PAP33-12.1

POSITION ON THE DEVELOPMENT OF ATON SERVICES

PAP33-12.1,
Secretariat
2017-01

1. THE PURPOSE OF THIS DOCUMENT

This document has the purpose of describing the Positions that that IALA will take concerning certain critical technical and operational aspects of its work with the object of assisting the work of the technical Committees of IALA and informing IALA members.

This is a living document and will be brought up to date as necessitated by external factors, by technology developments, and by decisions on the focus of IALA's work. It should be read in conjunction with the following three vital documents.

- Basic Documents – available from the website
- Strategic Vision – available from the website
- Work Programmes for the Committees – available from the Committee Secretaries.

2. TRENDS AND DRIVERS OF STRATEGY FOR THE PERIOD 2018-2026

Numerous trends and factors affect the work of IALA members and the directions in which the organization should focus its attention. We think that these can be summarized into Trends and Drivers.

The Drivers are derived from the Trends, and are a useful way of summarising a multitude of factors. We believe that four Drivers need to be considered in determining Strategy. These are:

- Volume of traffic and degree of risk
- Environment and sustainability
- Efficiency and safety
- New technology

The origin of these four Drivers is now explained. Trends are discussed and then a diagram draws these together into a Driver, with a diagram to illustrate.

2.1. Driver 1, Volume of traffic and degree of risk

There have been substantial changes in global shipping, including an increase in the volume of vessel traffic and the size of vessels, an increasing dependence on an interconnected global economy, and the rapid development and availability of modern information technology. In addition, there has been an increasing public demand for improved surveillance and management of vessel traffic. This is coupled with a developing expectation to prevent shipping related incidents along with a need to respond effectively to emergencies in all navigable waters, especially in port and coastal areas.

These increasing demands and needs have been imposed upon coastal and port infrastructures, as well as on the interaction between ships and shore authorities and stakeholders. New technologies have provided the opportunity for efficient and effective information exchange and re-use of the collected data by participants and stakeholders in the maritime environment.

Shipping rates are presently low and larger ships and corporate mergers are being seen as shipping companies strive to remain competitive. Despite this the world SOLAS fleet continues to grow. Globalisation including the associated manufacturing and assembly practices increases the international flow of components and completed goods.

Development of vessels which are controlled from shore is well advanced. Small autonomous vessels have been in use for many years, for example for survey and data gathering, but generally do not require (conventional) aids to navigation. Unmanned or autonomous ships are being developed in a number of countries, with some already at sea. As commercial shipping enters this new era, we can expect change in the electronic services which members will be required to provide. The manner in which these ships interact with other vessels and with shore services and authorities, and the Vessel Traffic Services (VTS) which will be required in VTS areas for these ships are matters of concern

Fishing vessels, pleasure craft, and smaller ships that do not fall under the provisions of the IMO SOLAS Convention are far more numerous than SOLAS ships. In many countries, perhaps most, the non-SOLAS vessels account for more accidents and emergencies than SOLAS vessels. Depending on the type of vessel, their equipment fit may vary from very basic, to systems of the highest sophistication. Some of IALA's national members are tasked to provide aids to navigation services for all vessels. Other members may be funded by "light dues" levied on commercial shipping arriving at their ports, and so may have a need to direct their main efforts to serving these ships. The need to provide better and modern shore services to non-SOLAS vessels is an increasing consideration.

The IMO has recognised a trend towards a reduction in the skills of bridge teams.

The volume of traffic and the desire by coastal authorities to reduce risk is resulting in increasing numbers of VTS being established.

The compulsory fitting of AIS to SOLAS ships, and its voluntary uptake by other vessels, originally for safety of navigation, has enabled shore authorities to build up a picture of shipping density, and preferred routes, assisting the computation of risk and the design of aids to navigation systems. AIS revolutionised VTS also, with vessel details and course, speed, and rate of turn all available on the VTS display. AIS receivers in satellites have extended knowledge of tracks to areas outside terrestrial VHF range. VDES will make this tracking capability more competent.

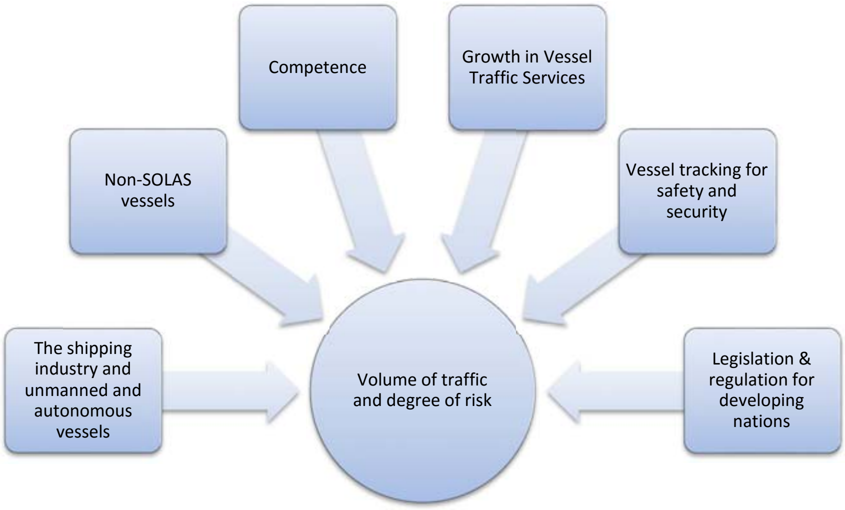
In some nations, the institutions for managing aids to navigation services including VTS require further development. Legislation or regulations may not be in place, or staff may not be aware of the country's responsibility under international laws and conventions.

At the same time, the job of VTS operators has changed from mostly radar observation tasks to interacting with vessels in an ever increasing traffic complexity. It developed from a reactive task to a proactive task. The number of ships in a VTS area has often increased but the main change is the increasing size of ships. In a VTS area with narrow navigable waters and a lot of channel bends, where inland ships weave with seagoing vessels constrained by length or draft, there is a huge impact on the operational VTS procedures. Not only the length and width of the constrained ships have to be taken into account, but sometimes more importantly their swept path width must be taken into account. More advanced operational solutions are needed including improved measures for effective slot management.

A future consequence of the evolution of VTS is the focus increasingly being placed on ensuring the general efficiency of vessel traffic from both operational and commercial perspectives. VTS is increasingly being utilised as a means to optimise the flow of vessel traffic to provide benefits to ship operators and ports ranging from enhancing fuel efficiency through to managing vessel traffic to facilitate optimal berthing windows and time alongside.

The global harmonisation of VTS procedures has not yet been achieved. There are moves in some regions to extend VTS services outside promulgated VTS areas.

The need for correct and complete training of aids to navigation and VTS personnel is now becoming universally recognised. Some national members are establishing dedicated training institutions, and offering their services to neighbouring countries also. At the same time, the availability of skilled technicians is reducing, especially in developed countries as cost pressures drive outsourcing and staff reductions.

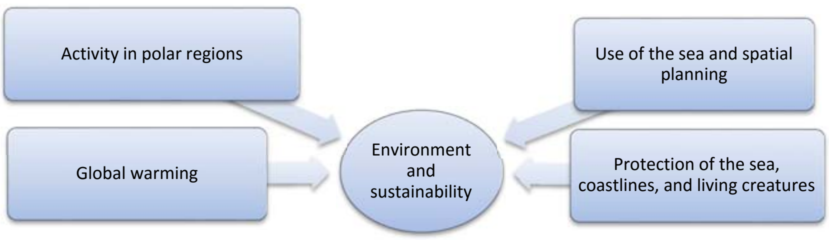


2.2. Driver 2, Environment and sustainability

The reduction in sea ice in the Arctic has led to a great interest in polar routes between the continents. At present, the increase in polar traffic for commercial purpose has been small, but the future may see this change. Provision of visual aids and of electronic services in Polar Regions is difficult. We can expect that area radionavigation systems and electronic dissemination of information will be important, but may be limited by the costs and difficulties of installation and of maintenance access.

Pressure has been increasing on the sea space available for navigation, as demands for offshore energy production (oil, gas, electricity) increase, and as exploration and exploitation of the sea and sea floor grow. The effect in some sea areas is to confine conventional ship navigation and fishing to more constrained spaces. Marking of offshore activities by conventional and electronic means, to make all classes of vessel aware, is an ongoing task. Further harmonisation is increasingly important here, both with light signals and electronic information, to avoid misinterpretation and thus accidents.

Marine aids to navigation services are generally required to observe best practice for preventing pollution of the seas, for preserving the beauty of littoral regions, and for avoiding harm to certain sea creatures. This is resulting in restrictions on the use of certain materials, in changes of operational practices, and in increased workload in planning and operations.

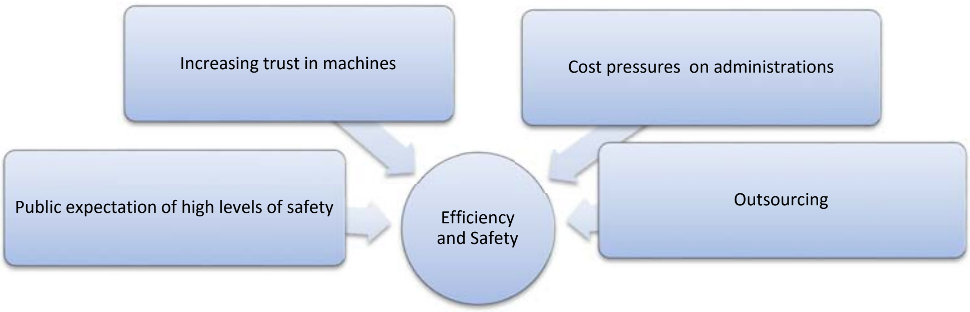


2.3. Driver 3, Efficiency ~~and~~ , Safety and Cost

The public has an expectation that commercial shipping, including the cruise industry, is managed and conducted in a safe manner. Accidents and pollution incidents, especially near shore, receive heavy attention in the media. There is also probably an impression among parts of the public that shipping traffic is monitored and controlled in a manner similar to commercial aviation.

As technology develops, accident reports for all transport modes show human error as a primary factor. Automated vehicles, on rails, on roads, and in the sky are accepted by the public and generally trusted to be safe and reliable. The development of personal technology and communications and the almost universal use of GNSS for all transport modes have created an impression that high technology and precise vehicle control must apply to the sea also.

The pressure on most governments to contain their operating expenses coupled with a technology focus is leading to a reduction in focus on traditional aids to navigation services. Outsourcing of activities in many service areas by governments means that for aids to navigation services the knowledge and competences of the services are lost and replaced by contract and performance monitoring. This requires a new skill set in the authorities.



2.4. Driver 4, New Technology

In contrast with the aviation industry, a provider of shore services for vessels at sea must remain aware of the wide range of capability that may be found on the bridges of vessels. This is a long-standing problem, but may be assuaged gradually by IALA's work towards harmonisation of electronic shore service provided to shipping by its members, driving bridge hardware and software gradually towards its own harmonisation. Cost pressures in the shipping industry will mean obsolete bridges remaining in service.

GNSS systems are now (almost) universally used by all. With GPS, GLONASS, Galileo, and Bei~~d~~Dou in service or soon to be, GNSS services are increasingly resilient. However deliberate jamming of GNSS is easy to do, solar weather can disrupt GNSS services, and some man-made radiation can unintentionally upset GNSS position fixing. At least one IALA member suffers deliberate jamming of GNSS, disrupting shipping, aviation, and land transport. Back-up systems will be important.

"e-Navigation" was proposed more than ten years ago, but has been slow in gestation. Taking account of this progress, IALA develops a roadmap for e-Navigation attached as Annex C. The advent of AIS drove a leap forward, as did development in bridge electronics. The harmonisation and delivery of electronic services from shore, packaged into "Maritime Service Portfolios", will be vital to ongoing progress. Developments in connectivity and information flow between ship and shore will create opportunities to increase port efficiency through advanced VTS services. Cyber security concerns will need to be addressed.

Despite these electronic advances, mariners still require the visual cues provided by traditional visual signals from light-beacons, buoys and day-marks in constricted waterways. These require only the human eye and the mariner's skill to use. We can expect them to be in service for the near future and probably longer

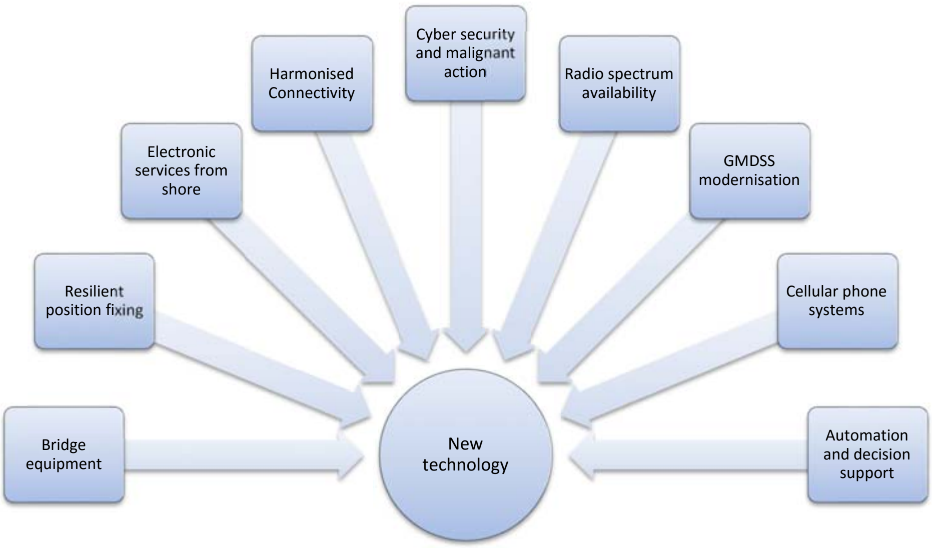
Legacy systems, including GNSS and AIS, can be disrupted by malignant action. Future communications and information services for marine navigation must be cyber secure.

Allocation of frequency bands for radio transmissions are governed by the regulations of the ITU. The provision of frequency allocations sufficient for digital information flow between ship and shore is vital for safety and efficiency.

The modernisation of GMDSS is a current task in IMO. The IALA concept of VDES is for the broadcast of maritime safety and other information, and for AIS vessel identification and tracking, but may have the capability to form part of a new GMDSS.

Sometimes viewed with disdain by traditionalists, the near-ubiquity of cellular phone aboard all classes of vessel, may provide a near-coastline communication system of good performance. The use of cellular phone systems for delivering shore services will become increasingly important, especially for non-SOLAS craft and for emergencies.

Decision support software for bridge crews and for VTS personnel are expected to become increasingly used.



3. STRATEGIES FOR 2018-2026

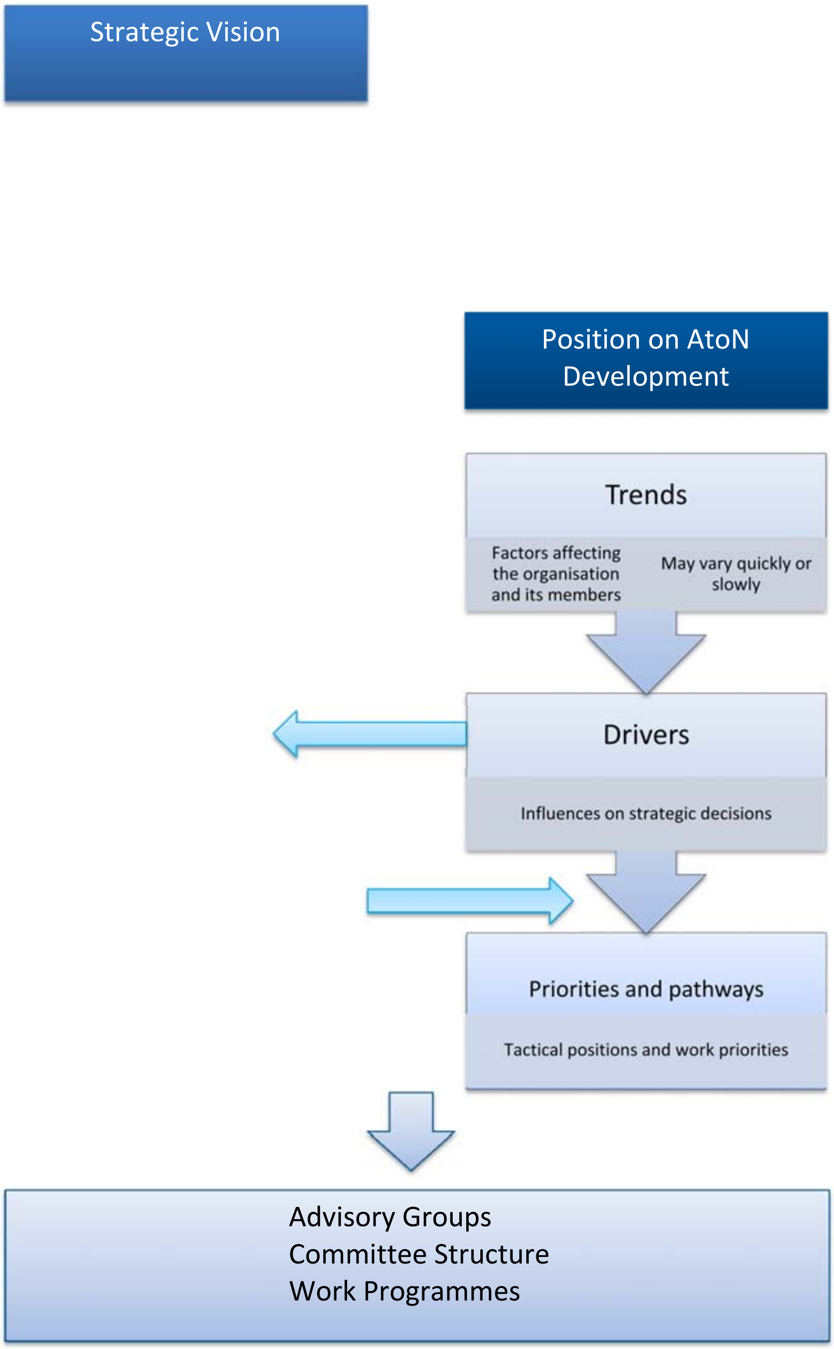
4. THE STRATEGIC VISION

The Strategic Vision for IALA was developed in 2013 to cover the period 2014-2026. It is presently being revised and will become the Strategic Vision 2018-2026. Its content is as follows.

- Purpose
- Motto
- Goals
- Strategies

The Purpose of the organisation is its reason to exist, its Goals are those it hopes to achieve in the medium to longer term, the Trends are external factors which create Drivers which influence the decisions on Strategies.

The following diagram will explain further.


Strategic Vision
Position on AtoN Development
Trends
Factors affecting the organisation and its members
May vary quickly or slowly
Drivers
Influences on strategic decisions
Priorities and pathways
Tactical positions and work priorities
Advisory Groups
Committee Structure
Work Programmes

5. POSITION STATEMENTS

5.1. Purpose of the Statements

Technical Position Statements have been created to provide a link between the Strategic Vision and the work programmes of the Committees, giving guidance where needed on the technical philosophy for an aspect of IALA's work and the preferred path of this work. In cases where the path should be obvious, no Position statement is necessary.

5.2. Structure

Position Statements are organised within a structure mirroring the organisation of IALA Standards and Recommendations, as follows.

AtoN Planning and Service Requirements

- Obligations and regulatory compliance
- AtoN Planning (offshore signals, bridge signals, traffic signals, MBS, fairway design)
- Levels of service objectives. (Availability and Categories)
- Risk Management
- Virtual marking
- Quality management

AtoN Design and Delivery

- Visual signalling (Vision, Colour, Conspicuity, Rhythmic characters)
- Range and performance (visual and audible)
- Design, Implementation & Maintenance
- Power systems
- Floating AtoN (buoys, moorings, stability, etc.)
- Environment, Sustainability & Legacy

Radionavigation Services

- Satellite positioning and timing
- Terrestrial positioning and timing (including eLoran, eChayka, R-mode)
- Racon & radar positioning
- Augmentation services (SBAS & DGNSS)

Vessel Traffic Services

- VTS implementation
- VTS operations
- VTS data and information management
- VTS communications
- VTS technologies
- VTS auditing and assessing
- VTS additional services

Training and Certification

- Training and assessment
- Competency certification and revalidation
- Simulation in training
- Human factors and ergonomics
- Capacity building (Model courses)

Digital Communications Technologies
Wide/Medium bandwidth systems (AIS & VDES)
Narrow bandwidth systems (NAVDAT, MF beacons, etc.)
Harmonised maritime connectivity (Maritime Internet of Things, intelligent sensors, AtoN monitoring, etc.)

Information Services
Data models and data encoding (IVEF, S-100, S-200, ASM, etc.)
Vessel tracking and data exchange systems
e-Navigation user requirements
Terminology, symbology, and portrayal

6. ATON PLANNING AND SERVICE REQUIREMENTS

6.1. Content

Content areas are:

- Obligations and regulatory compliance
- AtoN Planning (offshore signals, bridge signals, traffic signals, MBS, fairway design)
- Levels of service objectives. (Availability and Categories)
- Risk Management
- Virtual marking
- Quality management

6.2. Positions Statements

6.2.1. Obligations and regulatory compliance

The obligations of coastal states to provide aids to navigation are included in international Conventions. The Safety of Life at Sea Convention Chapter V, Regulation 13 is of importance for aids to navigation, but other Conventions such as UNCLOS and also regional arrangements, for example EC Directives, may also apply.

National legislation and regulations may also prescribe the obligations of aids to navigation services providers, whether government or private.

IALA will provide information and guidance to its members on the conventions and other instruments that provide the international framework for the provision of aids to navigation.

It will also provide guidance to assist members with creation of national frameworks for the establishment and operation of aids to navigation competent authorities, including

- Advice on content of legislation and regulation
- Responsibilities of a competent authority for aids to navigation, and organisational considerations
- Certification and auditing of aids to navigation providers
- Promulgation of aids to navigation information nationally and internationally

6.2.2. International framework for the provision of VTS

~~The legal basis of VTS lies in both UNCLOS and SOLAS. Although aimed primarily at coastal states, Harbour Masters should be very mindful of the legal and operational basis and the associated requirements for VTS in the management of waterways for which they have responsibility.~~

~~UNCLOS Article 21 pertains to coastal States' rights to adopt laws and regulations for shipping through the territorial sea in respect of such matters as the safety of navigation and the regulation of maritime traffic, the protection of navigational aids, the preservation of the environment of the coastal State and the prevention, reduction and control of pollution thereof.~~

~~SOLAS regulation V/12 affirms that VTS contribute to safety of life at sea, safety and efficiency of navigation, and protection of the marine environment from possible adverse effects of maritime traffic. Governments of SOLAS contracting States may establish VTS where, in their opinion, the volume of traffic or the degree of risk justifies such services. They have a legal obligation ("shall") to follow, wherever possible, the guidelines developed by IMO noting that the use of VTS may only be made mandatory in sea areas within the territorial sea of coastal states.~~

~~From the outset, IALA has taken a leading role in the development of IMO documents relating to VTS. In 1968, IMO adopted Resolution A.158(ES.IV) concerning Recommendation on "Port Advisory Services". Rather general in nature, this Recommendation was later superseded by Resolution A.578(14) concerning "Guidelines for Vessel Traffic Services", which was adopted in 1985. Twelve years later, in 1997, a new Resolution was adopted. Resolution A.857(20) supersedes Resolution A.578(14) and is still in force today.~~

~~Annex 2 of the Resolution contains "Guidelines on Recruitment, Qualifications and Training of VTS Operators". The following year, in 1998, IALA's much-anticipated "Recommendation on Standards for Training and Certification of VTS Personnel" (V-103) was published. Publication of a series of associated and internationally accepted model courses on training and qualifications for different categories of VTS personnel followed.~~

~~IALA will provide information and guidance to its members on the conventions and other instruments that provide the international framework for the establishment of VTS.~~

~~As necessary, IALA will work with its members and with other international organisations towards maintaining the international framework.~~

~~**6.2.3. National competent authority and legislation and regulations for VTS**~~

~~Guidance will be created to assist members in the establishment of national frameworks for the establishment and operation of VTS competent authorities, including~~

- ~~Advice on the content of legislation and regulation~~
- ~~The relationship of VTS with other Aids to Navigation services~~
- ~~Responsibilities of a competent authority for VTS, and its organisational considerations~~
- ~~Certification and auditing of VTS providers and their staff~~
- ~~Promulgation of VTS information nationally and internationally~~

~~6.2.4.~~6.2.3. AtoN Planning

The planning of an aids to navigation system should normally start with a consideration of the Safety of Life at Sea Convention Chapter V, Regulation 13, which states

> *1. Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.*

2. In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines when establishing such aids.*

3. Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated.

** Refer to the appropriate recommendations and guidelines of IALA and SN/Circ.107 - Maritime Buoyage System*

Consideration of "the volume of traffic" and "the degree of risk" require informed judgement, but this can be greatly aided by the following.

- Marine traffic tracks and volume, most easily obtained by recorded AIS data
- Use of the "IALA Risk Toolbox"

Not all traffic can be assessed by consideration of recorded AIS data as vessels which are not required to carry an operating AIS unit may not be emitting AIS data and so will not appear in the AIS data record. These vessels may include some coastal vessels, fishing vessels, and leisure craft. Other data sources may be needed.

~~6.2.5.~~6.2.4. Risk management

The improvement of existing risk management analysis tools and the development of new ones will be an IALA objective, and the training of users of the tools will be another. IALA will work to develop and expand the tools presently available and will create guidance explaining the need, purpose, and use of the analysis tools.

IALA may engage commercial partners, or participate in group projects, to develop risk management analysis tools.

The IALA World Wide Academy will play an important role in raising awareness of the merits of risk management analysis and in facilitating the training of users of the risk analysis tools.

At present the number of expert users of the IALA risk analysis tools is limited. An expansion of global capability is important, possibly in regional training facilities as well as individual aids to navigation authorities.

~~6.2.6.~~6.2.5. Gathering and use of historical AIS data

The development of traffic monitoring should be normal practice by coastal states wishing to protect their coasts from the consequences of unwanted incidents. Already some of them, such as the European countries, have a complete set of AIS transponders along their coasts, allowing them to at least follow vessel activities and allowing the centre in charge of the monitoring to provide important information to the ships. Although such centres are not always called VTS, it maintains an image of the traffic and delivers information services as VTS centre. The increasing population of coastal AIS installations, operated by maritime authorities, led IALA to create a system for exchange of AIS information between national authorities, called IALA-NET. It is a world-wide service available only to national competent authorities, who provide maritime data from their areas of responsibility in exchange for data from other participants. The service is intended to assist participating authorities in fulfilling their duties in relation to maritime

For some years, IALA has encouraged its national members to contribute received AIS data to the IALANET system which stores historical AIS data and also allows IALANET participants to exchange data between countries. With the development of improved risk analysis tools which use historical AIS data, the value of the IALANET system has moved emphasis from the exchange of near real-time information between participating nations to the use of the historical data for risk analysis.

IALA will promote the use of historical AIS data in risk analysis for waterway design and will encourage national members to establish national or regional AIS data banks and to use the historical data to optimise waterway design.

~~6.2.7.~~6.2.6. Service requirements

Guidance will be provided to describe the requirements for the use of the IALA Maritime Buoyage Scheme and other aids to navigation including AIS, radar, and virtual aids to navigation for marking natural or man-made hazards, giving position information, and marking safe routes to protect safety of life and the environment.

The guidance will take account of international norms for the accuracy required of on-board position fixing systems, including electronic systems, but IALA may comment on these for specific waterway types or circumstances.

Guidance will be provided on correct management of aids to navigation services with emphasis on levels of service, reliability and availability criteria and norms, and quality assurance methods and standards.

~~6.2.8.~~6.2.7. The future of visual aids to navigation

Lighthouses and long range lights are currently a vital part of the mix of AtoN provided, they will continue to play an essential role for the foreseeable future, providing a backup for GNSS, sectors to mark dangers and leading/directional lights for safe channel approaches. The use of lights for landfall and waypoint navigation will continue to decline. However, some lighthouses will have an enhanced role, providing a platform for additional services.

Visual marks in the form of lights and buoys are essential in providing the mariner with visual orientation, spatial awareness; and waypoint, channel and hazard marking. This requirement will not change significantly in the near future. Enhancement such as AIS and racons and the use of virtual marking has a growing importance to enable the interface with vessel on-board systems.

7. ATON DESIGN AND DELIVERY

7.1. Content

Content areas are:

- Visual signalling (Vision, Colour, Conspicuity, Rhythmic characters)
- Range and performance (visual and audible)
- Design, Implementation & Maintenance
- Power systems
- Floating AtoN (buoys, moorings, stability, etc.)
- Environment, Sustainability & Legacy

7.2. Position statements

7.2.1. Light and vision

IALA will maintain and develop its guidance on visual perception, light measurement and computation, colour, reflective effects, and similar. Coordination with CIE will be important as well as the advice of specialists in this field.

7.2.2. Design, Implementation & Maintenance

IALA will develop and update guidance on Design, Implementation & Maintenance to assist all concerned in the long term provision of reliable, cost effective and environmentally responsible AtoN to deliver the IALA recommended AtoN availability

7.2.3. Floating Aids to Navigation

Guidance will be provided to support the design and operation of floating AtoN to include power systems, moorings, AIS and stability

7.2.4. Safe working practices

IALA will provide guidance for considered best practice for safe working but prescience will always be given to local and National regulation.

7.2.5. Providing AtoN Services in Extremely Hot Climates

This challenging topic has not been analysed by IALA before 2016, and work will be carried out to generate guidance on the design, performance, operation and maintenance of AtoN in extremely hot climates, including Human Factors related to working in extremely hot climates

7.2.6. Sustainability in AtoN provision.

Sustainability is a key area of interest for IALA and emphasis will be placed on environmental responsibility in aids to navigation provision, with an emphasis on sustainable power sources, especially renewable energy sources and newly-emerging power storage systems. Guidance documents will include advice on safe disposal of consumables related to aids to navigation power systems, including primary batteries, secondary batteries, solar panels, and electronic components. Treatment, use, and disposal of materials with a significant environmental impact such as mercury in older lighthouse pedestals, anti-fouling on buoys and structures, paints and solvents, will be included in guidance documents.

Legacy structures with ongoing use as AtoN and which may be subject to local preservation regulations will be the subject of specialist guidance to ensure that their heritage features are preserved while the aids to navigation service is not compromised.

7.2.7. Legacy

Aids to navigation have a long heritage and the history of lighthouses has an attraction for many outside the world of aids to navigation service providers and users.

In many littoral countries lighthouses and similar aids to navigation, and also artefacts and publications associated with them, form an important part of the national heritage and are being recorded and preserved for future generations.

When heritage structures continue to be used as aids to navigation, the generation of guidance to advise on their maintenance and correct preservation will remain part of IALA's work.

Although the conservation of structures and artefacts no longer used as aids to navigation, the preservation of historical records, and similar work are not within its remit, IALA will encourage this heritage activity and will support it when and as it can.

To facilitate the preservation and maintenance of lighthouses and other buildings no longer used as aids to navigation, and also to consider the preservation of artefacts and documents, IALA will from time to time convene the IALA Heritage Forum. The Forum will provide an opportunity for the exchange of information and experience in this maintenance and preservation work. It will be open to IALA members and to interested non-members by approval of the Secretariat.

8. RADIO-NAVIGATION SERVICES

8.1. Content

Content areas are:

- Satellite positioning and timing
- Terrestrial positioning systems
- Racon & radar positioning
- Augmentation services (DGNSS)

8.2. Position statements

8.2.1. ~~Positioning Services~~Satellite positioning and timing

IALA sees resilient positioning as desirable for safe and efficient navigation. At present the GNSS systems GPS GLONASS and Galileo provide global coverage. (Galileo initial services were~~was~~ declared operational on 2016-12-15 with 18 of its projected 30 satellites.)

The BeiD~~d~~ou GNSS system is under development and will provide extra resilience when operational.

IALA is not directly concerned with the provision of Global Navigational Satellite Services (GNSS) nor with the provision of augmentation services via satellite, but encourages the provision of these services.

All four GNSS mentioned above use the same frequency band for positioning signal broadcast, and all can be vulnerable to jamming and spoofing by a local terrestrial signal. Increased positioning resilience for navigators can be achieved by the provision of terrestrial radio-positioning services.

8.2.2. ~~SBAS~~

~~Maritime service providers could use SBAS data to enhance their marine beacon DGNSS services, either through the provision of additional integrity information, or as an alternative source of correction information. The aim is to develop a Guideline on SBAS use.~~

~~SBAS are designed primarily for aviation use and IALA will work to understand how SBAS data can be used safely and correctly in the maritime sector~~.

8.2.3. Terrestrial positioning systems

Mis en forme : Normal, Gauche

8.2.3.1 R-~~M~~mode

~~**8.2.3.** *radio-navigation services for GNSS resilience –Conversion of existing DGNSS radio beacons for GNSS backup service*~~

R-Mode (Ranging Mode) is a proposed terrestrial backup navigation system, independent to GNSS, which uses ranging signals typically transmitted from existing maritime infrastructure, for example, medium frequency (MF) radio beacons and/or AIS base stations.

Noting the large number of DGNSS Medium Frequency Radio Beacons in service worldwide, IALA views the conversion of these to R-Mode operation as having high potential for providing global network of harmonised terrestrial back-up positioning for GNSS for maritime use. Positioning accuracy would depend on beacon locations, geometry, and other factors.

IALA recommends ~~to~~that its members ~~to~~ provide DGNSS service in the band 283.5-325 kHz (R-150). However should its members opt to discontinue providing DGNSS ~~corrections~~ broadcasts, –IALA recommends that its members should retain existing DGNSS Medium Frequency Radio Beacons, and should use them for GNSS backup services, such as R-Mode.~~ when IALA has developed technical Recommendations and Guidelines in this area.~~

~~If existing DGNSS Medium Frequency Radio Beacon broadcasts are to be discontinued, then the sites and antennas should be retained in anticipation of conversion to R-Mode operation.~~

IALA will publish a Recommendation for GNSS backup operation of Medium Frequency Radio Beacons when the technical requirements are finalised. Further information about R-Mode as a concept as well as the present status of development is provided in ANNEX B.

~~Conversion of existing DGNSS stations to GNSS backup could include provision for adding the broadcast of Maritime Service Portfolio (MSP) information in NAVDAT format. The technological implications of this are still to be determined but IALA notes the potential for this service.~~

~~8.2.4.~~*8.2.3.2* ~~*Terrestrial radio-navigation services for GNSS resilience*~~ *– Loran-C, Chayka, eLoran, eChayka*

In some areas Loran-C and Chayka may not provide the position fixing accuracy for satisfactory GNSS resilience, and IALA views conversion of existing Loran-C and Chayka chains to eLoran-eChayka as desirable, or alternatively their replacement by a more accurate system.

~~**8.2.5.** *Terrestrial radio-navigation services for GNSS resilience – FERNS Council*~~

IALA will strongly support the work of the Far East Radionavigation Service (FERNS) to provide Loran-C and Chayka services and other future radio-navigation services. Future services provided by the FERNS Parties may include eLoran and/or R-Mode if the FERNS Parties so decide. IALA will cooperate with the FERNS Council for the creation of eLoran Recommendations.

Following the result of the 25th Session of the FERNS Council, IALA will work even more closely with the FERNS Council for coordination of radionavigation services and e-navigation services, including Maritime Service Portfolios.

~~8.2.6.~~*8.2.3.3 Timing services*

IALA does not consider that the provision of [terrestrial broadcast] timing services is normally within its scope, except as may be inherent in terrestrial positioning services. This may change as terrestrial positioning

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services or GNSS backup systems develop. Such future timing services could be used to backup timing for AtoN (e.g. synchronisation of lights) or used as backup of timing for communications systems (e.g. AIS/VDES).

8.2.4. Racon & radar positioning

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Mis en forme : Titre 3, Justifié

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~~-~~IALA continues to recommend the use of racons for relative positioning. The use of radar increases resilience of the entire positioning solution. IALA publishes guidelines on providing racon service.

Advanced radar technology, so called New Technology (NT), applied to maritime radar is rapidly improving the ability of radars to distinguish targets under poor conditions. IALA encourages the development of NT radars and the improvements they offer. However, there is a reduction of operating range when NT radars are used with racons. IALA encourages radar and racon manufacturers to continue work on NT radar compatibility with racons.

Generally, radar and racon are used for relative positioning. A new service known as eRadar/eRacon can be used for absolute positioning. IALA encourages continued research in positioning services that are independent of GNSS and increase PNT resilience.

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8.2.5. Augmentation services (DGNSS)

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Mis en forme : Titre 3, Justifié

8.2.5.1 Radiobeacon DGNSS

Mis en forme : Titre 4

IALA considers the potential for the provision of additional services ~~that may provide~~ using the 300 kHz broadcast infrastructure, in addition to DGNSS correction information. This may include corrections for additional constellations or the use of the ~~detail~~data link to convey other information.

~~8.2.7.~~*8.2.5.2 SBAS*

Mis en forme : Titre 4, Gauche

Maritime service providers could use SBAS data to enhance their marine beacon DGNSS services, either through the provision of additional integrity information, or as an alternative source of correction information. The aim is to develop a Guideline on SBAS use.

~~SBAS are designed primarily for aviation use and~~ IALA is working~~will work~~ to support SBAS use in the maritime sector ~~to understand how SBAS data can be used safely and correctly in the maritime sector~~

IALA encourages SBAS stakeholders to contribute to the development of guidelines on the use of SBAS.

9. VESSEL TRAFFIC SERVICES

9.1. Content

Content areas are:

- VTS implementation
- VTS operations
- VTS data and information management
- VTS communications
- VTS technologies
- VTS Auditing and assessing
- VTS additional services

9.2. Position statements

9.2.1. Operations

Apart from its major role in improving safety and efficiency of vessel traffic, and protection of marine environment, VTS will increasingly contribute to efficient information management in the maritime domain. In the global maritime environment, safety and efficiency not only depend on well-organized traffic management and exchange of information but also on standardized and harmonized concepts, systems and services.

The complexity of utilization of the seas is growing, threatening the manoeuvrable space for shipping. The need for proactive management of vessel traffic in these areas is thus likely to increase, further driving the interaction between ships and shore authorities. Management of operational space from a shipping perspective by evolving VTS, supported by the capabilities of e-Navigation and its Maritime Service Portfolio developments, and in conjunction with Marine Spatial Planning are seen as candidate combinations on how to deal with the challenges for safe, secure and efficient navigation in clean waters.

IALA will create guidance for the use of VTS providers, on the correct operation of a VTS to ensure the safety and efficiency of vessel movements in the VTS area. Guidance will cover the various types of VTS, port, coastal, regional, national, and the services that can be provided.

This guidance will aim at harmonising VTS operational procedures worldwide, so that ships' masters will encounter familiar VTS procedures, but recognising that local requirements, such as geographical characteristics, traffic density and diversity, accessibility, and environmental conditions may sometimes dictate special needs. The determination and decision of which services, and on what level they shall be provided to shipping and other stakeholders will remain assigned to the relevant national, regional or local authorities.

IALA guidance for VTS operations will include

- Performance standards
- Performance monitoring and evaluation
- Management and staffing
- Decision support tools
- Digital information exchange
- Voice communications procedures and standard phrases

IALA will cooperate with sister organisations, in particular with IMPA and IHMA, to ensure that its operations guidance is complete and appropriate.

9.2.2. Berth to berth VTS, Sea Traffic Management

Vessel Traffic Services should be provided in defined and recognised VTS areas. IALA does not support the concept of berth-to-berth provision of vessel traffic services. Similarly IALA views the concept of Sea Traffic Management as a concept meriting study, but for which adoption, if it occurs, is likely to be some years away, except perhaps for cooperating states in a limited sea area.

9.2.3. Interaction and cooperation of VTS with other national or regional services

Today there are several other operational organisations with specific maritime responsibilities, such as Maritime Rescue Coordination Centres, Maritime Assistance Services, Maritime Security Alert Centres, Pollution Information Centre, Fishing Surveillance and Police Centres, National Coordinator for maritime safety information etc. They all need similar information and communication systems as are used for VTS, and they are often run by people who have more or less a similar background and a common basis of training, such as the use of the Standard Marine Communication Phrases.

e-Navigation, which promises to assemble all the relevant information and deliver this to stakeholders through a common communication infrastructure, could facilitate the work of these organizations. In the light of e-Navigation developments, maybe the case can be made to regroup or merge some of these operational centres which the IMO calls Maritime Operational Services. IMO has discussed this matter some time ago, but no conclusion was reached, perhaps because the necessary concepts and infrastructure for seamless and effective information exchange did not exist. But this may change, now that e-Navigation is coming about. The discussion on e-Navigation encompasses the concept of Maritime Service Portfolios which has similarities with the concept of Maritime Operational Services. In any case we must keep in mind that it will be detrimental if individual shore side stakeholders would continue to develop their own systems and communication infrastructures in isolation. Not only will the cost and the technical complexity increase, but it will increase further the complexity of the task of the officer on watch. It is obvious that the VTS in its original port and coastal capacity will be the nucleus of such integration.
Although the coordination of VTS with other services, such as SAR, police, customs, and border control will be a matter for local, national, or regional decision, IALA will work to raise awareness of the capabilities of VTS sensors and VTS organisations to complement the work of these other services at times of special need, and will include awareness of this in its training.

9.2.4. VTS Technology

IALA's technological guidance for VTS will describe in general terms the sensor and system performance required for VTS equipment installations, but IALA will not concern itself with technical specifications.

9.2.5. ~~Unmanned~~ Autonomous ~~vessels~~ships in a VTS area

IALA will prepare for the advent of unmanned vessels and for their interaction with conventional manned vessels within VTS areas. IALA will cooperate with other international organisations in this preparation work.

Initial work in this area will consider the interaction process of ~~unmanned vessels~~ autonomous ships with conventional traffic, the information flow between ~~unmanned vessels~~ autonomous ships and shore authorities, and the related information exchange with conventional traffic.

IALA envisages that ~~unmanned vessels~~ autonomous ships will need services from shore, including MSI packaged in MSPs, perhaps in formats specific for ~~unmanned vessels~~autonomous ships. (See later in this document.)

10. TRAINING AND CERTIFICATION

10.1. Content

Content areas are:

- Training and assessment
- Competency certification and revalidation
- Simulation in training
- Human factors and ergonomics
- Capacity building (Model courses)

10.2. Position statements

10.2.1. Management of Training and Certification Documents

The WWA will take responsibility for the coordination, correct order, and completeness of the Recommendations and Guidelines which sit below the Training and Certification Standard. Committees will draft these Recommendations and Guidelines but the WWA will advise to ensure a complete and coordinated set of these Recommendations and Guidelines.

10.2.2. Training and assessment

In response to the need for correct and complete training, IALA, and in particular the IALA World-Wide Academy (WWA) will, together with the IALA committees, develop model courses on aspects relevant for marine aids to navigation and VTS personnel. This includes all significant managerial, operational and technical aspects described in IALA documents. Technical Committee work will normally be the source of the Model Courses used by the WWA, with the Committees assisted by WWA experts.

10.2.3. Competency certification and revalidation

Standards of training and certification of VTS operators, supervisors, and managers, as well as AtoN managers and technicians are provided as IALA WWA Model Courses. The Model Courses should be used by accredited AtoN and/or VTS training organisations (ATO´s).

The WWA will assist national competent authorities with the process of accrediting training organisations, and provide advise including advice on the training of trainers.

IALA recommends systematic and sustainable training as well as certification of AtoN and VTS personnel, and the WWA will continue to encourage both IALA members and non-members to do so.

10.2.4. Mandatory training and certification

Mandatory training and accreditation of VTS operators is considered to be essential for vessel safety in VTS areas, and IALA will work towards implementation globally.

While systematic and sustainable AtoN training and certification is recommended strongly, this is not mandatory at this stage.

10.2.5. Capacity Building

The WWA will focus its capacity building activities on those states in greatest need. A methodology to determine these needs, based on the maturity of maritime management, volume of traffic and degree of risk, has been developed.

Funding of the activities of the WWA is based entirely on donations, and IALA members are encouraged to support the WWA with donations and in kind support for dedicated projects.

11. DIGITAL COMMUNICATIONS TECHNOLOGIES

11.1. Content

Content areas are:

- Wide/Medium bandwidth systems (AIS & VDES)

- Automatic Identification System (AIS)
- VHF Data Exchange System (VDES)
- Narrow bandwidth systems (NAVDAT, MF beacons, etc.)
- ~~Harmonised maritime connectivity (Maritime Internet of Things, intelligent sensors, AtoN monitoring, etc.)~~

Commenté [JU1]: It seems to be better sit in Section12 of information services.

11.2. Position statements

11.2.1. Harmonised Connectivity / Telecommunications

IALA will focus on:-

- Automatic Identification System (AIS)
- The VHF Data Exchange System (VDES)
- 300KHz broadcast using converted DGNSS stations
- 500KHz broadcast
- ~~The Maritime Cloud~~

Commenté [JU2]: IALA is still recognized as the technical authority of AIS and thus needs to maintain its expertise.

Commenté [JU3]: It seems to be better sit in Section 12 of information services.

IALA notes that other digital radio communications, including existing and future satellites services and HF digital radio may be used for MSP broadcast, but will not expend effort in these areas.

11.2.2. Automatic Identification System (AIS)

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~~11.2.2.~~11.2.3. VHF Data Exchange System (VDES)

VDES will be the successor to the present AIS, and includes the present AIS frequencies AIS1 and AIS2. Shore authorities should plan to convert their existing AIS base station networks to VDES base station networks as soon as the technical characteristics of VDES have been finalised by IALA Recommendation and the publications of the International Telecommunications Union (ITU).

VDES is expected to become the primary means for shore authorities to provide toll-free higher-speed maritime services in coastal and harbour areas. Implementing VDES ashore and afloat will enable provision of harmonised shore services without communications time cost, and the freeing of the channels AIS1 and AIS2 for safety of navigation.

VDES will require upgrading of ship AIS systems to the VDES standard. This may involve firmware upgrade for some newer AIS ship units or replacement of hardware for older units.

IALA will maintain its online register of AIS Application Specific Messages and will encourage the moving of these and other messages which are not for safety of navigation from AIS1 and AIS2 to other VDES channels.

~~11.2.3.~~11.2.4. Longer range terrestrial broadcast of MSPs

IALA will encourage the provision of MSPs to longer range by digital terrestrial radio using converted MF DGNSS stations and 500 KHz broadcast.

In summary, IALA's work to achieve harmonised digital radio communications will focus on:-

- The VHF Data Exchange System (VDES)
  - For terrestrial and satellite communications for higher-speed delivery of MSPs

- To about 30 miles from shore

- Converted MF DGSS stations [possibly using NAVDAT format]
  - For lower-bandwidth delivery of MSPs
  - And optionally DGNSS messages
  - To about 100 miles from shore
  - And converted to R-Mode for GNSS back-up positioning

- 500KHz and possibly other channels using NAVDAT format as the replacement for Navtex services
  - For lower-speed delivery of MSPs
  - Over long range

12. INFORMATION SERVICES

12.1. Content

Content areas are:

- Data models and data encoding (IVEF, S-100, S-200, ASM, etc.)
- Vessel tracking and data exchange systems
- e-Navigation user requirements
- Terminology, symbology, and portrayal
- Harmonised maritime connectivity (Maritime Internet of Things, intelligent sensors, AtoN monitoring, etc.)
- The Maritime Cloud

Commenté [JU4]: It seems to be better sit in Section12 of information services.

Commenté [JU5]: It seems to be better sit in Section 12 of information services.

12.2. Position statements

12.2.1. Data modelling

The management and promulgation of information on aids to navigation is carried out at national and international level. As part of the development of e-Navigation, IALA has been allocated the S-200 domain in the IHO S-100 GIS registry.

IALA will provide advice for the use of national competent authorities on the correct management of aids to navigation information and its provision to international registries.

With the change from paper charts to electronic displays, the correct portrayal of AtoN on electronic displays is vital to safe navigation. IALA will work with its members and with the IHO to assist in ensuring correct portrayal of AtoN information.

~~12.2.2.~~ Harmonised Connectivity / Information Registries ~~/ Harmonisation~~

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The harmonised connectivity of all e-navigation elements is essential to ensure delivery of Maritime Services and to avoid erroneous interpretation of received data. This will require:-

- Common Marine Data Structure (based on IHO S100)

- Establishment of a Unique Indentifiers for Maritime Resources ~~[Maritime Identities Register]~~
- Harmonised MSPs
- Harmonised communications

The Common Marine Data Structure uses the International Hydrographic Organisation (IHO) S-100 Registry will be the means by which e-Navigation information is registered and made available to the maritime community.

IALA will use its S-200 Domain within the S-100 Registry for the registration of aids-to-navigation information. A management structure for maintaining this Domain will be established and operated by IALA, and guidance documents for this management will be created.

IALA will work to establish a system of Unique Identifiers for Maritime Resources ~~[Maritime Identities Register]~~, and will cooperate with other international organisations to achieve this. IALA does not have an ambition to be the host of this Register.

~~12.2.3.~~12.2.2. Delivery of Maritime Services / Implementation

IALA will work for the harmonisation of maritime services using the Maritime Services Portfolios (MSPs) scheme of the International Maritime Organization (IMO) e-Navigation Strategy Implementation Plan (SIP), updated to reflect the latest needs, and adapted for digital telecommunications. See Annex 7, page 11 of IMO document NCSR1/28, which lists sixteen initially proposed MSPs.

IALA will cooperate with other bodies, including the IMO, the IHO, and the World Meteorological Organization (WMO) to coordinate a structure of MSPs. IALA envisages that this set would include some globally harmonised MSPs and other MSPs that would be defined locally or by particular user groups.

IALA will work to harmonise MSPs for Vessel Traffic Services (VTS), including Information Services, Navigational Assistance Services, and Traffic Organisation Services, again with a mix of globally harmonised and locally defined services.

The provision of Maritime Safety Information (MSI) in the form of digital Maritime Service Portfolios (MSPs) is a future component of VTS. IALA will work with IMO, IHO, CIRM, and others towards the definition and harmonisation of these digital services. IALA will assume responsibility for the detail of MSPs allocated to VTS.

The provision of maritime services for unmanned vessels has not been addressed yet by IALA. IALA will decide at a later date what services for unmanned vessels should be within its concern.

~~12.2.4.~~12.2.3. Maritime Cloud

The Maritime Cloud is planned to be a digital Information Technology (IT) framework consisting of standards, infrastructure and governance that facilitates secure interoperable information exchange between stakeholders in the maritime community using the principles of Service Oriented Architectures (SOA). The core of the Maritime Cloud consists of three key infrastructural components providing central framework services.

It will contain a registry of Maritime Service Portfolios (MSPs), a Maritime Identity Register which is expected to be the set of Unique Identifiers for Maritime Resources mentioned above, and a geo-aware Maritime Messaging Service which takes account of available data links, and can use geo-casting or addressed messages.

This concept is presently being developed by the EfficienSea 2.0 project in which IALA is a contracted partner.

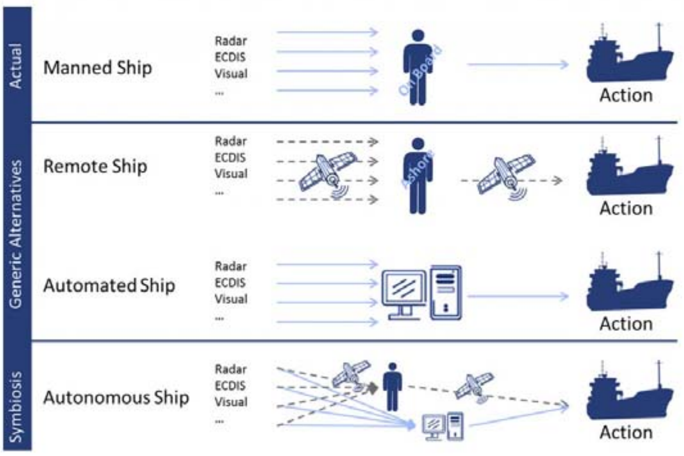
~~12.2.5.~~12.2.4. Digital services for autonomous vessels

Next generation modular control systems and communications technology will enable wireless monitoring and control functions both on and off board. These will include advanced decision support systems to provide a capability to operate ships remotely under semi or fully autonomous control.

Rolls-Royce describes communications and connectivity for its vision for the autonomous commercial ship as follows:

“Autonomous vessels will still need human input from land, making connectivity between the ship and the crew rucial. Such communication will need to be bidirectional, accurate, scalable and supported by multiple systems – creating redundancy and minimising risk. Sufficient communication link capacity for ship sensor monitoring and remote control, when necessary, has to be guaranteed. The project is exploring how to combine existing communication technologies in an optimum way for autonomous ship control. We have created a simulated autonomous ship control system which will be connected to a satellite communications link as well as land based systems. This will allow us to explore the behaviour of the complete system.”

The MUNIN project saw the evolution of the autonomous vessel as in its diagram below.



While the control and navigating of unmanned commercial ships is expected to be by private industry using digital connectivity of its own choice, it could be expected that some digital shore services may be adapted or extended in future to provide Maritime Safety Information (MSI) in an appropriate format for these vessels.

At this time it is not clear what MSI will be needed by autonomous ships, in what sea areas and via what communications. However IALA will maintain a close monitoring of developments with the intent of providing information and guidance to its members as this field develops.

~~12.2.6.~~12.2.5. Cyber security

Cyber security for maritime services will be developed in cooperation with other international and regional organisations and will require coordination of shore service providers, VTS system designers, and ship system designers.

Cyber security should be provided in applications, not within the communications transport layer.

At present IALA Committees have limited competence in cyber security and will not attempt to create guidance in this field. Members concerned about cyber security should address national or regional experts in government or industry for advice and implementation.

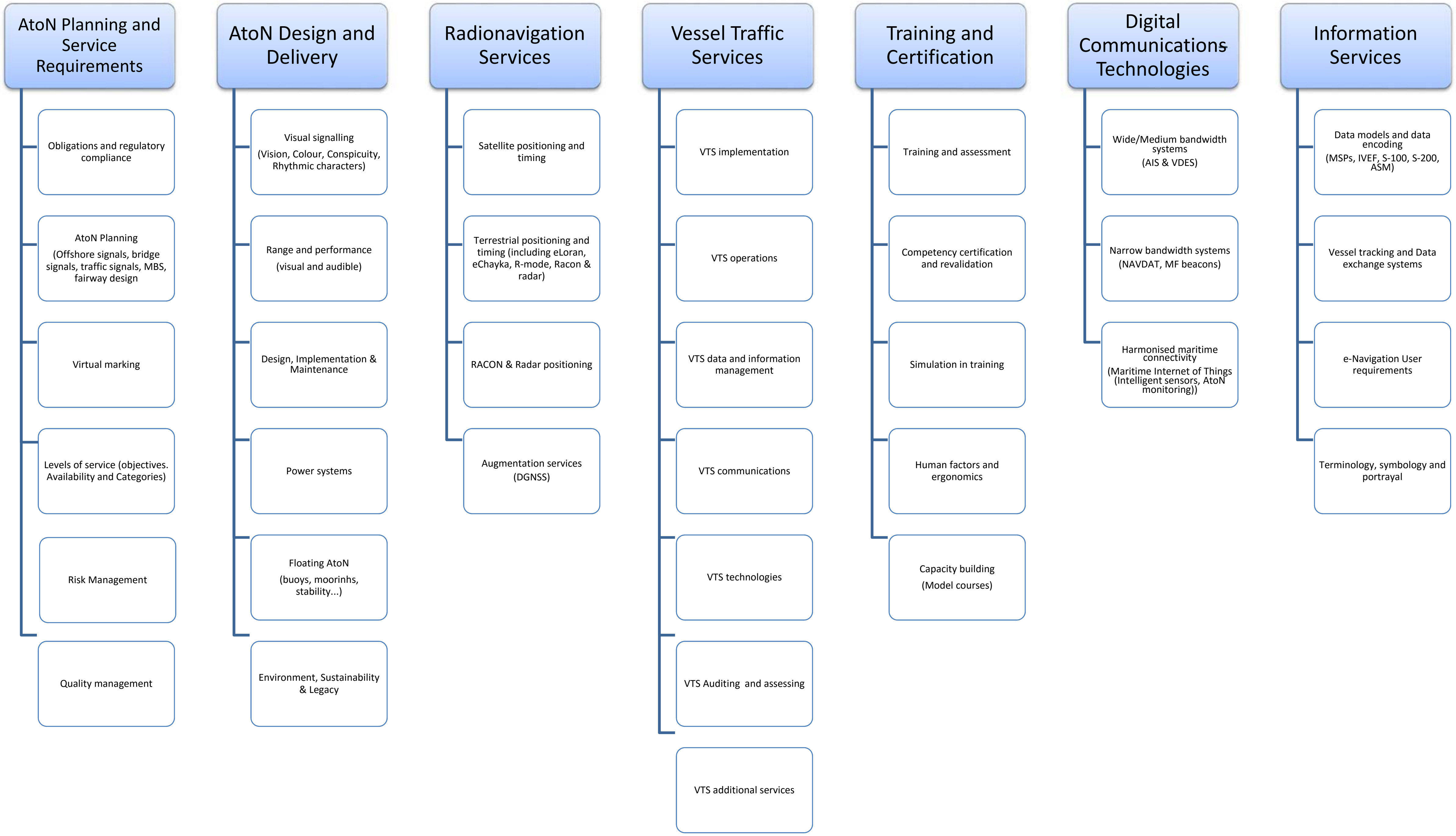
~~12.2.7.~~12.2.6. IALA Dictionary

At present there still remains some inconsistency in the definition of aids to navigation terms within IALA guidance documents. The IALA Dictionary was created to eliminate this by being a single reference point for aids to navigation terms to ensure consistent use and meaning throughout the IALA document suite. The Dictionary will also carry a list of standard IALA acronyms.

This work is increasingly important as IALA moves towards introducing its first standards and as the change to an IGO proceeds.

As the Dictionary is developed, definitions and acronyms within guidance documents will be removed, or reduced in scope.

13. ANNEX A – STRUCTURE OF STANDARDS



14. ANNEX B R-MODE - AIMS, TECHNICAL APPROACH AND CURRENT STATUS.

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14.1. INTRODUCTION

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The need for resilient positioning, navigation and time (PNT) data has been well documented [1]. Systems such as AIS (Automatic Identification System), ECDIS (Electronic Chart Display and Information System), ARPA (Automatic Radar Plotting Aid) and other navigation sensors use GNSS derived PNT data, the reception of which can be denied through natural and man-made interference.

In the near future further GNSS will become fully operational (Galileo and BeiDou) which will further increase the number of available satellite signals. However, these all GNSS share similar signal structures, frequency bands and low signal power levels, and therefore have a common vulnerability to signal interference; and the development of an alternative backup system is recommended.

R-Mode (Ranging Mode) is a proposed terrestrial backup navigation system, independent to GNSS, which uses ranging signals typically transmitted from existing maritime infrastructure, for example, medium frequency (MF) radio beacons and/or AIS base stations.

This Guideline provides a review of the current view of R-Mode operation, specification, hardware and software and provides a review of its current development. It is envisaged that this Guideline will be updated at key intervals and used to track progress of R-Mode development. It is provided as a living document detailing the current situation to allow other interested parties to participate in the development of R-Mode without having to start from the beginning. Interested parties interested in assisting in the development of R-Mode are invited to liaise with the IALA ENAV WG5 vice Chair, Mr Michael Hoppe (contact details provided in Section 14).

14.2. Scope

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The aim of this guideline is to capture the current considerations for R-Mode to enable the widest possible support in its development. Publication of the plans, activities and technical considerations should allow for collaboration and a cohesive development, in an open and unrestricted manner.

14.3. Background

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Adding additional ranging mode (R-Mode) information to existing maritime infrastructure is appealing as much of the hardware is already in place, removing the need to procure and install expensive transmitters and antenna systems. The system is already standardised and frequencies assured for maritime navigation. In addition, marine radiobeacons are already installed along most major shipping routes as shown in Figure 1~~Figure 1~~.

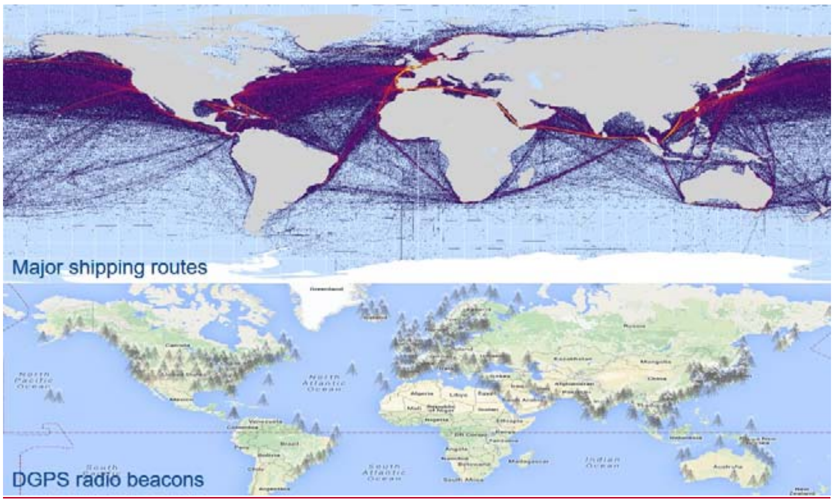

Figure 11: Image of the major shipping routes identified though AIS tracks (Top) and the location of marine radiobeacons (Bottom) showing good alignment of services [source forobs.jrc.ec.europa.eu & IALA]

AIS base stations have also been installed in significant numbers around many coastlines, have protected frequencies and already serve the mariner; and therefore are a good candidate for R-Mode transmissions.

14.3.1. ACCSEAS

The European collaborative project ACCSEAS developed the idea of R-Mode by supporting a feasibility study which considered the suitability of adding ranging information to marine radiobeacon DGNSS and AIS base stations.

The ACCSEAS feasibility study was split into the following parts:

- Parts 1 and 2 examined the R-Mode potential of the MF DGNSS signal [2, 3]; the recommended approach was to add CW signals to the broadcast and to develop the pseudorange from the carrier phase.
- Part 3 and 4 examined the R-Mode potential of the AIS signal [4, 5]; the recommended approach was to estimate the pseudorange from timing bit transitions and requires no modification to the signal structure.
- Part 5 examined the combination of MF transmission together with AIS and the combination with eLoran which at that provided time operated from 5 stations around the North Sea area [6].

The performance assessments for each of the three signal types outlined above were considered in the feasibility study, and the lower bounds of the expected positioning accuracy were calculated, based on conservative assessments.

As the position is calculated through trilateration from terrestrial transmitters, the resulting performance is a function of the received signal power, the observation time of the receiver (nominally assumed to be 5 seconds), and the geometry of the known transmitter locations. For each signal considered, sources of error were considered where possible, however errors such as unknown offsets in the synchronization of transmitters (this is relevant to all three signals) and propagation delays that would increase the observed range estimates (this is known to impact both MF and eLoran signals since they propagate as ground waves) were omitted.

The ACCSESS project concluded in 2015, and the project information remains available on the project website [www.accseas.eu] with the project deliverable reports available on the IALA website, within the e-Navigation test bed area.

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14.4. R-Mode MF

Marine radiobeacon transmissions are configured to provide signals over large geographical areas and are well distributed around the northern hemisphere and parts of the southern hemisphere.

The ACCSEAS feasibility study considered a number of possible methods of adding a ranging signal to the existing marine beacon system. The different options considered are outlined in the ACCSEAS feasibility study [1, 2], from which the approach outlined in section 2.1.3 was selected as the optimum solution at this time.

The selected approach was the maintain the existing MSK signal for legacy users, but to add two continuous wave transmissions to the band, one above and one below the central frequency. The separation of the two CW signals allows for a carrier phase type solution to be performed in order to estimate the accuracy. In addition, the MSK signal may be used to provide other information to the receiver, and may be used in the future to help resolve any ambiguities.

The ACCSEAS report suggests the two CW signals are positioned ±250Hz with respect to the center frequency, however this has been amended to ±225Hz to prevent overlap of CW signals between neighboring (in terms of frequency) stations.

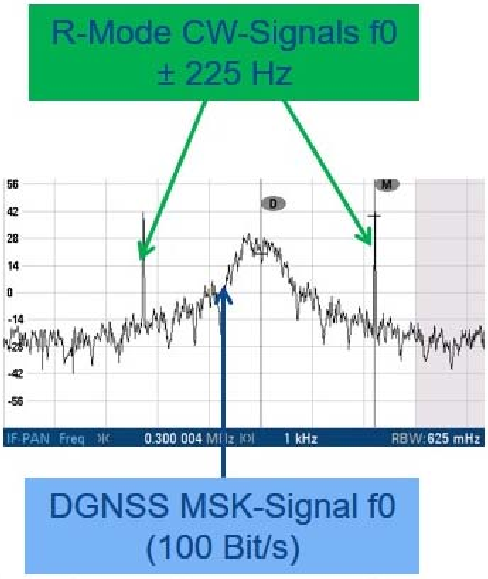

Figure 22: R-Mode spectral plot showing the two additional CW signals and the legacy MSK .

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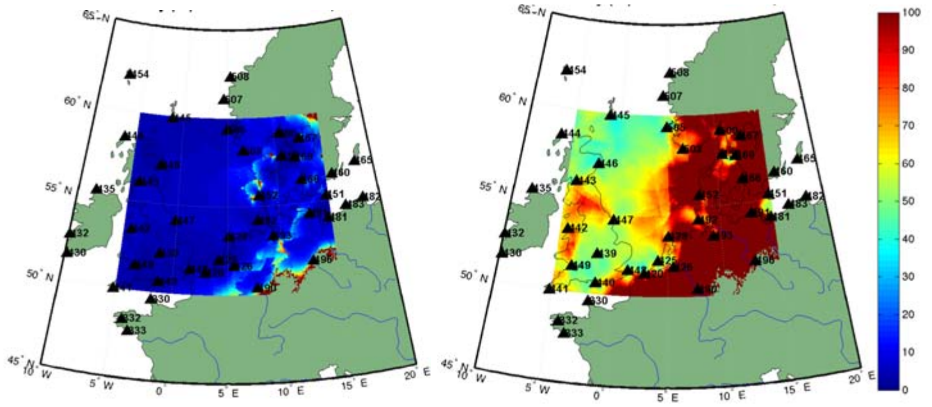

Figure 3~~3~~: MF DGNSS R-Mode day (left) and night (right) predicted positioning accuracy (m) using a 0-100m scale [3].

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The ACCSEAS feasibility study provides an estimation of the expected accuracies of marine radiobeacon R-Mode for day and night time conditions, taking into account the radiobeacon sites located in the North Sea region (Figure 3~~Figure 3~~). The theoretical performance by day is promising with the expected accuracies in the order of 20-30m deemed possible. At night the expected accuracy drops to 90+m as the effect of skywave interference is observed.

Further consideration and work is required to understand the impact of skywave effects and whether they can be suitably mitigated for MF R-Mode solutions. This question, and others will need to be addressed in due course and will form part of the further work.

14.4.1. Required hardware changes

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R-Mode provision via marine radiobeacon stations will require the introduction of a new modulator including a CW signal generator, connected to a precise source of UTC (independent of GNSS). It is likely that most service providers will opt to modify one processing channel on site, leaving the second channel as is to preserve DGNSS correction availability, at least until the approach is proven.

Costs for the modified hardware are to be defined.

14.4.2. Netherlands trials

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The ACCSEAS project developed and installed an R-Mode transmitter along the Dutch coast at Ijmuiden, capable of transmitting a test signal for approximately 50km. For the transmission of the R-Mode signals a typical MF transmitter and MF transmitting antenna were used. Based on the different solutions evaluated in the feasibility study the R-Mode transmitter was able to provide a standard MSK signal (legacy signal) and two CW signals (R-Mode signal). For this purpose, a prototype R-Mode modulator was developed which enabled the transmission of standard RTCM messages used for the DGNSS service and two independent CW signals which can be adjusted in terms of frequency and output. A rubidium clock was used to provide a source of precise timing.

The ACCSEAS project also developed a test R-Mode receiver with the capability of measuring the pseudo-range from the R-Mode transmitter. Further the R-Mode receiver was able to demodulate the MSK signal and decode the RTCM messages. Data on pseudo-ranges were logged along with position and time for later analysis. For the R-Mode test bed, a prototype R-Mode receiver was developed consisting of an H-field antenna, a band filter with pre-amplifier, and a PC with ADC board running MATLAB software. The receiver together with a rubidium clock were installed on a lighthouse tower in Noordwijk, about 25 km from Ijmuiden.

The first measurement campaign was performed over a two day period (07-08 February 2015). The recorded data were analyzed with respect to signal to noise ratio and the standard deviation of the measured range. The range was based on the phase determination of the two CW signals and the beat frequency of both signals to solve the ambiguity. The resulting ranging performance of the R-Mode signal using MF transmissions was very encouraging and validated the theoretical findings of the R-Mode feasibility study. The standard deviation (1-sigma) measured was in a range of 2-5 m (see Figure 4~~Figure 4~~). Nevertheless, it must be noted that these results were taken on a short distance of about 25 km and do not consider skywave effects; they also do not constitute a position solution.

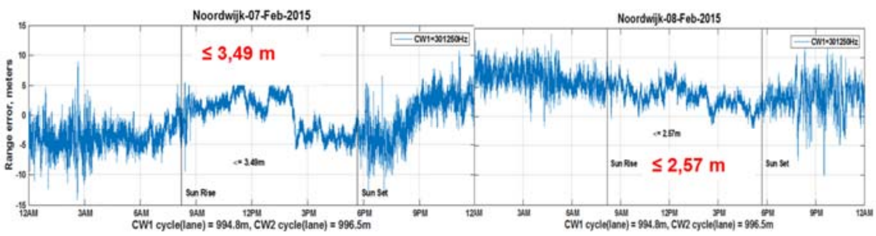

Figure 44: First R-Mode range accuracy measurements from Ijmuiden Noordwijk, February 2015

This was the extent of the work on marine radiobeacon R-Mode conducted under the auspices of the ACCSEAS project.

14.5. R-Mode AIS

As indicated previously, AIS base stations provide a significant opportunity for ranging, given the number installed and the timing nature of the signal. AIS transmissions are suitably configured to ensure the best range for a given location, generally providing data to users within line-of-sight reception.

The ACCSEAS feasibility study considered a number of potential options for using AIS for ranging [4,5] however the “Standard AIS transmission including Message 8” option [Section 2.3.1. in the above reference] was selected as the most suitable solution.

The feasibility report describes the solution in detail, however it can be summarised as making use of the existing signal specification through which a modified receiver would estimate both the times of bit transitions and the carrier phases of all available AIS base station signals. The approach would use the data bits from a Message 4 data string as they are predictable in both time and content, which enables better tracking. Message 8 data strings could also be used, for longer, more frequent signals with a fixed form which should improve the ranging performance and position update frequency.

The expected accuracy of R-Mode using AIS was considered in the feasibility report (Figure 5~~Figure 5~~). As with all triangulation systems, AIS positioning will be a function of transmit power, station numbers and their geography to the user and the antenna height. The primary limiting factor of AIS ranging is the short propagation distance of the signal, which limits the coverage area provided by such a system since a user must receive signals from at least three different AIS base stations to solve for latitude and longitude. Therefore, this approach, when used on its own, may be more suited to waterways with land on two sides, such as port entrances, canals and straits.

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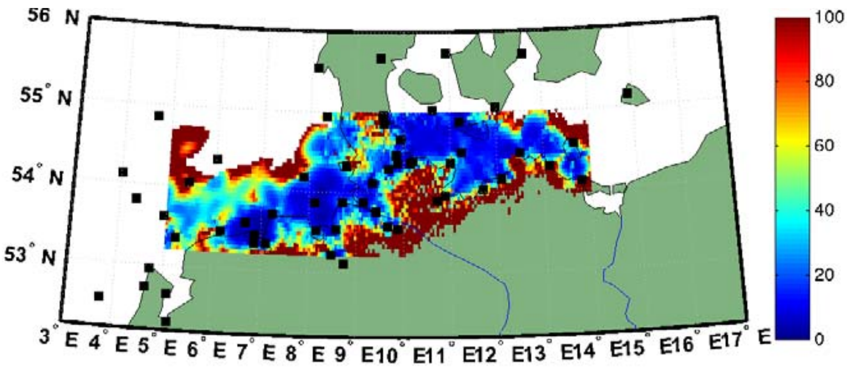

Figure 55: Predicted AIS R-Mode positioning accuracy (m) using a 0-100m scale [5].

The ACCSEAS project did not conduct any trials into AIS R-Mode. As such, there remain a number of questions to be addressed and investigated for AIS R-Mode, many of which are explained further in the guideline.

A different approach to positioning a vessel by using AIS transmissions have been presented at IALA ENAV18 by Dalian University [7].

It is also noted that a True Heading AB has a patent on the use of AIS data to confirm the reported position of vessels, which it considers may clash with AIS R-Mode. IALA is currently investigating this further.

14.5.1. Required Hardware Changes

A precise source of UTC will be required at the AIS base station, however most AIS base stations should be designed to accept an external clock and therefore should not require replacement.

14.6. R-Mode combination

The feasibly study also considered the use of multiple ranging sources, including a mixture of R-Mode signals from marine beacon and AIS transmitters. One of the strengths of the approach to R-Mode is that any timing signal can be considered, as long as its time can be traced to UTC, without the use of GNSS.

The study considered the addition of an eLoran signal and modelled the performance of it combined with marine radiobeacon and AIS R-Mode signals serving the Kiel canal (Figure 6~~Figure 6~~). As expected, the best performance was achieved when all signals were used. This approach reduced the degradation in the estimated position at night to being marginally poorer than the day time accuracy. The eLoran signal provides accurate timing over a very large area and therefore few are needed to provide a significant improvement, with the additional benefit of being able to provide time to the R-Mode transmitter. Precise timing of transmissions is one of the fundamental pre-requisites for any R-Mode services.

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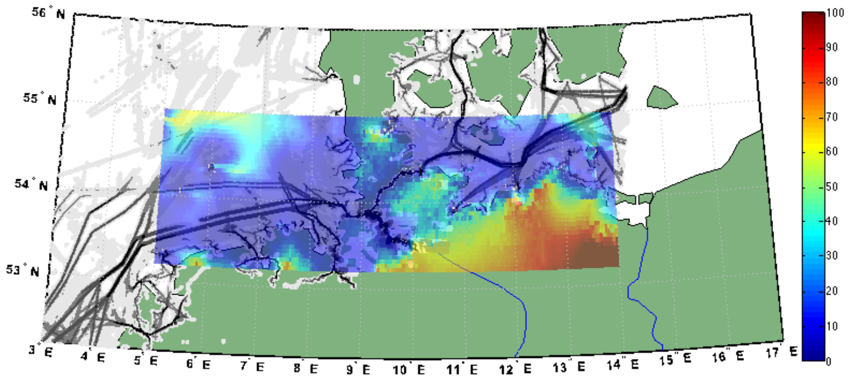

Figure 66: R-Mode performance overlaid on top of shipping density plot. Predicted R-Mode performance shaded using 0-100m accuracy scale. Shipping density shaded so that darker is higher density traffic.

The feasibility study concluded that as expected, more signals will result in increased performance and recommended that to achieve widespread resilient PNT, the best solution would be to use all signals available in a true all-in-view receiver.

It is also important to note that the need for a backup PNT is not uniform. The performance of a backup PNT system is most critical in the areas with the highest density of shipping traffic. Figure 1Figure 6~~Figure 6~~ shows the predicted R-Mode performance overlaid on top of the AIS derived shipping density plot. It is likely that this alignment of R-Mode performance with the high density shipping lanes will be true in other parts of the world as well, since those are the areas with the largest numbers of AIS and MF DGNSS stations.

The ACCSEAS project did not conduct any trials for combined performance.

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14.7. Prototype Transmitt and receive equipment

Tests performed during the ACCSEAS project, and since, have used one R-Mode transmitter and one R-Mode receiver. Both were connected to an atomic clock (Rb) to provide timing synchronization and therefore ranging measurements to be made at various distances. **Erreur ! Source du renvoi introuvable.**~~Figure 7~~ show the general system architecture and pictures of the prototype system equipment used for the tests to date.

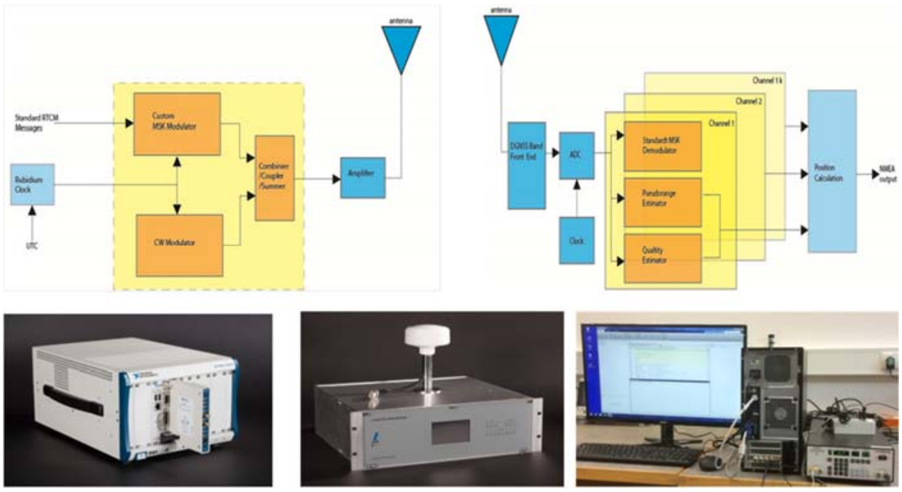

Figure 7~~7~~: R-Mode test equipment and system architecture

14.8. R-Mode Roadmap

Since the ACCSEAS project closed, a number of interested parties have been continuing the development of the R-Mode concept within the IALA E-Navigation Committee (ENAV). The ENAV Committee has developed an R-Mode development roadmap (Figure 8~~Figure 8~~) which provides a high-level overview of the expected duration and tasks needed to develop R-Mode from the conceptual ideal to reality.

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The roadmap was developed from an initial mindmap that was used to capture all of the remaining tasks required for the development of the system, for which estimated durations and priorities were added. These tasks were then ported to the Microsoft Project application through which the high level roadmap was generated. All three files are available in the following references [8, 9 and 10], should greater clarity be sought. The roadmap was calculated assuming consecutive tasks, however current developments are actioned as and when possible and therefore the dates indicated are unlikely to be met.

It is anticipated that the roadmap will be maintained annually during ENAV Committee meetings and updated within this document.

Figure 8~~8~~: High level R-Mode roadmap

14.9. Current activities

Interested parties continue to develop the R-Mode concept and the amount of interest in the approach is growing. The following sections outline the current investigations and studies taking place.

14.9.1. R-mode (MF) field tests

After the tests in Ijmuiden, further tests were performed in the German Bight by re-locating the prototype R-Mode equipment to an operational DGPS site in Helgoland. These tests are currently ongoing using various locations for the R-Mode receiver. This site enables a testing of the MF R-Mode ranging performance along the German and Dutch coastlines with distances of up to 230 km. The tests started in mid-August 2015 and will run over 2016. During the tests the R-Mode receiver was placed in different locations, starting from a distance to the transmitter of about 70 km with a stepwise increase towards a distance of 230 km. Table 1~~Table 1~~ provides information about measured distances and locations.

Receiver location	Time/Date	Measured Distance [km]	Remarks
Tönning	14.08.15 to 27.09.15	70	Propagation over sea water, low influence of sky wave
List (Sylt)	30.09.15 to 01.12.15	100	Mainly propagation over sea water moderate influence of sky wave
Groß Königsförde (Kiel canal)	03.12.15 to 24.02.16	130	Mixed sea and land propagation strong influence of sky wave
Terschelling (NL)	Ongoing since 05/2016	230	Propagation over sea water, strong influence of sky wave

Table 1~~1~~: Performed measurements from R-Mode site Helgoland

Figure 9~~Figure 9~~, Figure 10~~Figure 10~~ and Figure 11~~Figure 11~~ provide first results of the measured ranging error performed at locations in Tönning, List and Groß Königsförde. Measurements from Terschelling have not been analyzed, yet.

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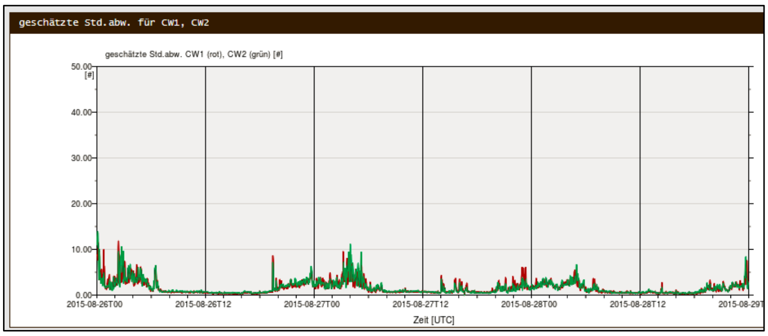

Figure 9~~9~~: Ranging error measured in Tönning at 27-29.09.2015

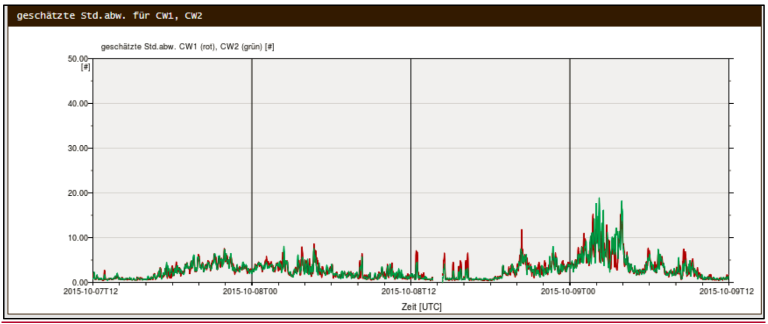

Figure 10~~10~~: Ranging error measured in List at 27-29.09.2015

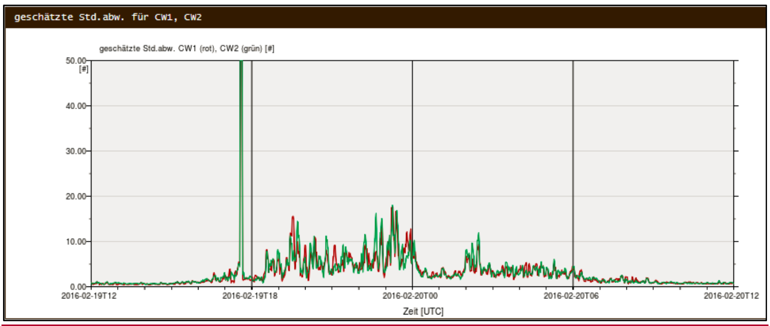

Figure 11~~11~~: Ranging error measured in Groß Königsförde at 19-20.02.2016

An analysis of the figures during day time shows a range error of approximately 1 m (1-sigma). This is much better than the results measured in Ijmuiden/Noordwijk (February, 2015). The reason for this could be due to a more robust transmitting antenna located on Helgoland. The day time error is more or less the same for distances between 70 and 130 km. Maximum errors are in a range of about 5 m (see Table 2~~Table 2~~). The effect of skywave could be clearly seen during night in most cases, with range errors up to 10 m at night at a distance of 70 km, and a range error of up to 20m at a distance of 130 km.

As shown in the above figures the resulting ranging performance of the R-Mode signal using MF transmissions were very encouraging. Especially the daytime ranging accuracy of about a 1-2 m (1-sigma)

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shows the potential of MF R-Mode as a possible backup to GNSS. Nevertheless, as already shown in the feasibility study, the performance will degrade during night by a factor of about 10. It should be kept in mind that these measurements are for a single baseline from the transmitter to the receiver and the results represent a 1-sigma accuracy. These results do not yet relate to a 2D position, which remains to be calculated.

The main results can be summarised as follows:

- For R-Mode via marine beacons, the standard amplifier and antenna equipment already located at a DGNSS transmitter site may be used without specific modifications
- The additional R-Mode signals could be modulated to the MSK signal (DGNSS) without any measured degradation of the legacy signal (measured through the use of a local DGPS receiver which maintained operation)
- The on air field tests could validate the findings and estimations of the feasibility study performed in the ACCSEAS project.

As a summary of the performed measurements and the findings of the feasibility study table 2 provides a comparison of estimated and measured accuracies.

Results	Ranging (Day) [m]		Ranging (Night) [m]		Position Accuracy (Day) [m]	Position-Accuracy (Night) [m]
Estimated in feasibility study	2,7		-		≤ 10	≤ 100
Measurements from Ijmuiden/Noordwijk	2,5		-		≤ 10[1]	≤ 10[1]
Measurements from Helgoland	δ	Max	δ	Max		
- Tönning	0,5	4	1,5	10	≤ 5[1]	≤ 20[1]
- List	1	5,5	3	20	≤ 5[1]	≤ 20[1]
- Groß Königsförde	1	7	8,5	46	≤ 5[1]	≤ 50[1]

Table 22: Comparison of estimated and measured range accuracies

Test measurements will continue to be conducted at different baseline lengths to investigate the effect and impact of skywave.

14.9.2. Interference investigations

A contract has recently been let to investigate the potential impact of marine radiobeacon R-Mode signals to legacy marine DGPS receivers. The receivers have been developed to work to a set minimum interference level as defined by the ITU [11], however this approach does not consider the presence of the additional CW signals in the band.

While it is considered that the impact of the additional energy from the CW will be small, there are a large number of radiobeacons located across Europe in particular which could result in a receiver being exposed to multiple R-Mode transmissions.

As such, the study will investigate whether R-Mode is likely to cause interference and if so, how may simultaneous R-Mode signals are likely to be sufficient to affect legacy receivers. The results of this study are expected early 2017.

[1] Estimated value considering a HDOP < 2 in the dedicated region of the North Sea Area as illustrated in in [3, Figure 17].

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14.10. Planned future work

The R-Mode concept is in its infancy and more work is required. The results of the ACCSEAS feasibility study and trials, along with the further trials since the close of the project show that there is significant potential for R-Mode using both AIS and marine radiobeacons.

However, a large number of issues remain to be addressed, which are contained in the R-Mode roadmap documentation. At a high level, these include, but are not limited to:

- Agree technical specification for R-Mode signals
- Test to ensure there is no interference to legacy users
- Investigate positioning accuracies and limitations (trials, test-beds etc)
- Investigate the best approach for integration of different positioning systems
- Perform cost benefit analysis
- Develop international standards (IMO, ITU, IALA etc)
- Encourage equipment development

14.10.1. R-Mode Baltic Sea project

A number of interested stakeholders are currently investigating in an R-Mode specific project in the Baltic Sea region. The project is currently part of a competitive tender and if successful, will further develop the concept and introduce an R-Mode test bed to the Baltic Sea region.

This project is being led by the German Aerospace Centre (DLR) with other consortium members including service providers, users and equipment manufacturers. The main topics of this intended project [12] are:

- Setup advanced test beds for R-Mode using MF transmissions from IALA radio beacons installed in the Baltic Sea area
- Development of a test bed concept for the Baltic Sea
- R&D actions concerning the influence of sky wave and other environmental variations as well as transmitter and receiver setup
- Assessment of various R-Mode solutions and agree specification
- Equipment for reception of multiple MF-radio beacons with R-Mode functionality to perform real position tests
- Development of a solution for time synchronization independently from GPS or find another way to solve the time problem
- Development of an R-Mode receiver to perform position calculations
- Enlarge the test bed to include transmissions from AIS shore infrastructure and preparation of the R-Mode receiver for AIS functionality
- Test the combined solutions
- Support the standardization process by participation in dedicated committees and organizations as well as organization of workshops etc.

14.10.2. North Sea test area

Assuming a good outcome of the current interference study, the General Lighthouse Authorities of the UK and Ireland expect to add R-Mode signals to two of its DGPS sites on the east coast of the UK, subject to gaining the necessary regulatory approval. Signals from these sites, in combination with the test site installed at Helgoland, would provide a large test area across the North Sea within which the user should be able to receive three R-Mode signals.

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The Netherlands is also considering the development of a marine radiobeacon R-Mode signal which would help enlarge the test area further.

Such a test area should then allow a modified receiver to calculate a full R-Mode position and facilitate a positioning accuracy measurement campaign designed to understand the effect of geometry, skywave and seasonal effects.

This work would be aligned with the ongoing activities of the R-Mode Baltic Sea project (if successful).

14.11. Conclusions

As reported in the ACCSEAS R-Mode feasibility study the R-Mode concept has a potential to be used as terrestrial backup radio navigation system to GNSS. First on air measurements, using MF R-Mode validated the theoretical finding of the study. Furthermore, the practical field tests confirmed a proof of concept and the coexistence of the R-Mode signals and the legacy MSK signal in one transmission. Nevertheless, as identified in the roadmap, a lot of future work is still required until R-Mode could be used as an operational service in coastal areas.

Work on R-Mode continues, and the planned R-Mode Baltic project in particular should hasten the speed of development if successful. However, more contributing parties are sought and those interested are advised to contact the IALA ENAV WG5 Vice Chair, Mr Michael Hoppe (contact details in Section 14).

14.12. ACRONYMS & Definitions

14.12.1. Acronyms

ACCSEAS	Accessibility for Shipping, Efficiency Advantages and Sustainability
ADC	Analog-to-digital converter
AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
BeiDou	Chinese GNSS
CW	Continuous wave
DGNSS	Differential GNSS
DGPS	Differential GPS
DLR	German Aerospace Centre
ECDIS	Electronic Chart Display and Information System
eLoran	Enhanced LORAN
ENAV	IALA E-Navigation
Galileo	European GNSS
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
ITU	International Telecommunication Union
LORAN	LOng Range NAVigation
MF	Medium frequency
MSK	Minimum-shift keying
NMEA	National Marine Electronics Association
PNT	Positioning, navigation and time
Rb	Rubidium atomic clock
R-Mode	Proposed Terrestrial backup navigation system based on ranging signals

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RTCM Radio Technical Commission for Maritime Services
UTC Coordinated Universal Time
WG5 IALA ENAV working group 5

14.13. REFERENCES

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[9] R-Mode Mind Map, PDF format, Input document to ENAV 19, ENAV19-13.9.1

[10] R-Mode Mind Map, Mind map format, Input document to ENAV 19, ENAV19-13.9.2

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

[12] Thoralf, Noack, “Project R-Mode Baltic“, R-Mode intersessional meeting, Paris, February 2016

14.14. Contact

Anyone interested in knowing more about R-Mode or wishing to contribute to its development are encouraged to contact:

Mr Michael Hoppe
Vice Chair IALA ENAV WG5
Traffic Technologies Centre
German Federal Waterways and Shipping Administration
Am Berg 3, 56070 Koblenz, Germany
email: Michael.Hoppe@wsv.bund.de

[2] The references can be downloaded from the IALA website, http://www.iala-aism.org/products-projects/e-navigation/test-bedsprojects/accseas/

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