L3 Harris, Atlas Elektronic.

7.3 Maritime Data to Support Trials

UKHO has produced Digital Twin datasets of both the Plymouth Smart Sound and Solent areas to support the development, testing and safe operation of autonomous systems in these areas. In addition, UKHO has supplied trial S-100 data, where the specifications are developed to a mature enough level. This has included S-101, S-102, S-104 and S-111 data sets.

UKHO will continue to identify and support the data requirements, internationally through the IHO and with national initiatives, testbeds, and trials, to ensure that future hydrographic and maritime data standards support the future of both conventional and autonomous maritime navigation.

8 CONCLUSION

MASS is a significant technology development that offers important opportunities, but also poses challenges across the maritime navigation domain. MASS will affect the maritime regulatory framework, the infrastructure, and the information that all contribute towards the safe and effective conduct of maritime navigation.

Establishing collaborative testbeds and other trial and evaluation environments will be key to informing the requirements and issues that need to be addressed by regulation and guidance. These test environments need to be conducted within real-world scenarios to ensure the issues and risks are correctly identified. Collaboration will also be essential between international organisations including IALA and IHO.

Navigation solutions will evolve with varying degrees of automation and technological complexity with respect to human interaction, infrastructure, data, and systems. However, these must exist alongside of, and work effectively with, more traditional and less technologically developed navigation methods for the foreseeable future.

As the technology and systems become more integrated and interdependent, so the supporting elements of regulation, processes and data provision, and the organisations that support these elements, must act in a holistically coherent way. This will remove ambiguity and confusion to the navigator regardless of whether they are human or automated.

The provision of maritime geospatial data continues to be a key element to safety of navigation. The continued development of the S-100 data standard and associated specifications will ensure safe, timely and coherent data can be interpreted by both humans and computer systems effectively to achieve safe and effective navigation.

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Paul has almost 40 years' experience in the hydrographic domain having joined the UK Hydrographic Office (UKHO) in 1984. Over his career he has been involved in the transition from hand-drawn nautical chart compilation, through digital chart production systems, to the design and implementation of the first-generation digital maritime navigation products and services extant today. He has led in the specification of maritime geospatial standards including the development of the NATO S-57 Additional Military Layers (AML) specification and early work on the International Hydrographic Organisation (IHO) S-100 framework.

Other areas of expertise covered during his career are deep-water surveying capability, bathymetric handling techniques and specialist underwater navigation products. Since the beginning of 2023 he has taken up the role of Maritime Autonomous Surface Ships (MASS) Technical Engagement Manager at the UKHO. The role will cohere the UKHO involvement in the maritime autonomous domain. This will ensure the UKHO can enable and support the standards, maritime geospatial data provision and legislative requirements, both nationally and internationally, to make autonomous shipping a safe and effective reality.

S8.3 Coastal authorities and concerns in automatization and autonomous shipping (214)

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ABSTRACT

This paper focuses on Coastal States' administrative concerns in the new situation in which automatization is increasing and the share of human labour is transforming and decreasing. The focus is on Coastal Authorities and not on Flag States.

Administrations have controlling and safeguarding roles. It is their duty to safeguard and ensure safety of navigation around the coastline under their legal system. Sufficient traffic management requires capability and preparedness to interact and to respond to traffic situations. This is related to communication and accessibility. Especially the intelligence-based traffic management - both human and artificial - is an evolving area. For these purposes digitalization is a tool, but it also requires capability to interact and function with others reciprocally. Interoperability is the key issue.

The expansion of autonomy is also strongly tied to the development of international regulation, liability issues and the necessary infrastructure. This has implications for the roles of Coastal States and the development of their legislation. The traditional legal thinking needs re-examination. The coastal states' legislative systems should be ready to respond to situations arising from technical development. It is also questionable whether the traditional indemnity regime can give sufficiently answers for the needs of new technical solutions.

Moreover, liability questions on autonomy have been studied in several presentations and articles, but the focus has been on the ships and shipowners' sides and Coastal States' liability questions need further clarification. The purpose of this paper is to fulfil this loophole.[11]

KEYWORDS: maritime autonomous surface ships, maritime affairs, maritime law, governance, logistic system

1 INTRODUCTION

It is the duty of Coastal States to safeguard and ensure the safety of navigation around the coastline in their respective jurisdictions.[12] This requires not only compliance with international and national standards, but also consideration of the requirements set by practice.[13] Coastal States are responsible for ensuring that the system is functional.[14] When ships are sailing in challenging shallow waters and where traffic is heavy in merchant fairways, the traffic management and safeguarding systems have important roles in preventing collisions and environmental disasters. Increased automatization and autonomous shipping have brought new kind of challenges to Coastal States' authorities when monitoring and managing the traffic on merchant shipping fairways.

Maritime transport is part of the national logistics system, which is an integral part of society at large. Full automatization in one transport mode affects other transport modes. Harbors are hubs for all transport modes and serve as meeting places for fairways, railroads and roads. Development of the transport system, in turn, is an improvement that will have societal implications. Changes in any one of these will influence the others. Realizing the full benefits of automatization would require digitalized unity of all transport modes. This applies especially to adoption of the concept where various forms of transport and services are combined and connected to offer people a comprehensive mobility service (MaaS). However, the benefits that can be achieved from digitalization vary greatly depending on transport mode and the traffic. The maritime operating environment consists of traffic lanes and their infrastructure, means of transport, transport services and traffic

[11] More about the subject: Eronen 2023.
[12] Sutela 2003.
[13] Kurki 2014.
[14] McWilliam – Cooke 2006.

managing systems. They form a network of communication connections and services used by individuals, companies and authorities.[15]

The increasing automatization and the declining human factor set challenges for traditional legal thinking. Reducing the human factor is the right direction for development and increases traffic safety. Question is whether the traditional indemnity regime gives sufficient answers to the needs of Coastal States. Legislation must be developed to meet the new challenges posed by digitalization and automation. The existing laws do not seem to be sufficient or lead to the right results on questions of liability regarding the increased automatization. This applies especially to autonomous operations.

2 NEW CHALLENGES FOR COASTAL STATES

Increased automation and the declining human factor pose challenges for Coastal States as the services provided to maritime transport in the coastal waters are under revision. Basically, the focus is on *how* the interaction takes place, *who* the parties are, *how* traffic monitoring and managing is carried out and *how* to react to dangerous and emergency situations. The development of information and communication technology has increasingly brought real-time connections to the outside world and various electronic information services to support the ships' navigation. In principle, the information provided to the ship is intended to support and help the navigational decisionmaker. As false or conflicting information has the potential to cause confusion or even distract and mislead the decision-maker, the accuracy and timeliness of information have become increasingly relevant. The more the activity and control are out of human hands, the more the system itself is autonomous.[16] This concerns the managing of ships navigating the merchant fairways, but it also sets requirements for the coastal states' traffic management and safeguarding systems.

As Finnish coastline is challenging to navigate, traffic is heavy and ships are sailing on shallow waters and rock bottom twisted fairways, VTS is an important method in managing the traffic, preventing collisions and environmental disasters. The primary task of VTS is to conduct the traffic through merchant fairways in a navigationally and environmentally safe and efficient way.[17] VTS needs to be aware of ships' movements and plans for the purposes of situational awareness. This has introduced new technical challenges. To perform this task, the controlling system must be aware of the movements of the vessels in real time. This is called situational awareness, which means always good knowledge of the ship's surroundings and environment. At shipside it is a significant part of good seamanship.

The VTS surveillance system is a collection of equipment that enable the tracking, identification and monitoring of a ship's position and any other detailed information in manoeuvring and stabilizing the ship's route and course. It is using all available information radar-pictures and ships' AIS-information in forming the graphical situational picture to present real-time navigational circumstances in merchant fairways to achieve and strengthen situational awareness. The sensor network provides information about other vessels in the VTS area as well as weather, ice conditions, water level, operation of pilots and icebreakers, condition and availability of fairways and safety equipment, hazards to the vessel and other factors affecting the safe operation of vessels. The vessel side tracking system is a system that enables marine vessels to track, identify and monitor ship's position, location and any other detailed information in maneuvering and stabilizing ship's route and course. Ships communicate with VTS and other ships by VHF-radio. AIS-system sends on time information about the ship, its position and destination. It has not only made it possible to follow ships, it also has made the situational awareness significant. Safety control must be kept, and the existing mechanisms must be compatible with the new systems to keep the safety standards.

As part of waterway maintenance, the responsibility is to ensure that the AtoNs operate in accordance with regulations plus instructions and subsequently correspond to the information presented in the nautical charts.

[15] Tapaninen 2018

[16] Aawa White Pape.r

[17] Bievre 1985.

This requires baseline design data and management of disturbance data such as AtoN failures, water traffic signal failures, site-related failures, and water traffic disturbances. The above contribute to what is known as "safety of navigation." The development of increased level of automation and the introduction of intelligent solutions does not remove the importance of sufficient physical marking of the waterway. Their task is to mark the fairways and to act as a backup for exceptional situations and extreme conditions to ensure ship safety. There are many objects in the fairway that one practically must drive through before being in safe water area to do, for example, responding to emergencies.

3 COOPERATION BETWEEN SHIPS AND COASTAL AUTHORITIES IS GETTING DEEPER

Digitalization is related to communication and accessibility between ships and authorities. The business models, services and transportation chains are under change. From the administration's point of view, there is a need to identify and anticipate the potential impacts and changes in logistics chains and the development needs and opportunities of these transport systems. VTS and AtoN play a key role in ensuring the safety of the marine environment and maritime transport. This requires new kind of cooperation between authorities and the shipping industry. The new modes of cooperation, the shore-based and remote pilotage as well as plans to deeper cooperation between MRCC, VTS and pilotage are taking first steps on that path. Service ideas based on traffic automation play a significant role in the promotion of digital infrastructure and information sharing with technological solutions.

Digitalized and autonomous shipping is dependent on accurate and up to date safety and safeguarding measures. Successful traffic monitoring and management and supporting services along merchant fairways are based on proper situational awareness.

Autonomous and remotely controlled ships may need the support of completely different AtoNs and their maintenance is nevertheless on the responsibility of the coastal state. Technically VTS and AtoN must be compatible with the communication systems that ships are using when sailing remotely controlled or autonomously. They should be able to inform ships about the prevailing conditions and vessel movements in the fairway. VTS system should cover the different components of communication. It is to ensure that vessels' routes are safe and efficient. There must be a clear interface between AtoN and ships' new electronic device. AtoN must be adapted to conditions and vessel movements. For example, up-to-date weather reports, water level data and a model of the seabed will be transmitted directly to the autonomous or remote navigation systems of vessels approaching an intelligent fairway.

Particularly intelligence-based traffic management is an evolving area and as such it requires a new kind of cooperation between authorities and the shipping industry. The effects of increased digitalization and autonomous shipping for Coastal States should be taken into consideration. International regulations, conventions and agreements need to be studied and legislative action must be taken to avoid unintended consequences. This is natural because the more automatic and remote-controlled the traffic is, the more important and significant the role of control systems are. However, the larger the digitalized system is, the more sensitive and vulnerable it is. This is related to the misuse of digital networks. A major challenge is cybersecurity, which aims to ensure the reliability of the transport environment, and enhancing cybersecurity is essential. The increase in automation (incl. intelligent safety devices) brings security risks, also in the form of cyber-attacks and possible malfunctions. This should be kept in mind when interference tolerance of navigation systems, such as GPS are being developed.

As far as the controlling and safeguarding measures are concerned, Authorities are bound to be able to develop their system to respond to the technological development onboard. In this regard there is a project of *Intelligent Fairway* -project in Finland. This includes the AtoNs of the fairway that respond both the needs of maintenance work and the users of the fairways, digitalized and autonomous ships. In the future this could expand to such data as water flow and level, on-line information about broken AtoNs, status of autonomous and remotely controlled ships. At pilotage sector the legislation has for some years allowed *remote pilotage*.[18] One example of interoperability and how digitalization is used as a tool is that the road ferries are allowed in Finland to use *virtual cable* instead of a physical one.

The traffic management and safeguarding systems play key roles in ensuring the safety of the marine environment and maritime transport. They complement the ships' seaworthiness requirement.[19] This has been considered to include compliance with maritime regulations on a general level.[20] It requires new kind of cooperation between authorities and the shipping industry. The deepening and transforming cooperation as well as the land-based and remote-controlled pilotage are taking first steps on that path. The definition of intelligent fairway and service level requirements are positive from the point of automation needs. This enables an intelligent communication and transport model that combines information describing both digital and physical infrastructure. Developing the dynamism of information and related responsibilities, organizing the introduction of new technology solutions, and intensifying cooperation between different actors in the exchange of information is important.

4 LEGAL THINKING UNDER EVALUATION

The movement of remotely controlled and completely autonomous vessels at coastal waters impose new requirements for the authorities. The traditional causality-based liability regime is dependent on the roles and responsibilities of the different Parties. These mainly relate to communication and accessibility between the ship and the authorities.

The Coastal States' authorities must be up to date and are obliged to participate in all changes to international maritime legislation. However, the remote-controlled ships and especially autonomous ships will certainly alter the traditional liability regime.[21] The more the autonomy is significant, the more important is the question of the level of human attendance.[22] Traditionally there has been an interface that connects a person to a machine, system, or device (HMI). The increased automation and autonomous shipping have brought new kind of challenges for traditional legal thinking as the causality no longer seem sufficiently give answers to liability questions. Product liability offers solutions to many questions but that possibly is not enough.

The liability is very much depending on LOA. The more the activity and control is out from human hands, the more the system itself is autonomous. It is notable that HMI is there until the fully autonomous shipping has been developed and taken place. Coastal Authorities' decision-making process is primarily expected to remain in human hands as due to the principles of good governance, there seems to be barriers to algorithmic based decision-making in public administration.[23] But more decisive is the development of digitalization in the users of the merchant fairways. The Coastal Authorities must be up to date to meet these challenges. It is the administration's task to provide safe and functional infrastructure for traffic as well as ensure safe traffic routes and their maintenance. The administration's liability for accidents and damage at sea is to be reconsidered. The authorities must consider the legal implications if there is a shipping accident caused by their traffic control systems.[24] Subsequently, the concept of AtoN comes under review which inevitably mean to a re-examination of the concept of "maintenance of the fairways".

It has been proposed that new kind of command-centers would be built where VTS were an integral part of ship's navigation control mechanism.[25] The starting point is that VTS works with possible autonomous and

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[18] Which however actually has not been defined nor even exercised yet.
[19] Abdulla 2011.
20 Kurki 2014.
21 CMI Position Paper.
22 Ringbom 2019.
23 Suksi 2018.
24 Hughes 2009.
25 Aawa White Paper.

remote-controlled vessels, as it does today. The task of VTS is to manage the overall picture of traffic, not the control of an individual ships. It is primarily to "*assist Onboard decision-making*".[26] Even though no actual change to this is unlikely to happen, deepening cooperation is ahead. And the deeper the liaison between ship and authority is, the closer is the situation where the control system as VTS is considered to perform services for an individual ship. In such situation it could be argued that VTS would not anymore be a general informative system for all ships sailing in fairways. It would assist a particular ship and its master in the navigational decision-making process. This would reveal the situation to change fundamentally.

In several international conventions, it has been ruled that the ship is responsible for the damage caused by those who perform services for the ship.[27] This may also have a significant impact on liability arising from environmental damage. Coastal States would be held responsible for the waste oil disposal in the case of VTS or AtoNs are contributing to the risk of pollution by an individual ship. The liability for compensation of environmental damage may have relevance in this case. The liability pre-supposes that the work relates to the ship in question and its operations. Of interest in this respect is the case of MT Erika disaster. In the Court decision the liability and channelling were held applied only to persons that work for the ship and participate directly in the ship's maritime activities.[28] The classification society was held liable for the oil spill disaster because it had a direct connection to the ship's condition.[29] Based on the decision, liability is incurred by those who contribute to an increased risk of pollution by failing to meet their obligations. It could be argued that logical consequence would be in case of VTS performed service to an individual ship in its navigational decision-making process, that the ship owners would carry liability pertaining to VTS's action. In such a situation, the liability would be transferred from the Coastal States to the ship owners.

The same is not in case as far as physical AtoNs like buoys and lighthouses are concerned as they are placed at the fairways. They are not service in the same way than VTS, but failure in AtoN's maintenance has the same kind of consequences for liability on environmental damage as VTS. The Coastal State is responsible for damages caused by persons employed by it.[30]

As digitalization increases and ships shift towards autonomy, the Coastal States' legislative systems should be ready to respond to situations arising from technical development. The indemnity regime should be able to reflect new technical solutions and the liability questions need further clarification. Already awareness of liability *per se* has an effect that promotes maritime safety.[31]

5 CONCLUDING REMARKS

This paper is focused on the Coastal States' duties, responsibilities liability questions in the new situation where automatization is altering the traditional roles in shipping. Administrations have controlling and safeguarding role when ships are sailing on merchant fairways. Motivation is to prevent accidents and protect marine environment. In this regard the focus is on VTS, AtoN, PSC and pilotage.

Primarily digitalization itself is a tool to enhance safety and sustainability in shipping. Digitization and automatic data exchange bring public services closer together, speed up decision-making and increase legal certainty and equality in decision-making.[32] Increasing automatization and the declining human factor set challenges for traditional legal thinking. The key issue is LOA. If the traffic is not fully automatic and ships still are under human control, the normal liability rules seem to apply when an accident has occurred.[33] As far as

26 IMO Res A.1158(32).
27 CLC Convention Article III.
28 Jacobsson 2014.
29 Wetterstein 2015
30 Rak – Wretterstein 2011.
31 Abdulla 2011.
32 Pöysti 2018.
33 van Hooydonk 2015.

there is a remote-controlled situation, the vessels controller is generally taken held responsible equally as to onboard captain is held nowadays. Increased automation and autonomous shipping bring new kind of challenges. The existing legislation is under review whether it is sufficient or leads to the right results on questions of liability regarding fully autonomous operations.

It is very important for the administrations to follow and be aware of the new technical requirements that automatization and autonomous shipping set for ships that are sailing at their merchant fairways. Technically the safeguarding and controlling systems need to be compatible with the new communication systems that ships are using when sailing remotely controlled or autonomously. It is vital and very important that the Coastal States are aware and follow the development of international regulations concerning ships' technical requirements. Thus, failure in this may cause liability.

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Matti K Eronen has an LLM degree in maritime law from the Turku University in 1988. He also has run Oslo University Nordic Maritime Institute in 1986. He did court training 1990-91 and Helsinki University EU-expert training 1994. He published research on EU Market Protection Mechanisms at Finnish Lawyers' Association, 1994. He did national expert professional training (NEPT) at EMSA in 2012. Since 2015 he has been a Turku University post graduate doctoral student on subject “VTS liability issues”. He is specialized to transport and maritime legislation and has in-depth experience in handling international administrative matters for more than 30 years. His employment history includes working at private shipping companies as forwarding agent, P&I- and H&M insurance specialist and maritime lawyer. Since 1989 he has worked at the administration, Finnish Maritime Administration as Secretary for international affairs, Deputy director and Chief of legal department. Since 2010 he has worked as legal counsel at the Finnish Transport Infrastructure Agency. He has represented Finland at committees and subcommittees of IMO since 1989. He regularly represents Finland at the Legal Advisory Panel (LaP) of IALA.

S8.4 VTS as information provider to MASS and other maritime stakeholders (041)

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ABSTRACT

The development of maritime automation and digitalization creates different requirements for different actors throughout society. VTS's role as a provider of vessel traffic services and a provider of maritime safety, as well as a provider of maritime situational awareness, will in future require a more diverse information exchange and mediation capability between different actors. In addition, new types of information needs, the use of artificial intelligence (AI) as a situation picture creator and the rapid development of communications also require new ways of working.

Maritime Information eXchange Solution (MIXS) develops technical information exchange and communication solutions, services and information sharing management model. The project will enable intelligent traffic control and situational picture and information services for maritime users. The information can be transmitted to different actors by technical means, however, the production of reliable and verified information takes place in such a way that the information is validated by the measures of the VTS operator. Fintraffic VTS develops both operational activities and tools (eStrip) to create high-quality information and acts as a reliable distributor of information to various maritime actors (MIXS). The technical and operational elements together are required in order to create a functional whole.

(No paper submitted)

AUTHOR BIOGRAPHY

Olli Soininen has worked since 1998 in various positions in the Finnish Navy, where since 2004 he has been responsible for project and development of C2 and surveillance systems as a Chief of Systems development. Olli Soininen has worked as a programme manager in Fintraffic VTS since 2020. He is responsible of company's development and investment projects, project stakeholder activities and international co-operation activities. Olli Soininen has long expertise on VTS-systems, VTS-sensor systems, maritime logistics and maritime single window.

S8.5 The application research and prospect of navigational aids in the trend of Smart Ship (092)

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ABSTRACT

As the important navigation facilities to guarantee the ship to have a safety, economic and convenient sailing, aids to navigation can help ships to voyage, locate and mark navigation obstacles, and can also play an important role in waterborne industry and marine resources exploitation. With the continuous improvement of smart ship, the existing navigation aids technology has been unable to effectively guarantee the navigation safety of autonomous navigation ships. Therefore, this paper analyzes the navigation requirements of autonomous navigation ships in complex navigable waters, such as the situational awareness of navigation, decision and navigation control. Combined with the trend of intelligent navigation aids, the paper studies how to provide navigation assistance services for autonomous navigation ships, and provides the future outlook of intellectualization, dynamic, collaboration for navigation aids.

KEYWORDS: intelligent navigation aids , Smart Ship, autonomous navigation, aided navigation

1 BACKGROUND

The world's first intelligent unmanned autonomous navigation ship "Mayflower 400" , which has attracted much attention, set sail from Plymouth Harbor, England, and arrived outside Plymouth Harbor, Massachusetts, USA on June 30, 2022, completing the history. The revolutionary transatlantic feat, the door of research on long-distance voyage of fully autonomous ships has been opened. It is true that all intelligent unmanned autonomous ships that have completed long-distance voyages so far are small ships without cargo. However, we should be aware that unmanned autonomous ships, as a trend, will inevitably mature and bring revolutionary changes to the shipping industry. As an indispensable and important link for safe navigation of ships, navigation marks should also follow the development trend of intelligent ships and continue to improve. Therefore, it is imperative to think about how to reshape the function of the navigation mark following its subversive changes under the state of autonomous navigation of intelligent ships. Based on the above thinking, the author and his team members consulted a large amount of information, conducted a lot of thinking, summarized the navigation risks of smart ships in complex waters, and tried to give a development path for how to provide navigation aids for smart ships in the state of autonomous navigation.

2 SMART SHIPS AND THEIR NAVIGATION AID REQUIREMENTS IN COMPLEX WATERS

2.1 Introduction to Smart Ships

The smart ship mentioned in this article refers to the Maritime Autonomous Surface Ships (MASS) proposed by the International Maritime Organization (IMO) at the 99th meeting of the Maritime Safety Council (MSC) . IMO divides it into four class according to the degree of autonomy- ships equipped with automatic systems and auxiliary decision-making (class I), remote control ships with crew on board(class II), remote control ships without crew on board (class III) and fully Autonomous ships (class IV) , the discussion in this paper on the development of intelligent navigation aid technology is based on the navigation of class IV MASS.

2.2 Requirements for navigation aids in complex waters

From the setting of MASS, in order to realize the completely autonomous navigation from berth to berth, it is necessary to grasp all the changes in the navigation, including the ship itself and the external conditions, especially when the traffic flow is dense, the hydrology and meteorology are complex, and the competent authority issues for safety reasons. For complex waters with special management requirements, MASS needs to obtain a large amount of information such as its own hull structure, mechanical equipment, algorithm system operation information, ship motion attitude, weather and sea conditions, and traffic flow in the water area in real time, quickly and accurately, so as to make correct decisions. The collision avoidance decision is made to ensure the safety of navigation and ensure the completion of the scheduled route tasks. MASS should also take appropriate and effective emergency measures in case of emergencies. Therefore, in complex waters, MASS can rely on itself to identify some navigation risks and solve them. Its demand for navigation aids is the demand generated by MASS facing the risks that it cannot solve.

Combining the characteristics of complex waters with MASS navigation, the following requirements for navigation aids should be provided when navigating in complex waters.

2.2.1 Testing requirements

According to the current research trend, the route tasks of Class IV MASS will be completely completed by intelligent systems. Although the current industry agrees that when necessary, human intervention should be used to control the ship, but the unmanned nature of MASS means that in the process of fully autonomous navigation, intervention Timing is mainly initiated by MASS in terms of underlying logic judgment. Therefore, when MASS enters complex waters, especially special waters such as ports and waterways, the current operation and maintenance status of MASS needs to be confirmed by the outside world, so that the MASS control system (including remote shore-based control) can confirm whether it is in a normal state.

2.2.2 Scheduled route correction requirements

The "berth-to-berth" fully autonomous navigation mission will be preset when the MASS sails. According to such settings, MASS should have mastered the general information of the entire voyage before sailing. However, according to the implementation of the "voyage plan" of the ships currently in operation, when ships sail to complex waters, there are often deviations in the execution of the ship's planned route due to special circumstances such as wind currents, obstructions, and temporary control by the competent authority. MASS also faces such problems. When navigating to complex waters, there are unpredictable changes in the preset voyage. For MASS, relying on its own data collection and sensing functions, it can solve the changes in the current waters, but it cannot cover a sufficient range. Optimize the follow-up route in the program setting. Accurate wind and current meteorological data, information on navigable waters of obstructions, and temporary management and control by competent authorities are required in a larger area.

2.2.3 Traffic Flow Organization Requirements

In the setting of MASS, there is no concept of fleet, marshalling, or traffic flow organization. However, in complex waters such as ports and narrow waterways, ships need to be marshalled and sailed in a unified manner according to the actual situation at the time. However, most of MASS's discussions on safe navigation focus on the two dimensions of "predetermined route execution and safe collision avoidance", and do not involve discussions on the organization of traffic flow in complex waters, especially when entering and leaving narrow waterways, channels, and when ships are avoiding collisions. Collision avoidance decision adopted and traffic flow, conflicts with special port regulations, etc.

3 AID-TO-NAVIGATION SERVICES ADAPTED TO MASS NAVIGATION IN COMPLEX WATERS

The development of future aid-to-navigation technology aims to solve the navigation aid requirements of MASS in complex waters. Therefore, according to the above three requirements of MASS, the future navigation aid technology should provide the following services.

3.1 Testing and verification services.

It can provide scanning service of hull appearance and structure for ships arriving in a certain range of waters, identify whether the hull has damage and deformation that affect navigation safety, and obtain the status of the ship's navigation attitude; it can detect various key systems of MASS operation, To verify whether the acquired data is correct, whether the equipment, system, program, etc. are normal, including but not limited to data such as vibration amplitude, heading, speed, etc., as well as power system, control system, key data acquisition system, fire protection system, and power control system etc.

3.2 Navigation aid information service

It should be able to autonomously transmit important navigation aid information to the ship. Including the navigation aids information indicated by the existing common navigation marks, such as navigable waters, channel direction, obstructions, etc. It should also be able to transmit hydrometeorological information such as measured wind force, current velocity and direction, wave height and water depth in a certain water area to the ship. In addition, key information such as course, speed, and position of all ships in the water area should be able to be transmitted to the ship, and accident information that has occurred in the water area can also be considered to be transmitted to the ship for its decision-making.

3.3 Navigation assistance service

It should be able to provide navigation decision-making assistance for MASS navigation, so that it can better execute the scheduled route or correct the scheduled route. By providing ship position verification services for ships, it is helpful to verify the implementation of the preset route; by providing advice on avoiding collisions in complex traffic flows, assisting them to navigate safely under the premise of complying with the traffic flow organization; Ships in the water area provide information such as the distance from the berth, ships near the berth, weather and other information, and give suggested course, speed, whether to anchor and wait for berth and other maneuvering actions to guide them to enter the port safely. It should also be able to provide traffic flow organization services according to the overall situation of the current traffic flow in the water area, guide the MASS to the correct course and route, and provide assistance for the navigation safety of the entire water area. In addition, for a malfunctioning MASS, it should also be able to provide it with the navigation method it should adopt, including guiding it to sail to safe waters or waters designated by the competent authority.

3.4 Rules Interpretation Service.

In the future, the navigation mark technology should be able to interpret the mandatory regulations of the local competent authority for certain waters, such as speed limits and navigation regulations in some waterways and waters; temporary restrictive measures taken in severe weather such as typhoons and cold waves, etc., after interpretation Give the ship and give the navigation actions that need to be taken, so that the ship can take navigation actions in a timely and reasonable manner to maintain the order of the entire port.

4 THE REQUIRED CHARACTERISTICS AND FUNCTIONS OF FUTURE NAVIGATION AID TECHNOLOGY

The current aid-to-navigation technology is divided into two types: physical aid-to-navigation (including three subcategories of vision, sound, and radio) and virtual AIS aid-to-navigation. There are many types of physical aids to navigation and complicated settings; virtual AIS aids to aids have the problems of being unable to actively collect information and relying heavily on digitalization, and both of them have the problem of single navigation aid information. Therefore, in order to realize the navigation aid service mentioned above, the future navigation aid technology needs to be intelligent, dynamic, and the characteristics of IoT collaboration and corresponding functions.

4.1 Intelligent features

Adapting to the navigation requirements of the advanced form IV MASS of the development of intelligent ships, the navigation marks must tend to be intelligent. At the same time, in order to avoid the current problem of virtual AIS, the intelligentization of navigation aids does not mean virtualization, but the development of intelligence in the form of physical navigation aids, which have information perception, analysis, decision-making, and interactive functions to meet the needs of navigation aids.

4.1.1 Information perception function

Future beacons of navigation should have the ability to perceive and collect all navigational information in a certain water area where they are located. Part of this perception is active. Certain technologies can be used to realize the intelligent detection of the MASS hull, the operation and maintenance verification of the software, and the overall information perception and collection of hydrometeorological information, ship motion posture, water traffic flow conditions, and accident situations. . Part of it is passive, and information such as mandatory regulations of the competent authority, temporary navigation warnings, traffic control, etc. should be set by the shore-based authoritative competent authority.

4.1.2 Analysis and decision-making function

Future navigation aids should have a certain degree of independent analysis and calculation of data, and the formation of decision-making functions. According to the information collected through active perception, according to the hydrometeorological conditions, obstructions, traffic flow, etc., according to the different ship types, different sizes, different maneuvering characteristics, different positions, and different navigation aid requirements, targeted navigation aid information is formed . At the same time, based on the collected information, it is also necessary to form a decision-making suggestion on whether to adopt interim control measures for the reference of the competent authority.

4.1.3 Information Interaction

The above two functions are based on the need for navigation aids to have information interaction capabilities. The information interaction of navigation aids should be two-way. Realize two-way information interaction with the ship, collect ship equipment operation and maintenance data to complete verification, and broadcast navigation aid information to assist navigation; realize two-way information interaction with the shore, transmit the collected navigation element information and formed decision-making suggestions, and receive the information set by the shore. Compulsory measures, temporary control and other information.

4.2 Features of IoT collaboration

In the process of intelligent development of the navigation aid entity in the future, in order to solve the problems of the existing physical navigation aid, it should be coordinated by the Internet of Things. Specifically reflected in two aspects of unified standards and information sharing.

4.2.1 Unification of standards

Future buoys can collect and broadcast all navigation-aided information, and there is no situation where the crew can recognize the buoy visually or audibly. Therefore, there is no need to set up complicated and complicated buoys such as the current "azimuth" and "forbidden buoy". The unified performance standards, functional standards, and technical standards set the navigation mark to realize the "one standard for multiple purposes" of the navigation mark, and a small number of navigation marks can be set in a wide range of waters to solve the problem of large number and miscellaneous types of navigation marks in complex waters.

4.2.2 Interconnection.

In the future, the navigation aids should not be independent and not communicate with each other. Instead, all navigation aids in a wider water area should be able to share information and communicate with each other to form a navigation aid network. For example, when a buoy starts to provide navigation assistance services for a certain ship, all information of the ship can be shared with all buoys in the water area. When the subsequent buoy interacts with the ship, it can reduce problems such as hull condition, system operation and maintenance, etc. The acquisition of information such as the situation and preset routes can avoid repeated information acquisition during interaction.

4.3 Dynamic characteristics.

As we all know, the existing physical buoys are fixed, unable to move and update information. Although the virtual buoys are easy to set up and compare prices, they also have the problem of being unable to move and update information independently to some extent. The development of future navigation aid technology should enable navigation aids to independently adjust their positions and functions within a certain permitted range according to the different environments at the time while possessing intelligent features. For example, when an emergency such as a collision accident occurs in a certain water area, the navigation mark with a closer distance can temporarily transfer its own information collection and navigation assistance functions to other nearby intelligent navigation marks on the basis of fully realizing the related functions of intelligence and IoT collaboration. Instead, more functions, energy, and time are devoted to cooperating with the competent authorities in dealing with emergencies and searching and rescuing people who fell into the water.

5 UNRESOLVED ISSUES

5.1 Information interaction requirements cannot be met

The information interaction between smart navigation marks and between smart navigation marks and smart ships mentioned in this paper involves navigation environment information, static and dynamic information of ships, navigation aid information, etc. The particularity of information transmission requires high precision, low latency, and full coverage. Neither VDES technology nor BeiDou satellite-based technology can meet the requirements of existing technologies, and 5G technology is also difficult to achieve full coverage of base stations due to the special environment at sea. Therefore, the primary difficulty in realizing intelligent navigation aids is the breakthrough of communication technology. At the same time, after the information exchange is realized at the technical level, the formulation of a unified information exchange standard protocol between all ships and navigation marks in the world is also a problem that cannot be ignored.

5.2 The legal position is not clear

5.2.1 The legal positioning of intelligent navigation marks

Navigation-aiding function level the navigation - aiding function of intelligent navigation mark mentioned in this paper involves in-depth information interaction with intelligent ships, including ship type characteristics, steering equipment, active power equipment, navigation equipment and a large number of navigation manipulation data and preset routes. And it is necessary to obtain, compare, and correct the above data, and provide functions related to ship navigation such as collision avoidance decisions and recommended navigation methods. However, there is currently no relevant convention on whether navigation aids have such powers or should be endowed with such powers, the law shall be clarified.

5.2.2 Boundary definition of smart navigation aids and smart VTS development

The functions of intelligent navigation aids described in this article include traffic flow organization, restrictions on mandatory measures, decision-making suggestions for emergency response, etc., and the above-mentioned functions and responsibilities are currently undertaken by the VTS of each port authority. In the follow-up period of the intelligent development of VTS , the difference between VTS and navigation aids, and how to divide the boundaries of them are issues that need to be addressed in the overall development of smart ships, when VTS also realizes unmanned autonomy.

6 EPILOGUE

600 years ago, when Zheng He of China's Ming Dynasty led his fleet to go far, maybe he never expected that the current ships can be so large and intensive. Similarly, when intelligent shipping is highly developed in the future, we may also lament that shipping is actually a Such a scene. In order to realize such an ideal, the development of intelligent navigation aid technology must be more intelligent, dynamic, and collaborative, and there must be more innovations and breakthroughs on this basis. It is hoped that the team's thinking on smart navigation aid technology can provide some inspiration for the future development of smart navigation aid technology.

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S108.1 Implementation and Pilot Operation of standard AtoN Management System in Korea (185)

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ABSTRACT

An AtoN (Aids to Navigation) management system monitors and controls the status of AtoNs using various communication networks such as VHF, CDMA and LTE to provide information to the operator when abnormal conditions occur. Currently, the regional offices of the Ministry of Oceans and Fisheries in Korea have been operating these systems, but it is difficult to integrally manages them because they have been independently developed and operated. Therefore, an AtoN management system applying a standardized protocol has been developed in Korea, from 2017 to 2020. The system was piloted in three regions in Korea from 2020 to 2021. User feedback was collected during the pilot operation phase, and it was reflected when stabilizing the system. The Ministry of Oceans and Fisheries plans to distribute the software to another 10 regions in Korea by 2023. When the software has been distributed to all regional offices in Korea, data on AtoN and marine weather will be collected and managed integrally at the central monitoring site. The integrated data will be able to be utilized when introducing MASS and e-Navigation in the future. This paper introduces the standardization and dissemination of the AtoN management system in Republic of Korea.

KEYWORDS: Dissemination of standardized AtoN management system, central monitoring site operation, nationwide services, server expansion and duplexing, utilization of idle information resources from regional government offices.

1 INTRODUCTION

AtoN management system is a system that can collect, manage, and monitor status information collected from AtoNs in real time using various communication networks by installing server systems and monitoring software on shore [1]. The system provides accurate and detailed information on the electrical, physical and communication status of each AtoN, which may increase the efficiency and safety of AtoN-related tasks. In addition, by quickly identifying the status of faulty or damaged AtoN-related equipment and supplies to be repaired, it contributes to the prevention of marine accidents and the improvement of navigational safety [2]. For efficient AtoN management, each regional government office in Korea has developed and operated an AtoN management system.

Nevertheless, with the individual method of developing and operating AtoN management system by each regional government office, it had been difficult to integrate AtoN information management due to a lack of compatibility with the data structure. Additionally, there was a problem in that redundant facility investment and maintenance costs was higher due to the establishment and operation of server systems for each region.

In this study, the standardization of the system was taken into consideration to solve various problems of the existing regional government AtoN management system. For this purpose, a related system that could manage the entire AtoN information at the central monitoring site was established. In other words, after the information on the entire AtoNs that needs to be managed was collected by the server system of the central monitoring site, it could then be transmitted to the regional government office system. In this process, works were carried out to standardize the data transmission specifications, the database, etc. [3]. With the standardization of data structures, the user interface of monitoring software operated by regional government offices have been unified, and the integrated management of AtoN information has been made possible. In addition, regional governments can now monitor AtoNs by installing AtoN monitoring software on a simple desktop computer, which eliminates the need for maintenance on the existing server systems.

In this paper, the existing AtoN management system in Republic of Korea and its problems are introduced, as well as the standardization process of the AtoN management system in Republic of Korea. The paper also elaborates the plans to disseminate and improve the system to regional government offices.

2 EXISTING ATON MANAGEMENT SYSTEM

Previously, regional offices of the Ministry of Oceans and Fisheries in Republic of Korea have individually developed and operated AtoN management system to manage AtoNs within their jurisdiction. AIS AtoN Station's monitoring message bypassed the central monitoring site and was transmitted to the regional government office. The transmitted AIS message was then processed by the regional office's data collection server and stored in the regional office's database server. However, in the case of AtoN that is equipped with Remote Terminal Units (RTUs) that transmit status information using commercial communication services such as LTE, the regional office had to collect it directly, load it into the database, and send it periodically to the central monitoring site's database. As a result, it was necessary to build a separate database server, data collection server, monitoring PC, and security equipment to establish the AtoN management system in each regional office, and maintenance costs were incurred for this. In addition, the regional government offices operated the AtoN management system using the AtoN information stored in the database of the regional government office, so when an AtoN is added or changed in the jurisdiction, the information is reflected only in the database of that respective regional government. If the central monitoring site needs the updated AtoN information from the regional government, it had to be added or changed separately using the central's system. Figure 1 shows the configuration diagram of the existing AtoN management system.

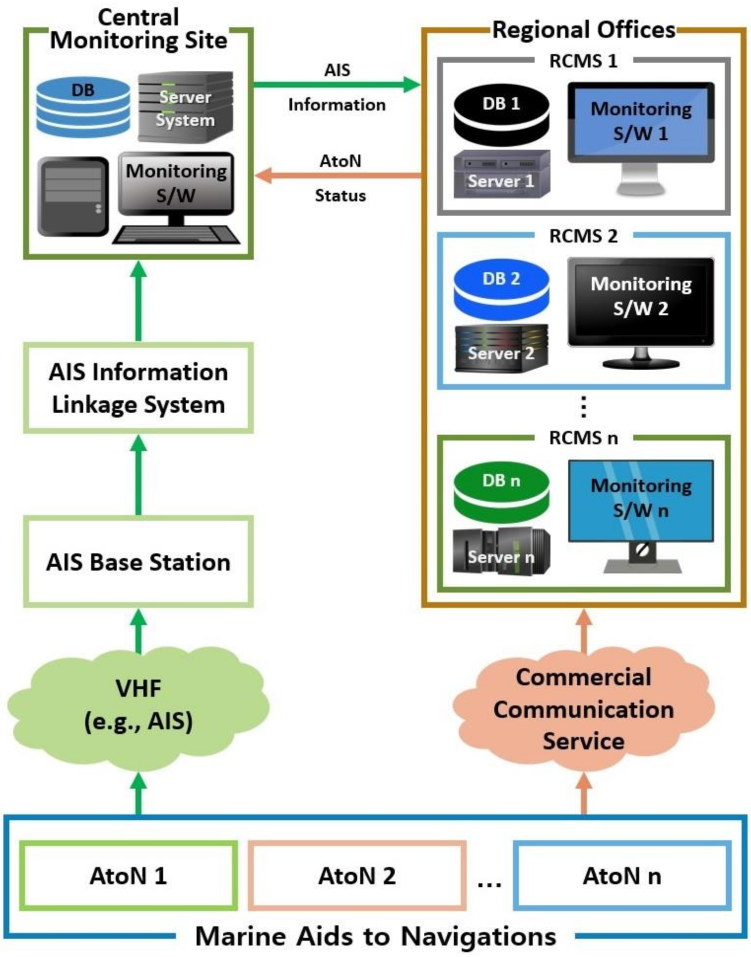

Figure 1. Configuration diagram of the existing AtoN management system

3 STANDARDIZATION OF ATON MANAGEMENT SYSTEM

The existing AtoN management system of regional government offices had various problems. For example, there were excessive network traffic, difficulties in linking the system to the central monitoring site due to different protocols and database structures for each regional office, and maintenance costs incurred for each of the regional office system. Hence, to solve this problem, a standardized AtoN management system was developed in this study to integrate and systematize AtoN information. Through this, the standardization of the AtoN management system was established by integrating and unifying the server system, protocols, and user interfaces.

Not only does the standardized system resolve the problems of the previous system, but it also provides additional functions. For example, it provides a user-friendly interface that can easily search and modify AtoN information. Furthermore, the modified AtoN information can be updated in the database of the central monitoring site in real time, to keep the AtoN information up to date.

With these new functions and solution to the existing problems, the standardized AtoN management system has enabled regional governments to manage AtoN information more efficiently. Moreover, the application of these standardized systems can increase the efficiency of AtoN information management nationwide.

3.1 System Integration

Both the database server and the data collection server were installed in the central monitoring site. AtoN status information is then collected from the central monitoring site and loaded into the central's database, whether using VHF (e.g., AIS) or cellular communications.

The central monitoring site system consists of a database server and data collection servers. The data collection servers itself consist of AIS Gateway, Data Collection Gateway, Database Gateway, and Service Gateway. The AIS Gateway delivers AIS information collected from AtoN AIS to Database Gateway and Service Gateway. The corresponding AIS Information includes information on AIS-equipped vessels as well as the AtoN status. The Data Collection Gateway collects AtoN Status Information transmitted through commercial communication service and delivers it to the Database Gateway and Service Gateway. The Database Gateway loads the received AIS Information and AtoN Status to the Database Server. Finally, the Service Gateway transmits information about AtoN Status and AIS-equipped vessels to regional government monitoring software in real time over the Internet. The configuration diagram of the standardized AtoN management system is shown in Figure 2.

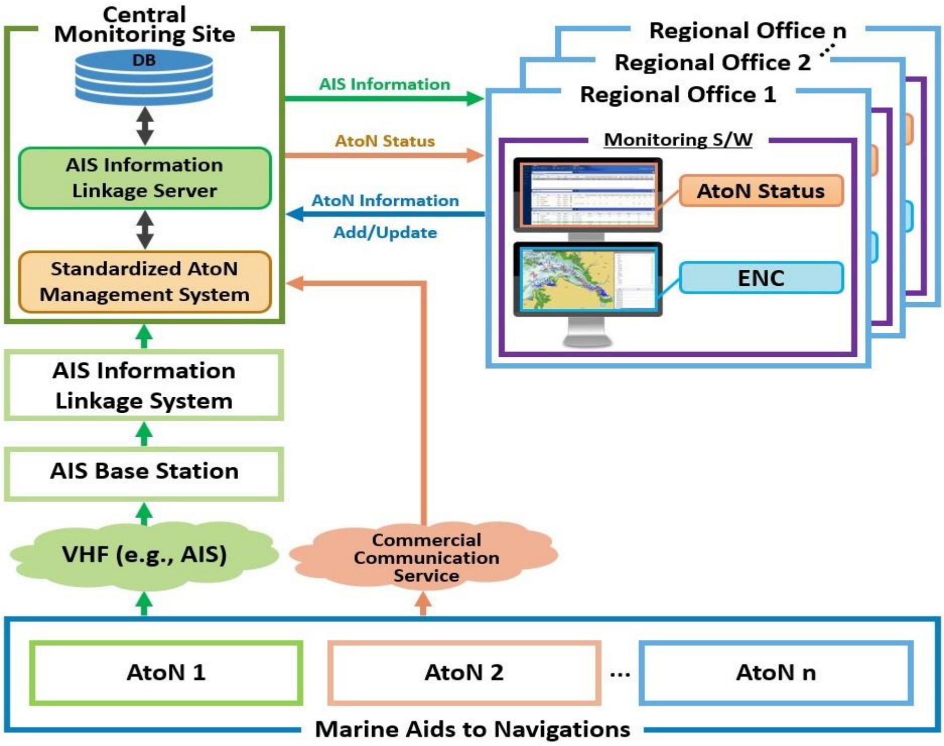

Figure 2: Configuration diagram of the standardized AtoN management system

Instead of a server system for AtoN management, regional governments only require a simple desktop computer and displays, with AtoN monitoring software installed on the PC. In the case of a modification of the information of an AtoN within the jurisdiction of the regional government office, i.e., setting up new AtoN, relocation of AtoN, and removal of AtoN, it would be reflected in the database of the central monitoring site in real time as soon as the information is entered.

In terms of data protection, the central monitoring site and each regional office are connected to each other using a secured transmission channel, e.g., a virtual private network (VPN).

3.2 Protocol Standardization

As a result of the research while conducting this study, it is discovered that various manufacturers have been developing remote terminal units for AtoN. However, since the protocols used by each manufacturer were different, standardization was required. Accordingly, the protocols developed and used by each manufacturer were integrated, organized, and standardized.

By using an integrated protocol, the database structure storing AtoN status information could also be standardized. The database is designed as a structure that can apply S-201 (Aids to Navigation Information) product specification [4]. By standardizing the protocol of the RTUs, the interoperability between systems can be improved and the system management efficiency can be increased.

Figure 3 shows the packet structure of a message transmission of a remote terminal unit using cellular communications. In addition, Table 1 shows the examples of using the function code used in the corresponding remote terminal unit.

Header				Body		
Flow Control	Device ID	Function Code	Encrypted Data	Data Length	Device ID	Encryption Checksum
1 Byte	7 Byte	1 Byte	16 Byte	1 Byte	7 Byte	1 Byte

Figure 3: Packet structure using cellular communications

Table 1. Example of using a function code with cellular communications

Function Code	Protocol Format Category	Intended Use
0x32	Meteorological and Hydrographic Data	Transmission of Meteorological and Hydrographic Data
0x33	Status Information	Transmission of AtoN Status Information

3.3 Monitoring Software

The monitoring software developed in this study is mainly composed of central monitoring site software and regional government client software. The software for the central monitoring site shows the server operation status of the standardized AtoN management system and the access status of AtoNs by regional offices. The server operation status UI helps the administrators figure out resource usage and usage trends of each server, network connection, and service operation. Furthermore, by using the AtoN access status UI for each regional office, the administrators can determine whether regional office clients are connected, figure out basic information on AtoNs for each regional office, and figure out the network connection status. Figure 4 shows an example of the user interface of the software for the central monitoring site.

The regional government client software consists of AtoN Status Information management software and Electronic Navigational Charts (ENC) based monitoring software. The AtoN Status Information management software provides the function to monitor and manage the electrical, physical, and communication status of AtoN within the jurisdiction of the regional government. The software's management information also includes meteorological and hydrographic data [5]. This software displays a list of all AtoNs within the jurisdiction of the regional government office on the home screen, and it also provides related alarm function. The alarm function alerts for a list of communication failures and abnormal AtoN in chronological order. The alert content consists of the basic information of the relevant AtoN, the time of occurrence of the failure, the location, and the description of the failure. This software also provides a history lookup function to display information about AtoN Status Information in a list or time series graph. Moreover, by providing a function to modify AtoN information, administrators at the regional office can easily modify the information, and the modified AtoN information would be reflected in the database of the central monitoring site in real time. Modifiable information includes not only basic information such as AtoN name and AtoN location, but also the setting up and removal of AtoN, and the equipment information mounted on the AtoN as well. Other features such as bookmarks are provided to enhance user convenience. Figure 5 shows an example of the user interface of the AtoN Status Information management software.

Figure 4: Example of the software for the central monitoring site user interface

Figure 5: Example of AtoN Status information management software user interface

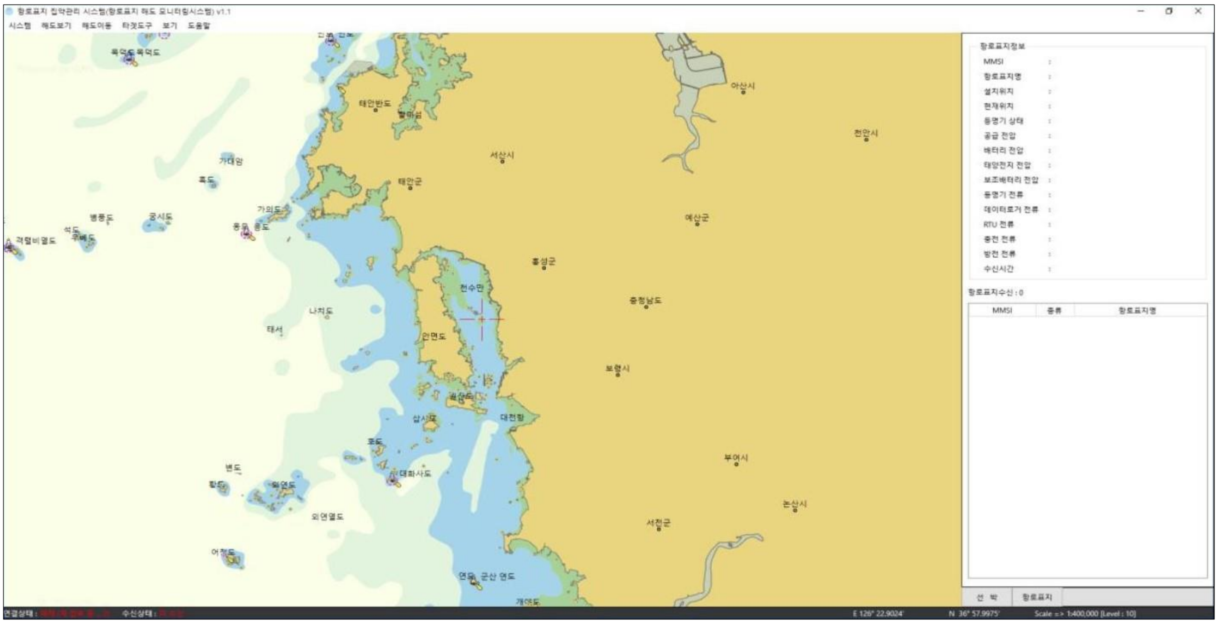

Figure 6: Example of ENC-based monitoring software user interface

ENC-based monitoring software was developed with the consideration of the flexibility and scalability of the ENC. The ENC engine was developed in the form of a shared library and designed so that users can easily upgrade it. In addition, it was implemented in anticipation for the application of S-52 (Presentation Library), S-201 (Aids to Navigation Information), S-124 (Navigational Warnings), and S-125 (Marine Navigational Services) product specifications. The regional administrators can view and monitor information about AIS-equipped vessels as well as AtoN on the ENC. Figure 6 shows an example of the user interface of the ENS-based monitoring software.

4 PILOT OPERATION AND DISSEMINATION

From 2020 to 2021, three South Korean regional government offices, i.e., Daesan, Busan, and Gunsan, have installed and operated the standardized AtoN management system on a pilot basis. During this period, some problems were identified, and improvement were made by operating in parallel with the existing system. The central monitoring site configured the system by dividing it into internal network and external network, according to the security policy. Furthermore, by configuring data collection and service servers for each region, it is prepared for nationwide area services and distribution of the load on the servers. The user interface has also been improved. Previously, separate software was developed for meteorological and hydrographic data, but it was improved by integrating it with AtoN Status Information monitoring software.

In 2022, the standardized AtoN management system was introduced to four other regional government offices in Republic of Korea, i.e., Mokpo, Incheon, Pyeongtaek, and Jindo. The regional government's AtoN database was customized to suit the standardized system and to be applied to the central monitoring site's database. Additionally, client software was installed on systems operated by regional government offices in those four regions and an operator training was conducted.

User feedback was collected from administrators of the central monitoring site and the seven regional offices that were introduced with the standardized AtoN management system. Improvement was made addressing to the approximately 66% of about 50 feedbacks collected by the second half of 2022, and the updates were distributed to each regional office. Furthermore, efforts were made to resolve user inconvenience by receiving software errors and improvement demands continuously.

5 FUTURE DISSEMINATION AND SYSTEM IMPROVEMENT PLANS

In 2023, the dissemination of the standardized AtoN management system to the remaining six regional government offices in Republic of Korea and operator trainings were planned. When the dissemination of the system is completed, it is expected that integrated management and monitoring will be possible for approximately 1,300 AtoNs nationwide. Table 2 below shows the dissemination plan of the standardized AtoN management system in 2023.

Table 2. Standardized AtoN management system dissemination plan (2023)

Category	Name of Regional Office	2023					
		May	Jun	Jul	Aug	Sep	Oct
System Dissemination	Yeosu						
	Pohang						
	Donghae						
	Jeju						
	Masan						
	Ulsan						
Software Improvements	All						

After the dissemination of the standardized AtoN management system is completed, expansion and duplexing of the central monitoring site system may be required. Accordingly, it would be necessary to expand the database capacity, add data collection servers for each region, and duplex the server systems. Since regional government offices only need a simple desktop computer, transferring the existing database server and data collection server to the central monitoring site and utilizing it for server duplication can also be a cost-saving measure.

Furthermore, user interface improvement promotion is planned, and continuous user feedback collection would be done to improve usability, for example, the addition of the vessel tracking function and the improvement of the software for the central monitoring site.

6 CONCLUSION

AtoN management system is a system that monitors and manages AtoNs through a combination of various communication networks. Regional government offices in Republic of Korea have individually developed and operated these AtoN management systems. As a result, AtoNs could not be managed in an integrated manner, and the maintenance costs were incurred for each of the system operated individually by regional government offices.

To solve these problems, a standardization of the AtoN management system was carried out in this study. System integration into the central monitoring site, as well as standardization for data transmission protocols and database structures have been accomplished. While standardizing the AtoN management system, the same data structure could be used, and accordingly, the same user interface could be applied to regional government office client software.

As the development of the standardized AtoN management system have been completed, the system was installed as pilot project and was operated at three regional government offices from 2020 to 2021. In that process, system stabilization and improvement were achieved. The dissemination of the standardized system was started in 2022 for four regional government offices, and it would be completed with the remaining six regional government offices in 2023. When the dissemination is completed, integrated management and monitoring for approximately 1,300 AtoN would be made possible. While carrying out the dissemination of the standardized AtoN management system in 2023, additional system improvement work is planned to be done. In the future, the standardized AtoN management system would enable more stable operation through the expansion and duplication of the central monitoring site' system.

7 ACKNOWLEDGEMENTS

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Jonghyun Park received the B.S. and M.S. degrees in electrical and computer engineering from Sungkyunkwan University, Suwon, Korea, in 2006 and 2008, respectively. Since 2020, he has been with AtoN R&D Center, Korea Institute of Aids to Navigation, Korea, as a researcher. His research interests include remote control and monitoring systems (RCMS), digital twin technology, mobile user experience design, and embedded systems.

Index by Conference paper number (paper no. in parentheses)