**Working Paper**

**Draft text on digital communication technologies, information services and e-navigation matters**

**For the 2022 Edition of the IALA NAVGUIDE**

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# Digital communication technologies

The global community has an expectation to be ‘connected’ at all times and in all places. We use digital communications to work, connect with friends and family and be entertained (by games, on-demand television programs, streaming video and more). Technology continues to develop rapidly, often without us even understanding the full extent of what the technology can do for us.

Over the years, digital communications have been introduced in the maritime environment. As technology advances, the previous limitations of transmission range, bandwidth, data speed and costs are slowly and steadily being overcome.

## IALA ‘s Maritime Radio Communications Plan

The first IALA Maritime Radio Communications Plan (MRCP) was issued in December 2009. Its focus was to identify expectations for the future use of maritime radio spectrum. The plan was visionary and highlighted the development of digital data exchange to support maritime operations. Now in its third edition, the MRCP continues to provide a future view for the use of maritime communications by aids to navigation (AtoN) authorities. It highlights the status of radio spectrum available for use in the maritime mobile service and incorporates relevant results of the recent International Telecommunication Union (ITU) activities, including the outcomes of the World Radio Conferences (WRC).

During the 2018-2022 work term, the IALA MRCP was revised to align with the new IALA documentation structure. The updated content is now provided in IALA Recommendation R #### and IALA Guideline G #### [include links].

## Automatic Identification System

Automatic Identification System (AIS) was designed as a ship-to-ship collision avoidance system and a VTS tool. It operates in the VHF maritime mobile band. AIS also allows for the exchange of safety-related data between ships, and between ship and shore.

There are many types of AIS devices, known as ‘stations’, which are each identified by a unique Maritime Mobile Service Identity (MMSI). These include AIS for Aids to Navigation (AIS AtoN), AIS on search and rescue aircraft and AIS search and rescue transmitters (EPIRB-AIS, AIS-SART and AIS-MOB). They all use the AIS international open (unencrypted) standard to exchange data.

AIS enables the automatic exchange of shipboard data from vessel sensors (dynamic data), as well as manually entered static and voyage related data. Data is exchanged between ships and between a ship and shore station using terrestrial or satellite communications. AIS has been mandated as a shipboard carriage requirement for ships under Chapter V of the International Convention for the Safety of Life at Sea, 1974 (as amended) (SOLAS 74), section 19.2.4. In addition, some administrations require AIS carriage on non-SOLAS vessels. The main benefits of AIS are below:

* Data exchange, such as identity, position and course and speed, between ships within VHF range of each other, increasing situational awareness;
* Data exchange between a ship and shore authority, such as a VTS, to improve traffic management in waterways, coastal and remote areas, where AIS is sometimes the only mean to exchange data;
* Automatic reporting in areas of mandatory and voluntary reporting; and
* Exchange of safety related information between ships and between ships and shore station(s).

The development of AIS has expanded to include devices such as AIS for Aids to Navigation (AIS AtoN), AIS on search and rescue aircraft and AIS search and rescue transmitters (EPIRB-AIS, AIS-SART and AIS-MOB). The success of AIS has led to its solid growth over the last five years, raising concerns over the reliability of the system, as it becomes overloaded. Therefore, the International Maritime Organization issued Resolution MSC.347 (91) Annex 15 for the protection of AIS. This concern was also the driving factor for the development of the VHF Data Exchange System (VDES), discussed in the next section.

IALA Guideline 1082 provides a comprehensive overview of AIS and has an extensive list of all AIS-related documents from various international organizations (Annex E).

The technical characteristics of AIS are in latest version of Recommendation ITU-R M. 1371.

## VHF Data Exchange System

The VHF Data Exchange System (VDES) is a radio communication system, which operates in the VHF maritime mobile band. The VDES comprises of four related sub-systems:

1. Automatic Identification System (AIS) (already described in the previous section);

2- Two frequencies used for Application Specific Messages (ASM);

3- The terrestrial component of the VHF Data Exchange (VDE-TER) and;

4- The satellite component of the VHF Data Exchange (VDE-SAT).

The sections below provide a short introduction to each sub-system. There are three IALA guidance documents that provide additional information on VDES and its sub-systems.

- G1117: VHF Data Exchange System (VDES) Overview

- R1007: The VHF Data Exchange System (VDES) for Shore Infrastructure

- G1139: The Technical Specification of VDES

Additionally, these ITU documents also provide important technical information for VDES:

- ITU-R M.2092-0, Technical characteristics for a VHF data exchange system in the VHF maritime mobile band.

- Report ITU-R M.2231-1 (11/2014) Use of Appendix 18 to the Radio Regulations for the maritime mobile service

***Figure: VDES frequencies***



*Below provided by JCJ – should we retain / edit / delete ?*

*The VHF marine band (Radio Regulations Appendix 18) was initially used for transmission of voice communications on 25 kHz channels. The ITU introduced the first marine data transmission system, DSC (Digital Selective Calling) to help ensure that calling and distress communications attempts were successful. VHF DSC transmits data at 1.2 kbps, which is quite slow by modern data exchange standards, but is very robust.*

*As experience (and use of) with digital data grew, the ITU, at the request of the IMO to improve safety of navigation, approved the use of two additional frequencies in the Maritime Mobile Band to transmit data in support of the Automatic Identification System (AIS). These transmissions were at a high data rate of 9.6 kbps. The new frequencies support exchange of data ship to ship, ship to shore and in support of aids to navigation (AtoN) and search and rescue (SAR).*

*Building on the experience gained through the introduction of AIS, and noting the increasing use of AIS that was leading to overloading of the AIS in some parts of the world, IALA proposed the introduction of additional spectrum to support data exchange in the VHF maritime mobile band.*

### Why does VDES include AIS?

VDES comprises a suite of channels in the VHF maritime mobile band, and forms a contiguous block of frequencies that includes both international AIS frequencies, as shown in the figure above.

For this reason, the VDES was designed to simplify radio equipment complexity, allowing a single “smart” radio box to perform all VDES functions, including AIS.

Anchored in VDES design is the protection of AIS and the situational awareness it provides to mariners and shore authorities. As such, all AIS functions are a part of VDES, just as they would be available on an independent AIS device.

In principle, a VDES unit could replace AIS equipment (because it is part of the VDES) by using the same antenna, power and connectivity. For shore authorities, to make use of the full capabilities of VDES, enhancements to the infrastructure may be necessary.

### Application Specific Message component of VDE

The Application Specific Message (ASM) component of VDES uses 2 channels (ASM1 and ASM2).

The purpose of ASM is to reduce traffic not relevant to collision avoidance on the AIS channels. The separate ASM channels allow for the growing use of data messages.

Examples of ASM data that are currently carried over AIS frequencies include meteorological / hydrological data, waterways obstructions, recommended routes, etc. The ASM channels use a more efficient signal modulation than the original AIS frequencies, which allows for more data, almost twice, to be carried in the same time slot/frame.

Existing messages can simply be reused on ASM or VDE channels.

IALA maintains a list of all available AIS messages that have been created and are used across the world for ASM purposes. The list can be found on the IALA website at <https://www.iala-aism.org/asm/>. Proposed ASMs can also be registered at the site.

### VDE-TER component of VDES

The purpose of the VDE-TER component is to provide a communication system capable of supporting e-Navigation growing requirements for ships within VHF range (approx. 40 to 60 km). It is expected ASM will not be able to meet the native transfer requirements of the S-100 suite (S-1xx, S-2xx, S-4xx, etc.) of data products. As S-100-based product specifications develop, they will need a communication system with expanded capacity to carry this information to and from ships in waterways and coastal areas. VDE-TER aims to fill this gap.

VDE-TER uses 4 duplex channels to achieve 100khz of bandwidth available to carry data from ship-to-ship, shore-to-ship and ship-to-shore. The maximum total capacity of the channel is approximately 230kbps that is divided amongst the users (ship or shore stations) of the system in a specific area. For example, there could be one shore station and 5 ships using VDE-TER simultaneously to exchange data, each getting about 38kbps of throughput.

VDE-TER provides much more capacity than AIS and ASM, but it is still an order of magnitude slower than other commercial communication systems, such as cellular 3G/4G/5G. This limitation will require VDES to be carefully managed by shore authorities, to make sure priority is given to safety related data.

### VDE-SAT component of VDES

VDE-SAT is envisioned to be the equivalent of VDE-TER, but provided by satellites to offer global coverage. The capacity of the system is estimated to a maximum of 13.9kbps (is this a total or individual capacity ? can a simple explanation, like that provided at VDE-TER, be given please?) for downlink (satellite to ship) and 117kbps for uplink (ship to satellite).

## R-Mode

As GNSS signals are subject to intentional and unintentional interference, the international community considers the establishment of back-up systems for positioning, navigation and timing as good practice. One approach to achieve this is to equip shore communication systems with the option to transmit ranging (or R-Mode) signals. Ships can use these to determine their position, when in radio range of these stations. The VHF Data Exchange System (VDES), which is currently being developed, can be used for R-Mode.

The demand for a resilient positioning, navigation and timing (PNT) solution was reflected by the ACCSEAS project and is being further developed by the R-Mode Baltic Project which investigates in the MF and in the VHF band additional ranging sequences.

The proposal for such an alternative system is termed Ranging-Mode (R-Mode). R-Mode intends to utilize the shore based communication infrastructure, like DGPS (IALA beacons), Automatic Identification System (AIS) or VDE base stations [2] [9] with the existing housing infrastructure.

The accuracy of ranges between the base station on land and the vessel at sea, measured by means on the received radio signal, depends on the utilized bandwidth and of the received signal power versus the power of other noise sources.

## LTE - M as a communications infrastructure

The objective of Long Term Evolution-Maritime (LTE-M) is to provide high data rates (in the order of megabits per second), within the communication coverage of 100km from the shoreline.

In 2017, in order to confirm the feasibility of LTE technology in the maritime field, a test-bed was established in the Republic of Korea and several field experiments were conducted. The results show that, although there are interference issues with other communication signals, LTE-Maritime can provide the data rates (at Mbps) at a range of around 100km.

### Merits of LTE-M

LTE-M is based on LTE technology that is a promising solution for wireless maritime communications.

To support the requirements of various data services, maritime communications providing high-speed data rates and extended communication coverage, needs to be developed. Unfortunately, the conventional communication systems of maritime field, such as VHF, MF/HF were operated on terrestrial radio frequencies, specified in earlier GMDSS requirements. In the case of satellite systems, channel capacity and operative costs are relatively high for private users. They are required for GMDSS, but are not, currently, suited e-navigation services, especially in local waters where high data rates are required.

LTE is capable of providing increased data rate, capacity, and spectral efficiency, even in dynamic propagation environments. It can do this with the support of advanced techniques such as multiple-input multiple-output (MIMO) and carrier aggregation (CA). Furthermore, it has the potential to provide the communication coverage out to about 100 km, depending on the cell environments (although LTE for commercial mobile communication is designed for relatively short cell coverage). This superiority of LTE enables a single-hop network, enabling ship-to-shore data communication.

In general, the wireless mesh networks are vulnerable to link failures caused by radio interference and they cannot assure reliability. Contrary to existing maritime networks, for extending the communication coverage with multi-hop transmission, LTE-Maritime enables ships to directly communicate with onshore base stations and it could improve reliability (this is not clear..please rewrite). Therefore, it is more suitable especially for the safety-related maritime services that require high reliability as well as low latency.

## Autonomous Marine Radio Devices

For WG 3 to complete:

There are a number of marine radio devices which operate autonomously. These include, but are not limited to:

* Devices on towed or unpowered ships and barges
* Man overboard devices
* Diver locating, alerting and radiotelephony devices
* Fishing net marker buoys
* Oil spill tracking buoys
* Oceanographic and other drifting buoys.

Some of these autonomous maritime radio devices (AMRD) use AIS or digital selective calling (DSC) technology. Others transmit synthetic voice messages or operate with a combination of those technologies.

They have been developed for, and are operating in, the maritime environment. Their number is expected to increase.

Some of these devices do not enhance the safety of navigation nor serve the purpose of safety communication between coast stations and ship stations, or between ship stations, or between associated on board communication stations, or survival craft stations and emergency position-indicating radio beacons. However, they occupy the radio spectrum and identities of the maritime mobile service.

There is need to categorize and regulate the usage of autonomous maritime radio devices.

ITU, in 2019, adopted the preliminary draft definition of an AMRD. The categorization of AMRD and relevant information are contained in the draft new recommendation ITU-R M. [AMRD].

The generally agree IMO position is that:

* the integrity of AIS and the Global Maritime Distress and Safety System (GMDSS) should be protected;
* autonomous maritime radio devices which enhance the safety of navigation should be regulated for the use its frequencies and identities of the maritime mobile service; and
* for autonomous maritime radio devices which do not enhance the safety of navigation, regulation of the use of frequencies, and technical and operational characteristics, should benefit both the user of devices as well as maritime safety.

### AMRD Group A

These consists of Mobile Aids to Navigation (MAtoN) and Man Overboard-AIS Class M (MOB). Their technical and operational characteristics are described in the most recent version of Recommendations ITU-R M.1371 and ITU-R M.493.

Mobile AtoN and MOB should use the numbering scheme already defined in ITU-R M.585-7 “Identities in the maritime mobile service”, i.e. for MAtoN it is 99MIDXXXX.

### AMRD Group B

All other AMRD, that do not enhance the safety of navigation, are categorised as AMRD Group B. The characteristics of AMRD Group B were further developed and contained in two annexes, one for devices using AIS technology and the other for devices using other technologies.

AMRD Group B numbering scheme is still under consideration. The identity 979YYYYYY (not including the manufacturer ID) is proposed for the revised ITU-R M.585-7. However further work is needed and will be carried forward to the next WP 5B meeting.

## Emerging digital technologies

### What is 3GPP?

The use of mobile communications has been being recognized as a very useful means of communications for ships at sea??.

3GPP was created in 1998 by the signing of the "The 3rd Generation Partnership Project Agreement". 3GPP unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA and TTC). They are known as “Organizational Partners”. 3GPP provides members with a stable environment to produce the reports and specifications that define 3GPP technologies.

The original scope of 3GPP was to produce technical specifications and technical reports for a 3G Mobile System based on evolved GSM core networks and the radio access technologies that they support (i.e., Universal Terrestrial Radio Access (UTRA) both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes). The scope was subsequently amended to include the maintenance and development of the Global System for Mobile communication (GSM) Technical Specifications and Technical Reports including evolved radio access technologies.

The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security, and quality of service - and thus provides complete system specifications. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks.

More detailed information about 3GPP can be found in <http://www.3gpp.org/about-3gpp>.

### IALA’s position on 3GPP

IALA’s position is that communication based on 3GPP (currently 4G) technology is as an emerging technology for IALA and the maritime domain.

It may be beneficial to describe IALA members’ 5G requirements, identify other larger segments with similar requirements, join forces with the custodians of these segments and work jointly with 3GPP and CIRM, as appropriate to adopt the requirements

In the review of elements related to 3GPP, the role of CIRM and the IALA Industrial members was highlighted. In particular, IALA has highlighted the opportunities to explore possibilities for closer cooperation with CIRM on development of technical issues of mutual interest (e.g. 3GPP systems, and digital HF and VHF). This cooperation could include participation in CIRM working groups and technical meetings

### Digitalisation of marine VHF voice channels

Opening para ….

There are a number of options to implement voice over VHF. These include:

* digital Private Mobile Radio (dPMR) that uses Frequency Division Multiple Access (FDMA) and
* Digital Mobile Radio (DMR) that uses Time Division Multiple Access (TDMA) technology.

IALA has assessed that digital voice over VHF, using the example of dPMR, is a suitable candidate for consideration in meeting the needs of IALA members. However, a suitable vocoder needs to be identified as a standard for maritime use to ensure interoperability.

### Digital High Frequency radio

### How to assess new technologies?

IALA has a Guideline on ‘template for review of emerging technologies for possible use by IALA members. The objective of this guideline is to encourage identification of existing or emerging technologies that may be of interest to evaluate and identify their advantages, limitations and applicability of these technologies in consideration of user requirements and needs of IALA membership. The guideline can be found at Xx …yy..

#### New technologies

There are a number that IALA has looked at:

• LoRA / LoRaWAN – a low power-wide area network (LP-WAN) system that enables long transmission with limited power consumption. (https://www.mdpi.com/2079-9292/8/1/15/htm - tracking and monitoring system based on LoRa Technology for lightweight boats; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6163321/ Experimental study of LoRa transmission over seawater). This technology will be reviewed at ENAV 25 (ENAV25-2.1.1, action item 26 refers). This discussion may include a review of Sigfox if expertise is available.

• LEO constellation developments, noting the growth in digital communications capabilities from different low earth orbiting satellites. This technology will be reviewed at ENAV 25 (ENAV25-2.1.1, action item 25 refers)

• NAVDAT – noting developments as presented at IMO, including the recent input to NCSR, this technology may be reviewed if expertise and input is received for ENAV25.

• LiFi – LiFi, or light fidelity, is a communications capability based on Visual Light Communication (VLC) that uses LEDs to network a wireless system

Make the above generic - remove commercial names - , so say for example we looked at global services, low power WAN etc

It was noted that the listed technologies can be used for proprietary maritime communications but may not address standardization or security aspects.

## Digital communications in VTS

It is expected that the use of digital communication by VTS will increase significantly in the near future as a means to enhance communications and reduce the opportunity for misunderstanding caused by a miss hearing and/or a language barriers in communication between ship and shore and ship and ship.

In addition to AIS, some VTSs use other digital communication system such as satellites, internet and mobile phone with not only vessels but also other stakeholders and plan to use emerging digital communication technologies such as VDES, NAVDAT and LTE-M for the provision of clear, concise and unambiguous communications in VTS.

## Automation on board ships – implications for AtoN and navigation services

## IALA and GMDSS matters

IALA has an interest in maritime mobile services including Global Maritime Distress and Safety System (GMDSS) and radio determination service,

Services include emphasis on the development of VDES, VDE-SAT, AIS and autonomous radio devices (AMRD) operating in the maritime VHF mobile band.

# Information systems

## Digital information systems

### Background

Stated simply, the goal of e-Navigation[[1]](#footnote-1) is to provide harmonised information in electronic formats, in a seamless, customised and efficient manner, to better-designed navigational systems on board. Ashore, e-Navigation aims to streamline the way maritime authorities, agencies and other stakeholders gather and exchange information.

There are 16 digital maritime services agreed by IMO. The international community is working to develop and harmonise the supporting digital messages that constitute each service. The 16 services include three VTS services (information, traffic organisation and navigational assistance), a chart service and Maritime Safety Information (MSI). These maritime services, provided digitally to ships by shore authorities, will form the core of the navigation services in the coming years. The timely, bespoke, automated and error-free provision of safety-related information will result in a quantum increase in situational awareness on board ships and a commensurate increase in the safety of navigation.

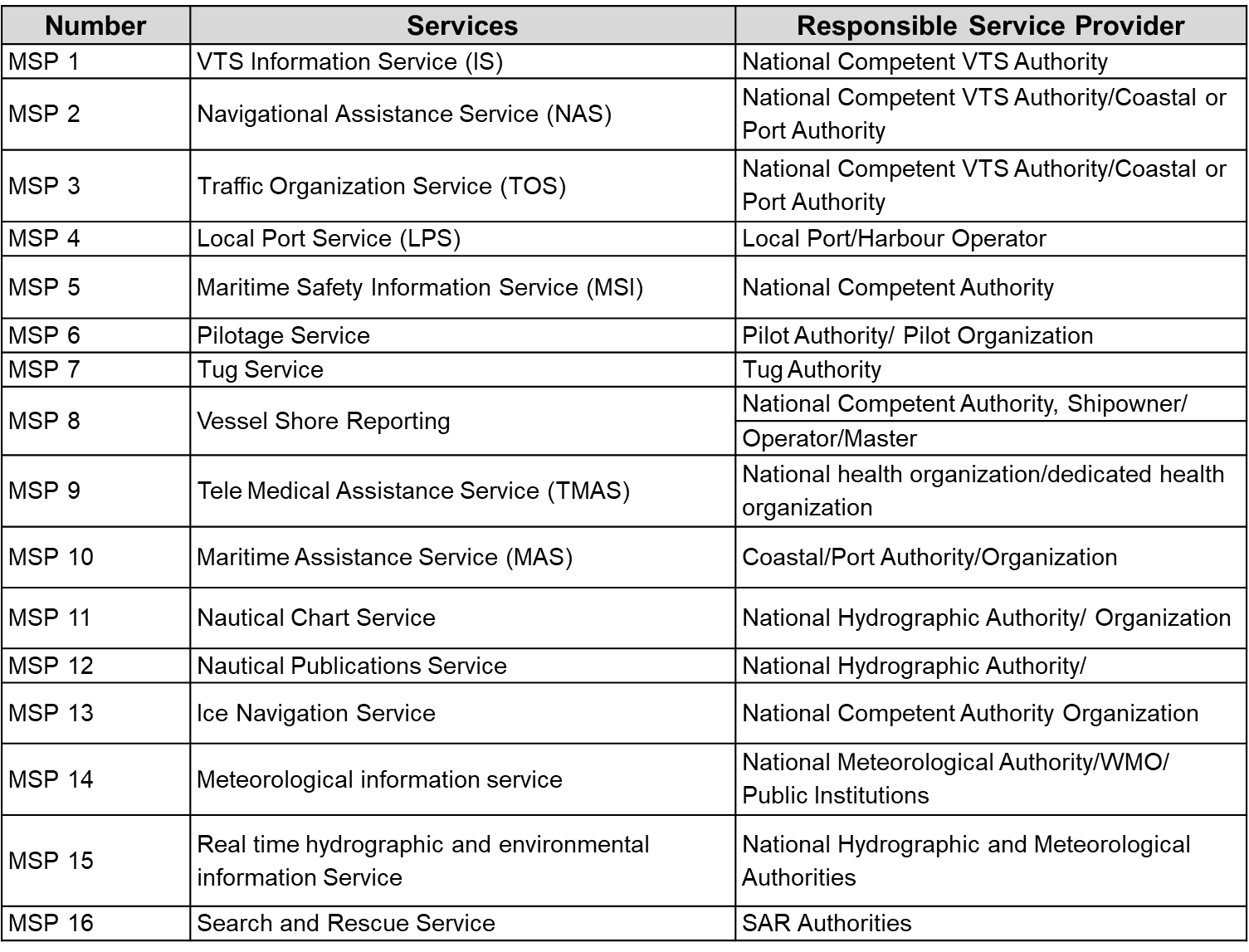
### Maritime Services in the context of e-Navigation

Maritime Services in the context of e-Navigation (agreed that we use this IMO term for now)[[2]](#footnote-2) refers to the provision and exchange of maritime-related information and data in a harmonized, unified format.

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) provides more information on maritime services.

Examples of Maritime Services include, but are not limited to, vessel traffic services, maritime safety information, pilotage, tug and nautical chart services. There may well be other services developed and implemented in the future.

The list of Maritime Services, as described in IMO’s E-Navigation Strategy Implementation Plan – Update 1 (MSC.1/Circ.1595), is presented in the table below. Each of these defines and describes the set of operational and technical services (and the level of service) provided by a stakeholder in a given sea area, waterway, or port, as appropriate (NCSR 1/ 28 Annex 7). IALA has submitted initial descriptions for the MSPs 1, 2 and 3 and is recognized as a coordinating body for these, together with IMO (MSC.1/Circ.1610).



### About Maritime Services

At its 101st session, MSC approved MSC.467 (101) (the Definition and Harmonization of the Format and Structure of Maritime Services in the Context of e-Navigation). This resolution explains the process and responsibilities for defining a new Maritime Service. It is important to note that any Maritime Service must be S-100 conformant as a baseline.

### More information

A lay-person description of e-navigation, which includes information on services, data models and operational and technical matters, is at Section XX.

IALA Guidance on this topic is:

* IALA Recommendation R1019 - Provision of Maritime Services in the context of e-navigation in the domain of IALA.
* IALA Guidance on platforms to support the provision of maritime services in the context of e-navigation (this guideline is still under development, likely completion ENAV 27)

### Maritime Services Description

For the development of IT based services, an Agile approach is commonly used. In an Agile organization, business and IT are working together on the development of the service. They interactively discuss information and user needs etc. and develop the software solution in an iterative way, where the usability is frequently demonstrated to the end user. Information exchange between business and IT is done in an informal setting, where teams work together daily.

In the case of the development of e-Navigation maritime services (MS), this is not possible, since the information transfer related to the MS is a ‘pan committee’ and even a ‘pan organization’ activity. Therefore, it is necessary to follow a more structured way of working, where information about a MS is well documented, and a defined process is followed. The relationship between the different required documents is critical for the development process. Especially, a gap between the formal specification of maritime services and the development of technical services specifications has been identified in past development processes. This gap is being closed by the development of a Maritime Service Description, which focuses on the business processes that are involved in the provision of a MS. In detail, an exhaustive service description, the context and goal of the service, user and information needs, a business process model and analysis and further implementation considerations should be discussed in a Maritime Service Description.

IALA provides further information on this topic in the “Guideline on the Development of a Maritime Service in the Context of e-Navigation”.

### Technical Services

A Technical Service comprises a set of technical solutions, based on an agreed data model and communications means, to provide a Maritime Service as per IMO MSC.467 (101). Based on the concepts of service-oriented architectures, a Technical Service also refers to a set of related software functionalities that can be reused for different purposes, together with policies that govern and control their use. Therefore, harmonization and interoperability of data models and interfaces of Technical services play a key role in the realization of Technical Services.

Technical Services should also be designed modularly. In this way, services offered by one electronic device can directly be used by another electronic device without any modification. Often, Operational Services are implemented by electronic devices or software components that rely on one or more Technical Service.

IALA is working on developing the operational and technical aspects of some maritime services.

### Establishing technical services

IALA Guideline G1128 on the specification of e-navigation technical services enables service providers, consumers and regulatory authorities to have a common understanding of a technical service and its implementation. The Guideline differs between the actual service specification (functionality and interfaces), technical designs (technology specific considerations) and instance descriptions (specific setup of a single service instance). All sections of the guideline are characterized by a fixed scheme. This enables the standardized specification of services in a Service Oriented Architecture.

A Technical Service should be formally specified and documented, as described by IALA Guideline G1128. At the time of writing, this guideline aims at improving the visibility and accessibility of available Technical Services and information provided by them. Data models of Technical Services should be implemented using the S-100 Universal Hydrographic Data Model (see section 9.2).

### Architectures for e-Navigation

The maritime domain is a complex ecosystem of multiple stakeholders and new and existing digital infrastructures. Secure, reliable and efficient architectures are required to fulfil the requirements of a harmonized network of technical services. The Maritime Architecture Framework[[3]](#footnote-3) is a framework for the design of maritime architectures. It can be used to describe the context of e-Navigation digital architectures and implement them.

In the past few years, platform solutions for the connection of decentralized services and databases have been established in a large part of the transportation and other sectors. IALA recognizes platforms as an important building block to implement the e-Navigation strategy, as they can facilitate harmonization, interoperability and collaboration between different services providers and support Service Oriented Architectures (SOA). SOAs enable services to interact with other services and furthermore, make it possible to build services based on existing services. Additionally, IP-based communication and web services open the possibilities for an efficient and more fine-grained communication. However, as this introduces a relatively new way of interacting with Maritime Services in a digital way, there are new requirements and risks that service architects and developers should be aware of. IALA is currently developing a Guideline to address these issues (G-XXX: Guideline on Platforms to support the provision of Maritime Services in the context of e-Navigation).

Julius M comment - some content of the NAVGUIDE 2018 could also be included here, as it does not seem to be outdated.

For WG1 – please add / let me know which sections

## IHO’s S-100 Universal Hydrographic Data Model

The S-100 Standard is a framework document that is intended for the development of digital products and services for hydrographic, maritime and GIS communities. It comprises multiple parts that are based on ISO geospatial standards.

The IHO has developed the S-100 Universal Hydrographic Data Model (UHDM) to cater for future demands for digital products and services.

The S-100 Geospatial Information Registry contains online databases of concepts, features, portrayal information, attributes, metadata and other resources. These items of information are relevant to those communities developing S-100 based products and services. A centralised registry also allows for harmonisation between product specifications within the maritime sector.

### S-100 for e-navigation

IMO is responsible for the overarching e-Navigation concept, which seeks to bring about increased safety and security in commercial shipping through better organisation of data on ships and shore, and better data exchange and communication between the two.

IHO had already established a system of standardised methods of codifying, encapsulating, and subsequently transferring and distributing hydrographic and charting data in its S-57 Electronic Navigational Chart standard. The concept can be applied into the entire e-Navigation concept by ensuring that the underpinning standards are in place from the beginning, through the S-100 family of product specifications and centralized information registry. The IHO maintains no controlling role, other than for its own standards. The principles are outlined in IHO publication S-99, Operational Procedures for the Organization and Management of the S-100 GI Registry, available at: [www.iho.int](http://www.iho.int). It is planned to introduce finalized S-100 products in the next years, initially with the simultaneous usage of S-57 products. Later, a complete transition to S-101 and other S-100 products is planned (NCSR7/22/x).

### S-100 dependent Product Specifications

In order to manage the development of S-100 based products; and with a view to minimizing duplication and encouraging conformity, the IHO Hydrographic Services and Standards Committee (HSSC) allocates S-XXX numbers to be used for the development of S-100 dependent products. The following Product Specification numbers have been allocated by the HSSC.

**International Hydrographic Organization (IHO) (S-101 to S-199)**

Some examples are

* S-101 Electronic Navigational Chart (ENC)
* S-102 Bathymetric Surface
* S-103 Sub-surface Navigation
* S-104 Water Level Information for Surface Navigation
* S-111 Surface Currents
* S-112 Open - (See Decision HSSC9/38)
* S-121 Maritime Limits and Boundaries
* S-124 Navigational Warnings (MSI)

**International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) (S-201 to S-299)**

Some examples are

* S-201 Aids to Navigation Information
* S-210 Inter-VTS Exchange Format
* S-211 Port Call Message Format
* S-230 Application Specific Messages
* S-240 DGNSS Station Almanac
* S-245 eLoran ASF Data
* S-246 eLoran Station Almanac
* S-247 Differential eLoran Reference Station Almanac
* S-2xx Port Collaborative Decision Making (PortCDM)

**Joint Technical Commission for Oceanography and Marine Meteorology (WMO/IOC JCOMM) (S-411 to S-414)**

* S-411 JCOMM Ice Information
* S-412 JCOMM Weather Overlay
* S-413 Weather and Wave Conditions
* S-414 Weather and Wave Observations

Check if this is an exhaustive list before finalising the doc

### IALA and S-100 development

The current (as on 1 Jan 2021) edition of S-100 is Edition 4.0.0. In that there is a section for online data Exchange. IHO is progressing a refinement of S-100, which aims to include the concept of on-line communications. Teething issues raised during the testing of a first proposal (from IALA) were dealt with.

As S-100 will be an increasingly used framework for the exchange of maritime information, ways for the secure, reliable, and efficient exchange of S-100 data must be taken into consideration. The standardisation of a common Web Service interface (based on IP-Technology) for exchange of S-100 based products will enable wider technical interoperability where the same service interface can be used for exchanging information regardless of operational use, i.e. common for several Maritime Services.

For example, the distribution of navigational warnings with the S-124 data model is a good example for the use of secure Web Services and is already being deployed by some IALA members. Therefore, IALA has released a guideline for S-100 based Web Services (G-1157: Guideline on Web Service Based S-100 Data Exchange). A general introduction to the topic and an overview of existing standardisation and guidance documents is given

Therefore, the IALA is working on a guideline for S-100 based Web Services (G-XXX: Guideline on Web Service Based S-100 Data Exchange). A general introduction to the topic and an overview of existing standardization and guidance documents is given.

JM – Also, this paragraph seems to be outdated. I will add a short paragraph here. For the development of the S-2XX Standards, maybe someone from ARM(?) could contribute.

*Maybe we can say something about the Product Specifications IALA is currently developing, and the dependencies between IALA and IHO. If necessary, we could also illustrate the collaboration between IALA and IHO in various committees. We could also be general, if the specifics aren’t needed (like not using references to the ENAV committee in Chapter 10).*

*From JM As far as I know IALA is responsible for all of the S-200 standards. I also think that there are some liaison meetings between IALA and IHO. Maybe Minsu can provide some additional information here.*

### Maritime Resource Names

Maritime Resource Names (MRN) are a concept for naming and identification of maritime entities, originally developed within IALA Committees. The system is based on the existing URN concept from the Internet Engineering Task Force (IETF)[[4]](#footnote-4), and has broad potential for application beyond IALA features. MRN is included in the S-100 framework documents and applied throughout the S-100 family of products and services. The interconnection between maritime entities (including data) and a MRN is applicable in a wide range of use cases. MRNs could for example be used as a unique Identity representation for SOAs.

On its 65th session, the IALA council adopted the proposal to obtain and manage the ‘MRN’ domain of URN (C65‐11.4.4.1). Furthermore, the IALA ARM committee (in collaboration with the ENAV committee) developed a guideline relating to MRN; G1143, which was adopted by council meeting #69. The ARM committee is currently revising G1143, and edition 2 is currently underway.

For more information, see this footnote[[5]](#footnote-5).

## Cyber security

Classical cyber security solutions have mostly been developed for office IT systems and applications. Cyber security for the maritime domain requires different priorities, management and operational characteristics and requirements.

According to emerging technology needs in the maritime domain, digital devices and software components will be developed and are expected to provide additional information to mariners. These new maritime digital necessarily require cyber security measures.

Cyber security of VTS, ships and maritime digital devices, etc. is emerging as a critical issue for the maritime environment and safety. Since each characteristic is different, it is not advisable to apply one cyber security standard to all areas. Therefore, the following strategic decisions are needed in applying international standards.

Table 1. Applicable cyber security standards

|  |  |  |
| --- | --- | --- |
| Category | Standard | Title |
| **VTS** | ISO 27001 | Information security management |
| NIST | NIST Cybersecurity framework |
| **Ship** | IEC 62443 4-2 | Technical security requirements for IACS components |
| IEC 62443 3-3 | System security requirements and security levels |
| IEC 61162 460 | Maritime navigation and radiocommunication equipment and systems – digital interfaces Part 460: Ethernet interconnection – safety and security |
| IEC 63154 | Maritime navigation and radiocommunication equipment and systems – Cybersecurity – General requirements, methods of testing and required test results |
| **High-level recommendation** | IMO MSC-FAL.1/Circ.3 | IMO Guidelines on Maritime Cyber Risk Management |
| **Maritime digital devices** | To be considered above international standards as a reference | |

## Conclusion

As a key element of the IMO e-Navigation strategy, Maritime Services are expected to enhance maritime navigation and related processes in the near future. However, there is a wide range of providers and technologies for implementing these services and communicating with users.

The harmonization and security of these services are key elements for the successful establishment of a Maritime Service. They offer potential to unlock the advantages of digitalization for safer, greener and more efficient maritime operations. As these trends lead to increased and improved connectivity, safety, and efficiency, IALA highly encourages the developments in this area.

# Other services

## About e-Navigation

### Introduction

The IMO-led[[6]](#footnote-6) initiative termed e-Navigation[[7]](#footnote-7) is a concept which covers many disciplines. Earlier, section 9.1 has introduced and described the concept.

Stated simply, the goal of e-Navigation is to provide harmonised information in electronic formats, in a seamless, customised and efficient manner, to better-designed navigational systems on board. Ashore, e-Navigation aims to streamline the way maritime authorities, agencies and other stakeholders gather and exchange information.

This chapter provides a brief history of the development of e-Navigation and describes the areas that IALA has been involved in.

### Background

#### Origins

In 2006, the International Maritime Organization (a proposal from seven of its Member States, which requested IMO develop an e-Navigation strategy.

The aim of the proposal was to *“...develop a strategic vision for the utilization of existing and new navigational tools, in particular electronic tools, in a holistic and systematic manner.”* (MSC 81/23/10). The sponsors of the submission were concerned that if the introduction of new technology remained uncoordinated, it would result in a lack of standardization on board and an increased level of complexity. The proposed e-Navigation vision was to create an overarching system that would provide a greater level of safety and incident prevention, resulting in reduced navigation-related accidents.

IMO led other international organisations, notably IALA and the International Hydrographic Organization (IHO) and developed a strategy for the development and implementation of e-Navigation in 2008 (MSC85/26/Add.1, Annex 20).

A plan to implement the strategy, termed the Strategy Implementation Plan (SIP), was completed in 2014 (NCSR1/28 Annex 7). This was reviewed and updated in 2018 (MSC.1/Circ.1595).

## IMO’s strategy for the development and implementation of e-Navigation

### The case for e-Navigation

The IMO strategy for e-Navigation (MSC 85/26/Add.1, Annex 20) states that about 60% of collisions and groundings are caused by direct human error. Despite advances in bridge resource management training, it seems that the majority of watch-keeping officers make critical decisions for navigation and collision avoidance in isolation. This is partly due to a general reduction in manning, it states.

The IMO strategy also states that in human reliability analysis, the presence of someone checking the decision making process improves reliability by a factor of 10. If e-Navigation can assist in improving this aspect, through well-designed on-board systems and closer cooperation with vessel traffic management (VTM) systems ashore, the risk of collisions and grounding (and their inherent liabilities and costs to administrations) can be dramatically reduced.

#### Vision

The IMO vision for e-Navigation includes the following general expectations for on-board, ashore and communications elements:

#### On-board

Navigation systems that benefit from the integration of own ship sensors, supporting information, a standard user interface and a comprehensive system for managing guard zones and alerts. Core elements of such a system will include actively engaging the mariner in the process of navigation, to carry out their duties in the most efficient manner, while preventing distraction and overburdening.

#### Ashore

The management of vessel traffic and related services from ashore, enhanced through better provision, coordination and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency.

#### Communications

An infrastructure providing authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits.

### Definition

The IMO strategy defines e-Navigation 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.”*

In other words, e-Navigation means:

* The harmonised exchange and presentation of navigational information in electronic formats.
* Harmonized data exchange and improved communications.
* Creation of a "wide area navigation team", which allows the Officer of the Watch (OOW) and the Vessel Traffic Services (VTS) Operator to share tactical and planning information.
* Improved design of navigational and communication equipment.

### What does the ‘e’ in e-Navigation stand for?

It is generally accepted that the IMO concept of e-Navigation can be thought of as a brand, without the need for ’e’ to be specifically defined. The concept of e-Navigation was first proposed by seven IMO Member States in 2006 as a process for the harmonisation, collection, integration, exchange and presentation of maritime information. As such, the ’e’ could have stood for ’enhanced’ or ’electronic’ (just like the ’e’ in e-commerce), but this would limit what could be done within e-Navigation. It must be noted that the generic term electronic marine navigation already exists in many forms. It should not be confused with this particular IMO initiative.

### Key elements

The key elements of the IMO strategy for e-Navigation, based on user needs include:

• Architecture

• Human element

• Conventions and standards

• Position fixing

• Communication technology and information systems

• Electronic Navigational Charts (ENC)

• Equipment standardization

• Scalability

According to the strategy, the implementation of e-Navigation should be a phased, iterative process of continuous development, taking into account the evolution of user needs and the lessons learned from the previous phase(s).

As part of the basic requirements for the implementation of e-Navigation, it was agreed that e-Navigation should be based on user requirements and needs and not technology-driven.

### E-Navigation solutions

The centrepiece of the current (2018) SIP is the following five e-Navigation solutions:

* S1: improved, harmonized and user-friendly bridge design;
* S2: means for standardized and automated reporting;
* S3: improved reliability, resilience and integrity of bridge equipment and navigation information;
* S4: integration and presentation of available information in graphical displays received via communication equipment; and
* S5: improved Communication of VTS Service Portfolio (not limited to VTS stations).

Solutions S1 and S3 promote the workable and practical use of the information and data on board. As regards S1, IMO finalised:

* Guideline on Software Quality Assurance and Human-Centred Design for e-navigation (MSC.1/Circ.1512)
* Guidelines for the standardization of user interface design for navigation equipment (MSC.1/Circ.1609)
* Interim Guidelines for the Harmonized Display Of Navigation Information Received Via Communication Equipment (MSC.1/Circ.1593)
* Guidelines for the presentation of navigation-related symbols, terms and abbreviations, (SN.1/Circ.243/Rev.2)
* Amendments to the Performance standards for the presentation of navigation-related information on shipborne navigational displays (resolution MSC.191(79))
* Guidance on the definition and harmonization of the format and structure of maritime services in the context of e-navigation (IMO Resolution MSC.467 (101)).

Solutions S2, S4 and S9 focus on efficient transfer of marine information and data between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore).

## IALA’s Role

### IALA’s Strategic Vision 2018-2026

The aim of IALA is to foster the safe and efficient movement of vessels through the improvement and harmonisation of Marine Aids to Navigation worldwide. This purpose is given effect by two key goals for 2026.

**Goal 1 (G1)**

Marine Aids to Navigation are developed and harmonised through international cooperation and the provision of standards.

The strategy for e-Navigation is to improve and harmonise VTS, information structures, Maritime Service Portfolios and communications, so as to achieve worldwide interoperability of shore and ship systems.

**Goal 2 (G2)**

All coastal states have contributed to a sustainable and efficient global network of Marine Aids to Navigation through capacity building and the sharing of expertise.

Here, the strategy is to coordinate the further development of VTS, e-Navigation and short range Marine Aids to Navigation, taking into account new technologies and sustainability. Additionally, to continue to develop capacity building activities to improve the global operations and management of Marine Aids to Navigation systems and related services.

### IALA’s work on digital communication technologies, information services and e-navigation matters

IALA has so far focussed on three broad streams:

Digital Information Systems

* Developing guidance on the description and implementation of “Maritime Services in the Context of e-Navigation”.
* Facilitating harmonization in the development of data models, technical services and platforms.
* Defining concepts, procedures, services and platforms for new initiatives such as identity management.

Emerging Digital Technologies

* Evaluation of new technologies relevant to e-navigation, in particular digital maritime communications
* Maritime Autonomous Surface Ships
* Single Window Data Exchange

Digital Communication Systems

* IALA’s Maritime Radio Communication Plan
* The technical characteristics and operation of the VHF Data Exchange System (VDES)
* Autonomous Maritime Radio Devices (AMRD), Automatic Identification System (AIS) and other digital communication technologies

## A lay person’s description of e-navigation

E-Navigation is based on the principles of data exchange, as used in the applications or “apps” that operate on smart phones.

For example, a weather app that provides information to a user, could be called a “Weather Service”. This weather service meets the user’s need for information about the weather. Similarly, a Maritime Service, in the context of e-Navigation, satisfies a user need for information concerning vessel navigation and other maritime considerations including safety, efficiency and the protection of the marine environment. Our weather service app needs to communicate with a server that runs software, which stores and provides weather information.



*Figure 1 – The Concept of a Client-Server based Maritime Service*

The interaction between the app and the server is defined by a technical service specification, which describes the exchange of standardised messages and the language that is used in the message contents. The language is described by a data model.

The software running on the server hardware is described as being an instance of the technical service.



*Figure 2 – The relationship between specifications of Maritime Services, Technical Services and data models in e-Navigation*

If someone wants to develop an app that is able to communicate with the server, or develop a server to be used by the app, the developer must refer to the technical service specification and the referenced data models.

Similarly, an e-Navigation Maritime Service draws together information through a combination of one or more running instances of a technical services. A technical service facilitates the exchange of data, by receiving messages, processing the data, and sending a result. The data is formatted according to the Common Maritime Data Structure, which is based on the IHO S-100 series of data models, thus ensuring harmonisation and interoperability.



*Figure 3 - The dataflow between Maritime Services, Technical Services and data exchange*

We can further explore the relationship between Maritime Services, Technical Services and Data Models with reference to Figure 3, which further expands on our example of a Weather Service App.

Here we now assume that our weather service app is now part of a set of e-Navigation Maritime Services, and parallels can be made with Figure 2. The Maritime Weather Service App developed by Stormy Corp Ltd. is composed of several Technical Services. Each Technical Service exchanges messages with servers that contain various data about characteristics of the weather. In this example we are using Temperature, Wind and Cloud Cover data. These datasets are obtained from sensors distributed around a geographical region and stored in databases. It is the job of the technical services to extract relevant data depending on the requirements entered into the user interface of the Weather Service app. The Weather Service app connects to an instance of Technical Service 1 for Temperature, Technical Service 2 for Wind, and Technical Service 3 for Cloud Cover (or Sunlight).

Let us examine the characteristics of the architecture outlined in Figure 3:

1. A single Maritime Service can use several Technical Services. This is an example of a 1:N relationship between Maritime Services and Technical Services.
2. The instances of these Technical Services can be deployed by a single organisation OR by multiple organisations. In our case for example, BlowFelt Inc. host a Temperature Technical Service on their servers and provide their Temperature Data. BlowFelt Inc. also provide a Wind Technical Service and provide their own Wind database. But the StormyCorp Ltd. Weather Service App has chosen to use Cloud Cover data from GreySkies Inc. BlowFelt and GreySkies servers could be widely separate.
3. Instances of Technical Services can be re-used by other Maritime Services. In Figure 3 we see a Maritime Service that provides a prediction of the amount of solar energy that can be harvested; the Solar Energy Predictor App developed by a company called SunShine Inc. A user of the app might enter a geographical location into the user interface to gain an understanding of the energy harvesting capability of his remote solar powered autonomous ship at its current location. Notice that SunShine’s App could use the same instance of GreySkies’ Cloud Cover Technical Service as used by StormyCorp’s Weather App, or it COULD have used the one hosted by BlueSkies. Decisions on which service provider’s technical service instance to use could depend on perceived quality of provided data, cost of subscription or numerous other factors.

### An example of an IALA National Member’s vision

In 2019, the Australian Maritime Safety Authority released *Navigation Services in Australian Waters—outlook to 2030*. This work provides an insight to the provision of navigation services (not just aids to navigation) in the coming years. It outlines the emerging trends and drivers in navigation technology and communications. It also describes the anticipated impacts these will have on the maritime industry. Importantly, it lists AMSA’s policy responses to these changes.

It can be found here:

<https://www.amsa.gov.au/safety-navigation/navigation-systems/navigation-services-australian-waters-outlook-2030>

### Testbeds

Several multi-million dollar projects (completed and underway) have made noteworthy inroads in developing aspects of e-Navigation.

The IALA website (<http://www.iala-aism.org/technical/e-nav-testbeds>) provides more detail on known testbeds and their results.

IMO and IALA have guidelines to assist with the reporting of testbed results

* Guidelines on Harmonization of Testbed Reporting (MSC.1/Circ.1494)
* IALA Guideline 1107 – Planning and reporting of e-navigation Testbeds (June 2016)

### Answers to Frequently Asked Questions on e-Navigation

IALA has developed answers to some Frequently Asked Questions (FAQs) on certain aspects of e-Navigation. These can be found on the IALA website at .

https://www.iala-aism.org/technical/e-nav-testbeds/enav-faq/ seems to be missing

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

1. The concept of e-Navigation is explained in detail in section 10.1 [↑](#footnote-ref-1)
2. As part of the improved provision of services to vessels through e-navigation, maritime services have been identified as the means of providing electronic information in a harmonized way. It is part of Solution 5 identified in IMO’s SIP. [↑](#footnote-ref-2)
3. Weinert, Benjamin & Hahn, Axel & Norkus, Oliver. (2016). A domain-specific architecture framework for the maritime domain. [↑](#footnote-ref-3)
4. <https://tools.ietf.org/html/rfc8141> [↑](#footnote-ref-4)
5. Maritime Resource Name (MRN) see: http://mrnregistry.org [↑](#footnote-ref-5)
6. IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented. [↑](#footnote-ref-6)
7. Until a few years ago, the term e-navigation was used universally. The term e-navigation has been left in in this chapter, when outlining some of the history, as words from IMO have been quoted verbatim…but, later on, digital maritime services is used. [↑](#footnote-ref-7)