IALA WORKSHOP ON RANGING MODE

WORKSHOP REPORT

9 to 12 September 2019
IALA Headquarters

Kevin Gregory
Workshop Secretary

23 September 2019

This page intentionally blank

Report of the workshop on Ranging Mode

Executive Summary

The inaugural workshop on Ranging Mode was held between the 9 and 12 September 2019 at IALA Headquarters, Saint Germain-en-Laye, France.

47 Participants from 19 countries participated in the Workshop.

The workshop participants considered the various presentations that were made and the subsequent discussions in the working groups and concluded that:

- There is international recognition that the GNSS alone is insufficient for critical applications. The combined use of radionavigation and augmentation systems, including R-Mode, onboard maritime vessels is enabled by IMO Resolution MSC.401(95) on performance standards for multi-system shipborne radionavigation receivers.

- Achieving the standardized and world-wide implementation of R-Mode depends on effective harmonization with the work programmes of other interested international organizations such as the IMO and ITU.

Requirements of stakeholders on the R-Mode system

- The stakeholder requirements were found to create a strong basis for the further development of the IALA Guideline on Stakeholder Requirements for R-Mode by the ENG Committee.

- The stakeholder requirements of R-Mode are also of importance to the IALA ENAV and ARM Committees from the technical and user perspectives respectively.

VDES R-Mode implementation

- The workshop welcomed the outcomes of the waveform measurement of VHF R-Mode on the Baltic Sea, Ammersee and the Bohai and Yellow Seas.

- The workshop endorsed the structure of the IALA Guideline G1139 annex related to R-Mode and further developed the VDES R-Mode base station architecture for consideration by the ENAV Committee.

- Suggestions as to how to continue the development of IALA Guideline G1139 were made for consideration by the relevant IALA Technical Committees.

- It was identified that benefits would be accrued by utilizing the data channel of VDES for the distribution of additional information relevant to navigation.

Guidelines on Implementation of R-Mode on MF and VHF

- The workshop was of the view that it could be beneficial to provide a common Guideline for MF and VHF R-Mode implementation.

- The system design and requirements should be scalable to enable various R-Mode implementations (contingency/back-up) in different areas.

Platform for coordination of test facilities and testbeds

- There was an agreed view that a collaboration platform for the use of testbeds could enhance and promote the development of R-Mode or other IALA activities. This could also serve to enhance collaboration with other organizations.

- It was recognized that the governance of the collaboration platform needs to be solved and that IALA could play a leading role.

R-Mode development, standardisation and implementation roadmap

- The workshop endorsed the R-Mode mind map and extended it by adding risks and opportunities for R-Mode and possible alternative applications of R-Mode.

- A draft of an IALA R-Mode roadmap was developed based on the mind map. It was stressed that it is difficult to estimate the duration of processes and time schedules after the end of currently ongoing projects.
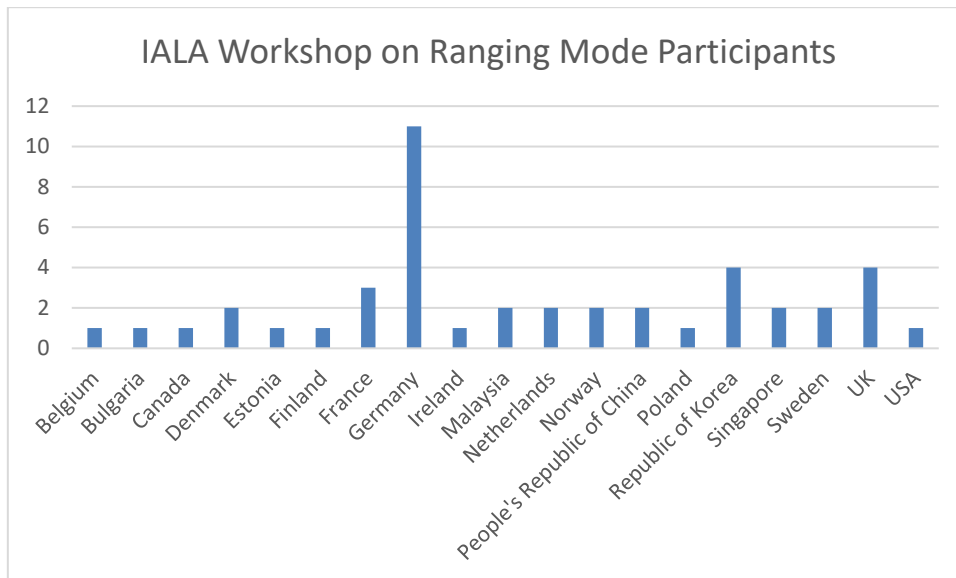
Contents

Report of the IALA Workshop on Ranging Mode

1. INTRODUCTION

The IALA workshop on Ranging Mode was held between the 9 and 12 September 2019 at IALA Headquarters, Saint Germain-en-Laye, France.

47 Participants from 19 countries participated in the Workshop. An analysis of the attendance is in graph format below:

IALA Workshop on Ranging Mode Participants

Workshop participants were provided the details of the temporary file sharing system which will be available for the exchange of documents, presentations and photographs. The file sharing system will be available until the 1 January 2020.

2. OPENING OF THE WORKSHOP

2.1 Welcome from Francis Zachariae, Secretary-General, IALA

The Secretary-General welcomed all workshop participants to Saint Germain-en-Laye, especially new attendees. The workshop is generously supported by the project R-Mode Baltic which is co-financed by the European Union through the European Regional Development Fund within the Interreg Baltic Sea Region Programme. IALA has been pleased to be involved in the advisory panel of the project.

The Secretary-General congratulated the Steering Committee, chaired effectively by Stefan Gewies, for the excellent work conducted to bring this workshop about.

The world is changing towards a more digital future and we have to look at, and probably learn from aviation. 2017 was the safest year in the history of aviation. Whilst the future for unmanned ships is still uncertain, automisation will definitely come, and quickly. With more automisation and less trained people on the bridge, we cannot rely on only one positioning system – GNSS.

R-Mode is an extremely exciting technology for providing globally-harmonised, but still regionally resilient positioning services in the coastal and harbour phases of navigation.

There are many possibilities; using base stations of Automatic Identification System (AIS) or, in the future, VHF Data Exchange System (VDES) and retaining and converting DGNSS Medium Frequency (MF) IALA Beacons to R-Mode. If the World Radio Conference agrees on the provision of a VDES Satellite link this can even expand further.

The future of DGNSS will be discussed further in Edinburgh during a workshop to be held between 27-31 January 2020 hosted by Northern Lighthouse Board.

At this R-Mode workshop we can look forward to hearing more about the:

- test bed work already under way in different areas;
- ongoing and upcoming R-Mode research from leading experts;
- conclusions on R-Mode requirements for implementation with VDES; and
- the road map for standardization and implementation.

The Secretariat is busy with the upcoming Committee meetings and, of course, the VTS/ENAV Symposium in May next year that will, for the first time, combine VTS and e-Navigation with around 100 abstracts for presentations received.

Next year, in February, Malaysia will host the final and very important Diplomatic Conference on the change of status of IALA to an Intergovernmental Organisation, in Kuala Lumpur after 10 years of preparation.

The Secretary-General wished all participants an interesting and fruitful workshop.

2.2 Working programme for the week and expectations, Stefan Geweis

Stefan Geweis welcomed all participants to the first R-Mode Workshop. The 47 attendees represent a good level of interest in this important topic which also highlights the importance of its future. With the move towards the development and implementation of autonomous services, the reliance on GNSS will grow and there is a need to examine options such as R-Mode to provide an increased degree of resilience.

R-Mode can help provide secure and resilient navigation services which will in turn help the mariner. R-Mode has the potential to suit the needs of the mariner assisting them in their daily work whilst also being acceptable to maritime administrations. There is a need to commence work on the standardisation of R-Mode so that harmonised services may be installed on a global basis.

A consistent approach to the implementation of R-Mode is needed on a world-wide level and this workshop will start to examine the options for the standardisation and harmonisation with a view to identifying the best approach and most appropriate way ahead for this important service.

2.3   E-Navigation and resilient PNT, Ringo Lakeman, Chair – IMO Sub-Committee on Navigation, Communication and Search and Rescue

Ringo Lakeman recalled his last visit to IALA Headquarters which produced a successful result and he hoped for the same at this R-Mode Workshop. The development of R-Mode is currently within the proceedings of the IMO Sub-Committee on Navigation, Communication and Search and Rescue (NCSR) and is very much related to e-Navigation. Much has been discussed about e-Navigation, but fundamentally, e-Navigation should result in stress free navigation for mariners and shore authorities.

Mr Lakeman provided an overview of the progress and current status of e-Navigation within the IMO between 2014 and 2019 with respect to the Strategy Implementation Plan (SIP) and the subsequent development of instruments. Whilst further IMO outputs are necessary, Mr Lakeman reflected that it is also important to ensure the implementation of the current instruments and evaluate them in line with user requirements and review the lessons that have been learned. There is a need to commence harvesting the results of the implementation of the IMO instruments related to e-Navigation and take the time to fully evaluate how they performed.

The SIP recognised that resilient position, navigation and timing (PNT) is a key enabler of e-navigation and is an important risk control option. The provision of resilient PNT information can be achieved through a combination of existing space-based and terrestrial systems, modernized and future radio navigation systems, ship-based sensors and other services. This means that R-mode can be a complement to resilient PNT but must be considered in conjunction with other technology based systems as well as conventional methods including visual, celestial and radar navigation.

The position of R-Mode within the World-Wide Radio Navigation System (WWRNS) is also of importance, would it fit in? According to resolution A.1046(27) on the WWRNS ships are to carry a means of receiving transmissions from suitable radio-navigation systems throughout their intended voyage which are:

- Suitable: capable of providing adequate position information within its coverage area,

- Adequate: performance not less than given in the appendix.

This performance included being capable of use by an unlimited number of ships. These requirements may be met by individual radio-navigation systems or a combination of such systems.

In principle, it seems as though the answer is that R-Mode could fit into the WWRNS. However, is there the business case to support this? R-Mode would not become a mandatory carriage requirement and it must be remembered that GNSS equipment is likely to be a fraction of the cost of R-Mode at the current time. As food for thought, will the results of R-Mode be worth the effort and will the service be taken up by ship owners?

Regardless of the business case, this pioneering work should continue and the next actions for consideration may be:
- Further develop and test!!!
- Develop performance standards for receivers,
- Develop technical standards for receivers,
- Request for IMO recognition of the system by a Government or Organization through the proposal of a new output (NCSR to assess and the Maritime Safety Committee to recognize),
- Provide a formal statement that the system is operational and available for use by merchant shipping,
- Publish the characteristics and parameters of the system and of its status,
- Declare the coverage area(s) of the system.

2.4 GNSS vulnerability – the mariners need for a back-up, Mr Simon Gaskin, Secretary General International Association of Institutes of Navigation

Mr Gaskin thanked the workshop organisers for inviting him to speak. He also acknowledged the assistance of the resilient navigation and timing foundation and the Royal Institute of Navigation in preparing his presentation.

Up until the final decade of the nineteenth century, arable agriculture utilised a variety of tools in order to sow, reap, move and process crops. Some specific machines were developed, such as those for threshing wheat, but most farming still required manpower, or beasts of burden, to achieve its objectives.

Then, in 1890, John Froelich imagined mounting a single cylinder petrol engine on a chassis and what would become known as a tractor was born. In 1892, in Clayton County, Idaho, he built his first machines. They were temperamental, unreliable, prone to get stuck, wouldn't work if you ran out of 'gasoline' and were really slow. In the same year the first recorded use of the term "back-up technology" occurred, when farmers were urged not to prematurely abandon their mules in favour of John Froelich's new-fangled gasoline tractor.

Developing the theme of back-up technology, a caution was found on a wall of a small nautical school on the Greek island of Chios:

"never fear to move with the times, but never lose touch with the past"

Captain Panagiotis n Tsakos

Being wholly reliant on a single source of information is not a new circumstance. On 2 June 1699, William Dampier described his uncertainty while approaching the Cape of Good Hope:

"I saw a large black Fowl, with a whitish flat Bill, fly by us; and took great Notice of it, because in the East India Waggoner, or Pilot-Book, there is mention made of large Fowls, as big as Ravens, with white flat Bills and black Feathers, that fly not above 30 Leagues from the Cape ... My Reckoning made me then think myself above 90 Leagues from the Cape, according to the Longitude which the Cape hath in the common Sea-Chart: So that I was in some doubt, whether these were the right Fowls spoken of in the Waggoner or whether those Fowls might fly further off Shore than is there mentioned... I found, soon after, that I was not then above 25 or 30 leagues at most from the Cape...."

From his log entry, it is clear that William Dampier was not entirely convinced by his single source of information for making a determination of his proximity to land! We may laugh at his dilemma, but it is not too much of a stretch to see our reliance on GNSS in the same light.

Consider the challenges facing, not only today's navigators and vehicle operators, but all those whose activities depend upon the reliable availability of time and/or position. They require a robust 'system of systems' which will enable them to withstand outages of GNSS supplied time and position. Considering robustness in more detail:

- Robustness - the ability to withstand or overcome adverse conditions; sturdy, tough, durable.

Is delivered by:

- Redundancy - the inclusion of components which are not strictly necessary to functioning, in case of failure in other components.

And

- Resilience -the capacity to recover quickly from difficulties, flexibility.

In short, we need some 'back-up technology' to resort to when the tractor has a bad day. We need to not abandon our mule, indeed maybe invest in a few more!

Navigators and others (or perhaps a.i.) should be taught to continuously compare and contrast the independent solutions for position (and time) provided by different systems so as to achieve two things:

- Confidence in the current solution; and

- An understanding of the likely errors of any one system over periods of time.

For example, comparison of a fix obtained by observed bearings with that obtained by observed ranges from radar and, again, with a fix obtained from another system such as main chain Decca. But, what do we compare GNSS with? In a multi-GNSS receiver the comparison is necessarily between GNSS. It may reveal that one of the systems has a problem. However, if all the systems are affected, such a comparison may only reveal that they are all behaving in the same way!

Today we have reached a situation where technology has, by means of constellations of satellites, delivered to the 'navigator' the ability to determine their position on the earth to millimetre accuracy, their direction of movement to hundredths of a degree, their speed of travel to centimetres per second and real time to nanoseconds.

But it seems that the user community have apparently stopped asking the question 'is this information reliable?' Specifically, 'what if the signals from some, or all, of those satellites are interfered with, distorted or denied, either deliberately by the ill-disposed or inadvertently by man or nature?'. Indeed, what is 'the way ahead?

It is not only navigators who should be asking the question; broadcasters, telephone network operators, farmers, financiers and power distributors are just some of the non-navigators who would be affected by a denial of service. So, in our headlong rush to expand GNSS in the twenty first century, we must include in that development the vital matter of ensuring that the global systems providing time and position to the user community are enhanced or assisted so as to be sufficiently robust that the community are able to continue receiving and utilising that information, despite partial, or complete, outage of the space based element.

GPS is a single point of failure for critical infrastructure and no lesser organisation than the US Department for Homeland Security recognizes this, and GPS is a us facility!

"GPS is a single point of failure for Critical Infrastructure"

US Dept. for Homeland Security

There are a number of factors which can cause GNSS to present erroneous information, or no information at all. The EU project 'strike3' aims to understand what they are and how to detect and resist them. A denial of signal is a very frequent event and if you wish to find out more about those events the strike 3 scorecards are a good resource.

Inevitably there would be a cost to the user community associated with an interruption to the availability of GNSS services. But, although the penalty may only be monetary, of more concern, it could be a serious pollution event or, at worst, an event resulting in significant loss of life.

For the United Kingdom an economic assessment of the impact of a prolonged outage was conducted and the quantified economic benefit of GNSS to the UK was £6.7bn per annum and the economic impact to the UK of a five day disruption to GNSS has been estimated at £5.2bn.

Note, the research indicated that the biggest impact is felt on the roads, closely followed by the emergency services and then the maritime sector.

Perhaps, given the challenges of establishing a 'global' terrestrial time and position service, we should aspire to a 'system of systems' whereby, at least two mutually independent methods of determining time and position are available and able to be continuously compared so that any indication that the integrity of either might be compromised can be acted upon before a platform suffers a total loss of time and position data. Clearly, if one of those methods is space based, then it must be reinforced by one (or more) terrestrial 'back-up technologies',

Following on from the economic assessment, the UK Government commissioned a scientific appraisal of the dependency of critical infrastructure on GNSS information. The output of that activity, commonly referred to as 'the Blackett Report', included a variety of recommendations for addressing the situation, including 'employ GNSS -independent back-up systems' (in other words – some mules) the old ones and/or some new ones.

For more information about robust (resilient) PNT and possible alternatives visit the resilient PNT resource portal at the Royal Institute of Navigation's website.

Today, systems, or 'systems of systems', are increasingly used to manage many aspects of life, often autonomously – examples are: communications, the distribution of power and goods, the management of buildings, the conduct of financial trading and the supervision of plant in complex civil engineering projects. These systems often interact with one another and they all rely more or less exclusively upon space based technology for the uninterrupted provision of time and position information.

So, what is to be done? Professor Brad Parkinson has proposed that we must 'protect, toughen and augment' our GNSS services. Consumers, regulators, nations and international bodies need to co-operate to find an answer to this challenge:

"how can we ensure that the provision of time and position information is sufficiently robust that it would be uninterruptible?"

The answer almost certainly lies with an architecture of alternative, but complementary, systems, such as R-Mode. Most of them may employ signals of opportunity. But we really do need to identify those systems and develop them sooner rather than later. If we don't act to establish adequate robustness, then the potential result for society will be chaos.

In conclusion – Mr Gaskin argued that, still, we should not abandon our mules! Rather we should continue to insist that the mules, including the one under discussion at this workshop, and maybe even some new ones, are retained to complement the tractor.

2.5   Early work on R-Mode, Michael Hoppe, WSV

Michael Hoppe briefed participants with respect to R-Mode in general as well as providing information and results from the first theoretical and practical trials stemming from a study performed during the EU project ACCCSEAS and the first trails performed in the North Sea area between the Netherlands and Germany.

The general idea of R-Mode is the transmission of synchronised timing signals from existing maritime radio infrastructure. By using several transmissions, GNSS independent positioning may be provided and the most promising candidates for such transmissions in the maritime sphere are systems such as the IALA MF radio beacons and VHF transmissions (AIS/VDES).

Real work on the proposed idea of using timing signals from IALA MF radio beacons and AIS were conducted in the EU research project ACCSEAS. The ACCSEAS project enabled the first work on R-Mode in the North Sea region and enabled a feasibility study related to the methods and achievable performance of R-Mode transmissions via MF radio beacons and AIS (VHF).

The ACCSEAS project results indicated that if all of the available MF radio beacons in the North Sea were used for R-Mode, an accuracy level or 10m or better could be achieved during daylight hours. Unfortunately, during the hours of darkness skywave interference needs to be considered which results in a three to five times worse position accuracy.

One of the main topics for current research activities is to find a mitigation option for the skywave. One option is to use additional e-Loran (LF) transmissions. With two e-Loran sites, suitable accuracy levels could be achieved which could fulfil backup requirements.

Part two of the ACCSEAS study sought to analyse options for AIS base station transmissions. The advantage of VHF AIS transmission are that modulation does not need to be changed and VHF propagation is not affected by the skywave. The disadvantage is the lower coverage in terms of range.

The results from various trials conducted in Germany produced positive results but highlighted that the night time accuracy levels needed to be improved.

Therefore, it is obvious that the best results can be achieved when using a combination of MF/VHF and LF transmissions.

In summary:

- R-Mode could help provide resilient PNT.
- The best solution can be expected when R-Mode is combined with other positioning systems.
- R-Mode will not be the answer in all areas (due to geometry, skywave, etc.).
- Work on AIS/VDES-R-Mode needs to be started.
- More active participants are sought so that this work can be developed in a co-ordinated, timely and efficient manner.

3.   CURRENT STATUS OF DEVELOPMENTS

3.1   R-Mode in the North Sea Region, Jan Šafář, GRAD

Jan Šafář updated workshop participants with respect to the following topics:

MF R-Mode:

- Spectrum licensing,
- Interference assessment,
- Long baseline performance assessment,
- Coverage modelling.

VDES R-Mode:

- System architecture considerations,
- Coverage modelling.

Marine radio beacon DGPS services broadcast in the 283.5-325 kHz bands, subject to international agreement. National licensing is provided based on the broadcast type, power and other parameters. MF R-Mode requires two additional CW signals to be added to the legacy MSK signal. The GLA sought advice from the UK radio regulator (Ofcom) on the need for a new licence should MF R-Mode signals be added. Ofcom confirmed that the existing license is sufficient.

GRAD let a study to Alion Science and Technology, to investigate the potential of interference caused by the new MF R-Mode CW signals to legacy receivers. Alion investigated the potential for MF R-Mode signals to impact legacy DGPS receivers. They found that, while the CW signals will have some impact, the level is well below that which would cause any problems. This theoretical assessment confirms the findings of other colleagues who have kept a legacy receiver running during MF R-Mode trials.

When considering long baseline performance assessment, due to the geometry of the British Isles and the locations of neighbouring marine beacon sites the geometry of stations will affect accuracy and availability. To receive signal from sufficient stations, baseline lengths of up to 200-300 km may be required and skywave effects may be more of an issue over longer baselines.

GRAD has developed MF R-Mode coverage prediction tools, building on data recorded to date. By understanding the effects of propagation and interference to the strength and phase of the wanted signal, it is possible to model the expected performance for each station. Combine this with information on the number of available R-Mode transmissions, their geometry and the expected receiver performance and it's possible to predict the overall performance of MF R-Mode.

The ranging method used in VDES R-Mode will have a substantial impact on the number of stations required for positioning, the dilution of precision factor and therefore on the achievable coverage and positioning performance. The use of (true) ranging (rather than pseudoranging) should be considered in order to avoid the need for off-shore VDES R-Mode stations.

GRAD has developed a VDES R-Mode coverage prediction tool, building on ITU propagation models, mathematical analysis of the VDES waveforms and results of radio noise surveys carried out on GLA vessels.

Positioning accuracies in the region of 10-20 m (95%) appear achievable with the 100 kHz VDES waveform in areas with a sufficient number of stations and good geometry.

In summary, GRAD has been working hard to support R-Mode development both nationally and internationally. GRAD studies have shown that MF R-Mode would need to operate over baselines of up to around 300 km. Long-range trials have shown reasonable MF R-Mode performance by day but very poor at night due to skywave effects.

A decision on which VDES R-Mode architecture to take forward needs to be made. GRAD has developed coverage prediction models which can be used to assess the performance of different R-Mode variants and different approaches.

Given the support for R-Mode and the potential for low frequency, pulsed signals to minimise skywave effects and aid cycle ambiguity resolution, should e-Loran be renamed 'LF R-Mode'?

3.2   R-Mode in the Baltic Sea Region, Stefan Geweis, DLR

Stefan Geweis updated workshop participants on the challenges and preconditions of the Baltic Sea region and introduced the project R-Mode Baltic that will set up an R-Mode testbed for the Southern Baltic Sea and described the results of measurements, theoretical analysis and developments of the past two years.

The Baltic Sea is surrounded by nine states and is important for transport of goods and persons. Conditions are challenging for maritime traffic with shallow waters, narrow straights, many small islands and a high traffic density with crossing traffic routes.

Mr. Gewies highlighted that R-Mode is a systems that requires cooperation of neighbouring countries. The challenge is to coordinate the activities of all Baltic Sea states alongside the EU strategy for the Baltic Sea region to increase maritime safety.

Mr Gewies provided detailed information on the coverage within the Baltic Sea of MF and VHF signals and introduced the R-Mode Baltic project. The R-Mode Baltic project seeks to build an R-Mode testbed in the Baltic Sea until 2020 that utilises MF radio beacons and AIS/VDES base stations with the aim of demonstrating that R-Mode is able to meet maritime user requirements for a backup system. The user requirement for the R-Mode Baltic projects is to setup a contingency system for GNSS, which in case of unavailability of GNSS should allow positioning for at least 2 hours.

Sub-10m accuracy (95%) should be available throughout almost all sea-space in the Baltic region, but only during the hours of daylight. Night-time accuracy performance is corrupted by sky-wave interference and will show accuracy levels around 10-20m (95%). Rejection of skywave interference remains a critical technical challenge for R-Mode.

The DLR measured the signal availability of MF radio beacons in the Southern Baltic Sea in 2017. A comparison of the number of available signals with a theoretical study using the station nominal ranges reveals at day in general good agreement and at night a significantly increased number of received signals due to the skywave effect.

During several site inspections on maritime radio beacons in Sweden, Denmark and Poland the R-Mode Baltic project team tested the compatibility of the station hardware with R-Mode signals. In general it works without modification of the transmitter chain. One exception is the non-linear amplifier in Poland which produces some intermodulations in the transmission channel of the beacon.

In conclusion, Mr Geweis stated that the Baltic Sea is a suitable region for a combined MF and VHF R-Mode testbed. Theoretical analysis shows that the user requirement can be fulfilled during daylight hours. The skywave has to be mitigated to reach user requirement between sunset and sunrise. The upgrade of existing radio beacons feasible when the amplifier is linear. Different approaches to estimate range for MF signals are available.

3.3   AIS Autonomous Positioning System (AAPS) in China, Sun Xiaowen, Dalian Maritime University

In order to overcome the vulnerability of the GNSS and provide robust PNT information for safety and security at sea, development and trials of R-Mode using MF and AIS signals to enhance marine navigation are encouraged.

A testbed of AIS R-Mode in China was developed within a three-year (2012-2015) project called the AIS Autonomous Positioning System (AAPS). A theoretical research and simulation test on VDES R-Mode was carried out to verify its feasibility and performance was better than AIS R-Mode (2016-2017)

A project of a VDES R-Mode Testbed (Jan 2018 - Dec 2020) is being implemented which is supported by China MSA. System specifications of VDES R-Mode are being drafted and it is hoped to contribute to the drafting of the VDES R-Mode Guideline and Recommendation.

The following workplan represents future the developments in China:

- 2019 complete the VDES R-Mode Testbed.

- 2020 test and improve the VDES R-Mode Testbed.

- 2021-2022 expand the usage of VDES R-Mode. Provide more details to VDES R-mode Guideline and Recommendation.

- 2023 complete the VDES R-Mode Project.

3.4   R-Mode in the Republic of Korea, Sang Hyun Park, KRISO

The Republic of Korea is very interested in GNSS backup and the status of existing offshore communications infrastructure related to R-Mode utilization.

It is known that GNSS is theoretically vulnerable to radio interference but we were not fully aware of the seriousness of the GNSS jamming. Perhaps we may not have suspected that anyone would jam GNSS, or we may have underestimated the impact of GNSS radio interference.

However, the GNSS radio interference that we face has overtaken our optimism and it made us rethink how much we depend on GNSS. Now we understand the fear, not the inconvenience caused by the GNSS jamming.

In other words, we have seen firsthand that GNSS jamming can prevent marine activities themselves beyond making them uncomfortable. One fisherman said in the news, "The GPS plotter is dead. There's nothing I can do.”

Since 2010, more than 5,000 jammings have been reported involving vessels, aircraft and cell phone base stations. Most of all, the concern is that the areas affected by Jamming are expanding. For this reason, the Republic of Korea is interested in R-Mode as a backup PNT system to respond to any GNSS disturbance.

R-Mode allows radio resources that were previously being used for maritime communications to be used as radio resources that can be used to measure distances (ranging).

Current R-Mode-enabled offshore communication resources are MF (Medium Frequency) in the 300kHz band used for DGPS services and VHF (Very High Frequency) in the 160MHz band used as AIS and VDES.

Given that the Republic of Korea has abundant communication resources that can be used by R-Mode, we expect that R-Mode along with the Loran-C infrastructure will play an important role as part of the terrestrial radio navigation system for maritime safety in the Republic of Korea.

The Republic of Korea completed a technical and economic feasibility analysis of R-Mode technology development and services in the first half of 2019. The performance prediction results of the R-Mode service were very positive through the analysis, and found that significant performance improvements were expected, especially when integrated with the e-Loran service scheduled for operation in the future.

3.5   R-Mode in Canada, Jean Delisle, Canadian Coast Guard

Canada has the world's longest coastline, measuring 243,042 km (including the mainland coast and the coasts of offshore islands). It is the second-largest country in the world with a total area of 9,984,670 km^2, including 891,163 km^2 of freshwater with unique environmental conditions.

The Canadian Coast Guard (CCG) has identified the R-Mode as a promising PNT technology. The CCG's objectives with respect to R-Mode are:

- To collaborate into the R-Mode development,

- To test the R-Mode technology on existing DGPS MF sites,

- To better understand the advantages and disadvantages of a larger Bandwidth (500 Hz vs 1 kHz),

- To perform tests in various Canadian conditions such as moving ice, tides (up to 6.5 m), water temporal salinity variation and ground conductivity variation during snow melting in spring season,

- To share lesson learned with international partner, and finally,

- To make recommendations based on facts toward an informed decision.

The CCG has learnt

- That CCG Class D transmitters are not R-Mode capable,

- R-Mode CWs encompass very little energy, a power meter on the amplifier gives the same power level with or without R-Mode signals,

- CCG Far Field Integrity Monitoring System was not disturbed by R-Mode CWs,

- DGPS Redundancy was removed during R-Mode tests.

On Ranging Performance

- Lower STD deviation with +/- 450 Hz during daytime, can possibly meet positioning IMO requirements (IMO Resolution 1046(27) and Resolution 915(22) – 10 m for Coastal, port approach, restricted/inland waters navigation),

- In night-time, the system (Tx and Rx) would need improvements to possibly meet positioning IMO requirements,

- What looks like skywaves (night-time) at 25 km need to be confirmed.

Continue tests

- Collect data at shorter distances (< 25 km) as a baseline,

- Collect data at > 200 km,

- Collect winter and spring data sets at the same distances,

- Test Rubidium clock holdover performance (not GPS steered),

- Analyse our data collection and draw conclusions.

The CCG will continue to collaborate to develop R-Mode using existing MF DGPS infrastructure.

3.6   Timing for R-Mode base stations, Carsten Rieck, RISE

Carsten Rieck provided workshop participants with a briefing on the principle of time in general. R-Mode timing is demanding, even in the context of metrological time keeping. Synchronization errors map directly into positioning inaccuracy. Administrations are advised to choose sync and local clocks according to the use case. Cross-border operation needs cooperation in terms of a common time scale, National Metrological Institutes can help and serve. Mr. Rieck advised that the R-Mode operators have to know the statistics of used clocks/links and propagate timing uncertainty estimates to the user - calibrate, and again calibrate!

3.7   VHF Data Exchange System (VDES), Stefan Bober, WSV

The VHF Data Exchange System (VDES) provides additional capacity for digital data exchange in the VHF maritime mobile band:

- Protecting the original function of AIS: identification, position reporting and tracking,
- Provides capability for maritime data exchange for safety, security, efficiency and the protection of the environment,
- Globally interoperability and availability,
- Dedicated to maritime communication.

e-Navigation aims to enhance berth-to-berth navigation and related services for safety and security at sea and for the protection of the marine environment. VDES supports the IMO prioritised e-Nav solutions:

- Standardised and automatic reporting,
- Using internationally standardised messages similar to ASM,
- Extended ship static and voyage related data,
- Dangerous cargo indication.

Improved reliability, resilience and integrity of navigation information:

- Met/Hydro data, tidal windows, area notices to mariners, berthing data, clearance times for port entry/exit.

Improved communication of VTS services

- Route information, navigational intentions.

There is a need to set up requirements for VDES to be incorporated into Recommendation ITU-R M.2092 to enable R-Mode using VDES and the following matters should be considered by the workshop:

Organisational:

- Revision of ITU-R M.2092-0 in 2020,
- Performance standard for VDE in 2021,
- Channel available and Frequency allocation in 2024.

Technical:

- Timing requirements, synchronisation,
- Message structure,
- Message content,
- New waveform design,
- Reporting interval of messages.

4. WORKSHOP TOPICS AND OBJECTIVES

Participants were provided with a briefing with respect to the workshop topics and objectives that would be considered by the various break out groups.

Plenary - Requirements of stakeholders on the R-Mode system

Chair: Jan Šafář

Rapporteur: Jesper Bäckstedt, SMA

Expected input:

- R-Mode Stakeholder Requirements (MF and VHF)

Expected discussion about / work on:

- Review identified stakeholder requirements
- Identify additional stakeholder requirements

Expected output:

- Revised R-Mode Stakeholder Requirements (MF and VHF)

Break out group 1: VDES R-Mode implementation

Chair: Ronald Raulefs

Rapporteur: Jan Šafář

Expected input:

- Draft Annex to G1139 The Technical Specification of VDES regarding R-Mode implementation;
- Presentations of R-Mode - VDES measurements results of NIT, DLR and Dalian Maritime University
- Result of the discussions on R-Mode Stakeholder Requirements (MF and VHF) from session 4
- Consider input from first day

Expected discussion about / work on:

- Final discussion between navigation and communication experts on the proposed implementation of R-Mode on VDES

Expected output:

- Revised draft annex to G1139 The Technical Specification of VDES regarding R-Mode implementation

Break out group 2: Guidelines on Implementation of R-Mode on MF and VHF

Chair: Michael Hoppe

Rapporteur: Harold Kiffer, USCG

Expected input:

- Draft Guidelines on the implementation of R-Mode on MF and VHF (rough structure)
- Presentation of R-Mode implementation in R-Mode Baltic project

Expected discussion about / work on:

- Review Guideline drafts
- Gather expectations on these Guidelines

Expected output:

- Revised draft Guidelines on the implementation of R-Mode on MF and VHF (rough structure)

Plenary - Platform for coordination of test facilities and testbeds

Chair: Jeffrey van Gils

Rapporteur: Jesper Bäckstedt

Expected input:

- IALA Guideline 1107 on Planning and Reporting of e-Navigation Testbeds

- Proposal for a concept of a platform for coordination of test facilities and testbeds

Expected discussion about / work on:

- What is the goal, what do we want to achieve with the platform?

- What information is needed?

- What functionality is needed?

- How should people use the platform?

- How could the platform be used to strengthen co-operation?

Expected output:

- Revised platform concept

- Proposal for possible realization of platform and/or revision of Guideline 1107

Break out group 3: R-Mode development, standardisation and implementation roadmap

Chair: Stefan Gewies

Rapporteur: Harold Kiffer

Expected input:

- Updated IALA R-Mode MindMap on necessary research, development and standardisation activities for implementation on MF and VHF (AIS/VDES)

Expected discussion about / work on:

- Review MindMap

- Identify ongoing and planned R-Mode activities

Expected output:

- Revised MindMap and roadmap

5.   REQUIREMENTS OF STAKEHOLDERS ON THE R-MODE SYSTEM

The aim of this session was to review the input document "Stakeholder Requirements for R-Mode" provided by the Research and Development Directorate of the General Lighthouse Authorities of the UK & Ireland (GRAD), and agree a way forward for managing the stakeholder requirements. The session comprised of all participants of the R-Mode Workshop and was chaired by Dr Jan Šafář; the rapporteur was Mr Jesper Bäckstedt.

The session Chair first provided an overview of the document's structure and contents before going into details. Subsequently, the group reviewed the document, focusing on key sections identified by the Chair.

Session participants provided valuable input and comments on the topics discussed, and the document was amended accordingly. The entire document was later checked for consistency by the Chair, making sure the changes introduced during the session were appropriately reflected.

The system's purpose and some fundamental definitions related to R-Mode were discussed and agreed during the review.

The anticipated system life cycle diagram included in the document was reviewed and revised to emphasize the role of laws and regulations in the early phases of the system's life cycle.

The document also includes a stakeholder identification table, listing the key stakeholders in the R-Mode System and their anticipated roles within the system during different phases of the life cycle. A majority of the stakeholders listed in the table were represented at the session. The table was reviewed by the participants and updated with additional information.

The session Chair then provided a brief description of a proposed operational concept for the R-Mode System, identifying the key actors and use cases, referring also to example use case scenarios provided in an annex to the document. The proposed operational concept offers the first hints as to the system's boundary, input and output requirements and the top-level functional decomposition of the system.

A set of external systems diagrams had also been provided in the document, clearly delineating the system's boundary by explicitly identifying all of the system's inputs and outputs. Some of these diagrams were presented to the participants during the session and subsequently revised to incorporate their feedback.

The session also reviewed some of the stakeholder requirements pertinent to the system's utilization (or operational) phase and saw interesting and fruitful discussions about the timing requirements in R-Mode. Several new or revised definitions were included in the document to address the points raised during the discussions, based on input received from the timing experts in attendance.

Lastly, a short discussion on the next steps for the paper was held. Since the session was unable to review the entire document in detail in the time provided it was proposed that the document be forwarded to the ENG Committee for further review and development. It was agreed that the session Chair would seek advice from the IALA Secretariat for the status of the document and the next steps.

The draft Guideline on Stakeholder Requirements for R-Mode will be forwarded to the ENG Committee for further review and development and to the ARM and ENAV Committees for their information and comment.

6.   VDES R-MODE IMPLEMENTATION

This break-out group was split in two sessions spread over two days, and was attended by 14 participants.

The key inputs to the work of this group were the draft Annex to G1139 on the Technical Specification of VDES R-Mode and the stakeholder requirements discussed in the plenary session 4. Further, several presentations were given by representatives of the National Institute of Telecommunications, Poland (NIT), the German Aerospace Centre (DLR) and the Dalian Maritime University (DMU). The objective of the session was to facilitate discussions between communication and navigation experts regarding the changes to the technical specification of VDES (IALA Guideline 1139) required in order to enable VHF R-Mode.

Day one saw presentations from NIT, DLR and DMU addressing the following topics: ranging sequence design; effects on propagation delay above land and sea; VDES resource allocation; and synchronization between R-Mode enabled VDES base stations.

NIT reported on AIS ranging measurements carried out on-board the Stena Baltica ferry on the Baltic Sea near Gdynia. A path parallel to the Hel Peninsula was used to investigate the impact of terrain on the propagation delay. It was reported that multiple frequency filters were required to cope with AIS and other VHF interference sources. Performance results showed a significant additional bias in the propagation delay for mixed propagation paths (i.e. paths crossing both land and sea). The ranging accuracy was better than 100 m under optical line-of-sight (LoS) conditions for ranges up to 20 km from the base station in Gdynia.

DLR reported on measurements carried out on two ferries on the Ammersee in southern Germany. The measurement campaign focused on comparing the performance of several ranging sequences and different signal bandwidths (25 kHz and 100 kHz). The following four ranging waveform configurations were used during the campaign:

- AIS message;

- an alternating VDE symbol transmission using a bandwidth of 25 kHz;

- Gold code transmission using a bandwidth of 100 kHz; and

- alternating VDE symbol transmissions, using a bandwidth of 100 kHz.

Theoretical analysis shows that the AIS waveform requires up to 24 dB more signal energy to achieve the same performance as the best case (i.e. the 100 kHz VDE waveforms). The theory also suggests that the Gold code-based waveforms should provide better performance than the alternating symbol ones at low SNRs, but the alternating symbol waveforms are expected to have a 3 dB performance advantage at higher SNRs. Both these theoretical results were confirmed during the measurement campaign, although the performance gains of the VDE waveforms, compared to AIS, were not as significant as predicted from theory.

The DMU representatives repeated the presentation given on the first day of the Workshop, allowing more time for in-depth technical discussions. It was reported that DMU intends to establish a VDES R-Mode testbed in the Yellow Sea by the end of 2019. A proposed slot map for AIS, ASM and VDE R-Mode transmissions from multiple base stations was presented and considered for inclusion in the Annex. The presentation also described a concept for base station self-synchronization which could be used during a prolonged loss of GNSS services. The details of the ranging sequence used by DMU will be presented at ENAV24 in October. The term 'additional secondary factor' (ASF), used in DMU publications, remains to be clarified. The ASF correction system developed by DMU is covered by patents - there is more to learn.

At the end of day 1, the session Chair provided an overview of the structure of the draft Annex to G1139 on R-Mode, which was drafted at the intersessional meeting of IALA ENAV WG3 in August. There were no comments, therefore the table of contents was accepted.

A discussion developed around the intended architecture of the R-Mode system, and in particular about the function of the timing device in the system and related requirements such as physical interfaces (10 MHz, 1 PPS and a data channel). The discussion was prompted by the different interpretation of R-Mode by different participants as either a contingency or a backup system. The latter requires stricter requirements for holdover times and the ability to cope with a cold-start without using a GNSS-disciplined clock. It may also require additional external synchronization interfaces compared to the contingency system architecture.

Day 2 saw discussions on the R-Mode system architecture (including timing device interfaces), navigation data, link layer considerations and on how to proceed with the development of the VDES R-Mode specification.

The group agreed that the base station architecture for a backup system should include the 10 MHz, 1 PPS and data channel interfaces to enable synchronization with a non-GNSS time source. For the contingency system configuration, the 1 PPS and data channel interfaces are considered optional as the information supplied through these interfaces can be obtained from the base station's internal GNSS receiver; however, the 10 MHz frequency reference interface is required. The changes agreed by the break-out group will be integrated into the next revision of the draft Annex to G1139 on R-Mode.

Link layer considerations: The current assumption is that VDES R-Mode will use three slots per second (corresponding to approximately 8% of the communication capacity). These figures were agreed at the IALA ENAV WG3 intersessional meeting in Yiwu in 2018 and are also quoted in the Stakeholder Requirements Document for R-Mode reviewed earlier during the Workshop. Alternatively, concurrent transmissions could be pursued; however, this is currently not supported by VDES. A change to enable concurrent transmissions in VDE seems desirable in order to reduce the channel load associated with ranging (this would also increase the communication throughput) but could have a negative effect on the AIS reception on shore. Further, the near-far effect may have a significant impact on the ranging performance. The different approaches and the impact on the VDES link layer were discussed with no conclusive result reached.

Navigation data (application layer): There was general agreement among participants that all transmission timing biases (due to, for example, the power amplifier, antenna feeder cable or the antenna) should be incorporated into a base station clock model which should be broadcast to the user. It was proposed that the clock model should also include an estimate of the uncertainty of the bias. It is anticipated that approximately 30 bits will be required to encode the parameters of the clock model.

Ideally, the navigation data would use the same format for both MF and VHF R-Mode. An RTCM format could be considered; however, a specific message does not yet exist. Therefore, the group agreed that the Annex to G1139 should only include a high-level description of the data required, with the exact format to be defined by another standardization body. A proposal for integrating the navigation data with the ranging signal (broadcast every second or so) and utilizing the FEC encoder/decoder of the current VDES standard was discussed. However, because of the anticipated update interval for the navigation data of one minute, a separate broadcast message may be more suitable. Alternatively, the group will investigate whether the VDES Bulletin Board or the Announcement Signalling Channel could be used to convey some (or all) of the navigation data.

Proposed actions:

K Bronk to review the use of the VDES Bulletin Board to identify any data relevant to R-Mode that is already included.

K Bronk to review the use of the VDES Bulletin Board and Announcement Signalling Channel and advise the group what navigation data (that isn't currently included) could be broadcast via those channels.

R Raulefs to provide Peak-to-Average-Power Ratio figures for the ranging waveforms using the alternating VDE symbol sequence proposed by DLR.

C Rieck to provide a proposal for the R-Mode clock model, identifying the number of bits and message update rate required.

R Raulefs and K Bronk to include the slot map proposed by DMU in the R-Mode Annex to G1139 as an example.

J Šafář to schedule a teleconference for 19th or 20th September to freeze the current stage of the discussions regarding changes to G1139 with the following agenda items:

- Discuss ranging sequences;
- Identify required changes to the VDES Link Layer – potential use of the Bulletin Board / Announcement Signalling Channel / new messages;
- Incorporation of navigation data;
- Application layer data: define clock model parameters.

R Raulefs & J Šafář to integrate input from the group into the draft R-Mode Annex to G1139 and submit to ENAV24.

The group members will communicate using the IALA VDES R-Mode mailing list. Workshop participants interested in contributing to the development of the VDES R-Mode specification are invited to contact Mr Jeffrey van Gils with a request to be added to the mailing list (ialavdesrmode@e-navigation.nl).

7.   GUIDELINES ON THE IMPLEMENTATION OF R-MODE ON MF AND VHF

A presentation was provided to inform the group about an R-Mode implementation example performed within the R-Mode Baltic project. Further, the group reviewed and discussed a first draft Guideline provided as input to the IALA R-Mode workshop.

The working group discussed main topics of the guideline in four small working groups.

The main topics selected were:

- General expectations of an R-Mode implementation Guideline,

- Operational aspects for an R-Mode service in an area,

- Requirements (e.g. 2 hours holdover time… is this enough?),

- Architecture and system design aspects.

The results of this discussion were collected on sticky notes on a flip chart. The photos were copied in the draft Guideline document. In addition, the group reviewed the general structure of the draft guidelines and provided some amendments.

The group provided the view that it is beneficial to provide a common Guideline for MF and VHF R-Mode implementation. Further guidance was given that the system design and requirements (especially hold over time) should be scalable to enable various classes of R-Mode implementation in different areas.

It is planned that further work on this Guideline should be performed in the IALA ENG and ENAV Committees. Thus, the draft Guideline together with the results of the workshop will be submitted as an input paper to ENG10 and ENAV24.

8.   PLATFORM FOR COORDINATION OF TEST FACILITIES AND TESTBEDS

The aim of this group was to present and discuss a web-based platform for R-Mode testbeds. Input for the session had been uploaded to the fileshare of the R-mode workshop in advance. Input papers were the IALA Guideline 1107 on testbeds and a presentation about different aspects of a common platform for testbeds.

The session started with a presentation about the current status of IALA beacon stations, the need of a platform and the possible structure of such platform. The group was thereafter divided into six different sub-groups with six to eight persons in each.

Each sub-group could then freely develop ideas with respect to the use and benefit of having a web based platform and how such platform should be made available to the maritime community. As support during the discussion, each sub-group were provided with a number of questions to answer or discuss and note the different ideas and suggestions. A large number of items could then be collected from the work in the six different sub-groups with the following highlights:

- There was a common sense that a collaboration platform on test facilities and testbeds could enhance the development of R-mode or other IALA developments when setup properly.

- The group also realised that the collaboration platform could be used to promote developments of IALA and enhance collaboration with other partners.

- It was recognised that the governance of the platform needs to be solved and IALA could play a leading role.

The output of the session was a mind map generated by the inputs from the sub-groups. This mind map should be considered by both the ENG and ENAV Committees.

9.   R-MODE DEVELOPMENT, STANDARDISATION AND IMPLEMENTATION ROADMAP

A presentation was provided to inform the group about the status of the R-Mode development, standardization and implementation mind map. The working group broke into 3 smaller working groups to review and discuss the R-Mode mind map and answer the following:

- Identify additional major tasks, update the status of tasks and who is going to work on certain tasks?

- R-Mode: What are the opportunities and risks? What are the risk mitigation measures?

- For which applications R-Mode is needed for? Which new applications would be possible if R-Mode were available?

The results of these discussions were collected on sticky notes on a flip chart and presented to the group. In addition, the group reviewed the general structure and content of the mind map and provided some amendments.

The group addressed the risks to R-Mode, particularly that it has taken a long time to get to this point, and continued slow progress could reduce support. Additionally, proper marketing is essential to long term success and support. The group once again reinforced the notion that R-Mode should be able to operate independently of GNSS.

During the second half of the session, the working group once again broke into 3 smaller working groups to review and update the following sections of the Roadmap from the mind map:

- R-Mode design

- R-Mode system development

- R-Mode system operations and R-Mode system standardization

The results of these discussions were collected on sticky notes on a flip chart and presented to the group. In addition, the group reviewed the general structure and content of the roadmap and provided some timelines and amendments.

The results were compiled into an updated mind map and roadmap. It is planned that further work on these documents should be performed in the IALA ENG committee. Thus, the draft mind map and roadmap together with the results of the workshop will be submitted as an input paper to ENG10 and ENAV24.

Further, IALA is requested to consider hosting a platform for the R-Mode mind map and road map.

10. PANEL DISCUSSION

A panel discussion was held with the following participants:

- Phil Lane – Technical Officer, CIRM

- Simon Gaskin – Secretary-General, IAIN

- Minsu Jeon – Technical Operations Manager, IALA

The panel was moderated by:

- Thoraf Noack, DLR

- Kaisu Heikonen, FTIA

The following questions were posed to the panel.

How do you see the specific role of CIRM, IAIN and IALA to do something within the scope of R-Mode system:

- *CIRM – the manufacturers role,*

- *IAIN – the navigation community (user) perspective,*

- *IALA – the regulative perspective.*

Simon Gaskin said that IAIN represents the user community, including mariners as navigations in addition to engineering and technical specialists. IAIN is able to represent the views of the user and act as a facility for promulgating the concept of R-Mode and encouraging our community to stand up and support the system or to raise awareness so that users may consider what they want from such a system.

Phil Lane commented that CIRM sees R-Mode as a business opportunity for its members who are equipment and technology manufacturers. CIRM members would seek to build products that are fit for purpose and meet the user needs which should ideally be driven by regulation and supported by standards. These will be the main drivers for CIRM members, some of which are participating in the workshop.

Minsu Jeon indicated that IALA is an international technical organization and not a regulator. Depending on the development status of R-Mode, IALA could do several things. A conceptual framework on R-Mode could be developed in IALA in many ways such as a Guideline or timeframe. IALA could promote R-Mode using its bulletin and other publications. There are a lot of good opportunities in IALA to support the development of R-Mode.

Do we need a supra-national authority for R-Mode and if yes, who can act as this authority?

Simon Gaskin indicated that the answer is yes, we probably do but care is needed in the use of the term authority. The example of the international consultative group for GNSS was suggested as a possible solution where coordination takes place with each respective constellation member with respect to matters such as commonality, conflicting signals and the management of constellations. Perhaps this could be a model for an R-Mode group but consideration would need to be given as to how it may be set up and it would need experienced personnel.

Who can be called the "founder" or "owner" of R-Mode in the future?

Phil Lane suggested that using the term owner may not be the best option. The strength of the R-Mode system is its openness. A guiding light is needed but perhaps we could look to AIS as example with the IMO performing the regulatory function, ITU dealing with spectrum issues and IALA dealing with operational standardization.

With respect to the founder of R-Mode, Phil Lane reflected that Michael Hoppe is the first person that you think of with respect to R-Mode in many circumstances.

What are the risks we have to consider with respect to R-Mode, such as the increasing influence of space-based augmentations?

Phil Lane considered that a threat was the timeline involved in the implementation of R-Mode. How long will it take to develop the system and technical specifications and put in place the regulatory framework. R-Mode is strong as it is terrestrially based but time could go against it. But, there is the opportunity to build something unique and the maritime sector could lead in solving a problem that could be of significant benefit to other transportation sectors (air, rail road etc.).

Simon Gaskin commented that a major risk is that others do not see the need for R-Mode. A business case is needed that will stick. R-Mode needs to be sold the right way to convince authorities when there are other systems that give PNT solutions. Effort needs to be expended on making the operational and business case.

Minsu Jeon stated that the requirements of R-Mode should be based on the requirements of the users and not technically driven. Many IALA National members are looking at how to maximise the benefit of existing infrastructure, using the existing DGNSS infrastructure is attractive and this opportunity should be promoted.

Do you see R-mode working alone or as a part of a multi-system concept?

Simon Gaskin considered that, in the future, position and timing will be delivered by a system of systems which will complement one another. The SOLAS Convention resulted from the loss of the Titanic and that a downside of society is that it is possible to take horse to the water, but you cannot necessarily make it drink. The concern is that it may take a major loss of the GNSS resulting in a significant loss of life or major pollution incident before action is taken. A lot of effort needs to be expended on making the case for alternative systems that are completely independent from the one everyone relies on at the moment (GNSS).

Phil Lane commented that flexibility is important, R-Mode is an interesting answer to the problem but we need to keep an open mind on a possible system of systems. With MASS and other autonomous applications being developed, the robustness of systems would be a major selling point.

Could the leisure market also be open to R-Mode?

Phil Lane commented that CIRM members would like to know the answer! Leisure is a hard sell as often the market tended to purchase the minimum equipment that they need for basic navigation and do not tend to go beyond that. Regulation is a key driver for selling anything. It will be hard to sell R-Mode to leisure users but as the IAIN commented, it may take a major loss of GNSS event to sell it.

Could IALA play a role in coordinating with other bodies and organisations in different transport sectors that may be thinking the same thing in terms of timing

Minsu Jeon stated that, in terms of cooperation, IALA has many official meetings with the IMO and IHO and other related international organisations. If there is anything the IALA Secretariat can do to promote R-Mode at relevant meetings we can certainly look at that. A main area of focus as the moment is e-Navigation and the Maritime Services but it is recognized that R-Mode is a risk control option for e-Navigation.

Simon Gaskin commented that we should be leading the way if we are ever to sell an alternative to GNSS. The unique selling point should be timing and not positioning. There are many users for whom time is fundamental such as the financial, broadcasting, mobile telecommunication and utilities sectors all of which need uninterrupted precision timing. If there is only one system, and that fails, there could be significant problems.

How can we improve the visibility of the R-Mode system and what can your organization do within this scope? How we can promote R-Mode to make it more popular (widely known)?

Phil Lane recalled that at NCSR6, there was an IALA input paper suggesting R-Mode as a possible topic for the ITU WRC. One outcome of the submission was that the IMO asked to be kept updated on progress. One solution could be to make an input to NCSR7 providing an update as we have a foot in the door which is a big opportunity. IALA also has status at the ITU so the terrestrial services group could also be a good forum and opportunity to talk across disciplines who may be interested in R-Mode.

Simon Gaskin said that the IAIN members regularly organise conferences. Navigation institutes may be invited to consider R-Mode as a potential agenda item. Additionally, an R-Mode update may be helpful at the next IALA World Congress.

Minsu Jeon indicated that an IALA workshop on the future use of DGNSS will take place in Edinburgh in January 2020. There could be a good opportunity to bring R-Mode into this workshop. Additionally, if WRC 19 approve the VDES satellite downlink that could also be a change or milestone for some kind of event to promote R-Mode.

Is there any preference between VDES or MF?

Phil Lane indicated that it had become clear that are pros and cons to both, we need to keep flexible rather than narrow things down. MF presents technical challenges on the one hand but advantages in available spectrum on the other. A flag needs to be raised on the WRC19 VDES agenda item and we should be aware that this could be the last opportunity for the VDES satellite frequencies to be allocated.

Simon Gaskin said that, from the users perspective, simplicity is important. Mariners want equipment that tells them where they are is and what time it is, they are not generally concerned as to the medium that is used. Requirements will vary with respect to the phase of navigation (i.e. deep sea vs. port and harbour). Users need reliable signals coming into their vessels to keep them safe.

When do you think R-Mode may be fully operational?

Phil Lane commented that test beds are becoming operational in should be in a usable state by 2024. Regulations are needed and the best possible case for this is around 2022 from the IMO. All in all, it maybe around 10 years to an operational system.

Simon Gaskin stated that there is a difference between an operational system and a regulated system. Whilst a system may be serviceable and demonstrable the implementation of any carriage requirements may take many years. There is a risk that some older vessels may never have R-Mode systems fitted. A time frame of around 10 years would seem reasonable.

The moderators thanked all panelists for their contributions and closed with two quotes:

"The future has many names: For the weak, it means the unattainable. For the fearful, it means the unknown. For the courageous, it means opportunity"

Victor Hugo

"The best way to predict the future is to create it"

Abraham Lincoln

11. WORKSHOP CONCLUSIONS

The workshop participants considered the presentations and discussions and concluded that:

- There is international recognition that the GNSS alone is insufficient for critical applications. The combined use of radionavigation and augmentation systems, including R-Mode, onboard maritime vessels is enabled by IMO Resolution MSC.401(95) on performance standards for multi-system shipborne radionavigation receivers.

- Achieving the standardized and world-wide implementation of R-Mode depends on effective harmonization with the work programmes of other interested international organizations such as the IMO and ITU.

Requirements of stakeholders on the R-Mode system

- The stakeholder requirements were found to create a strong basis for the further development of the IALA Guideline on Stakeholder Requirements for R-Mode by the ENG Committee.

- The stakeholder requirements of R-Mode are also of importance to the IALA ENAV and ARM Committees from the technical and user perspectives respectively.

VDES R-Mode implementation

- The workshop welcomed the outcomes of the waveform measurement of VHF R-Mode on the Baltic Sea, Ammersee and the Bohai and Yellow Seas.

- The workshop endorsed the structure of the IALA Guideline G1139 annex related to R-Mode and further developed the VDES R-Mode base station architecture for consideration by the ENG Committee.

- Suggestions as to how to continue the development of IALA Guideline G1139 were made for consideration by the relevant IALA Technical Committees.

- It was identified that benefits would be accrued by utilizing the data channel of VDES for the distribution of additional information relevant to navigation.

Guidelines on Implementation of R-Mode on MF and VHF

- The workshop was of the view that it could be beneficial to provide a common Guideline for MF and VHF R-Mode implementation.

- The system design and requirements should be scalable to enable various R-Mode implementations (contingency/back-up) in different areas.

Platform for coordination of test facilities and testbeds

- There was an agreed view that a collaboration platform for the use of testbeds could enhance and promote the development of R-Mode or other IALA activities. This could also serve to enhance collaboration with other organizations.

- It was recognized that the governance of the collaboration platform needs to be solved and that IALA could play a leading role.

R-Mode development, standardisation and implementation roadmap

- The workshop endorsed the R-Mode mind map and extended it by adding risks and opportunities for R-Mode and possible alternative applications of R-Mode.

- A draft of an IALA R-Mode roadmap was developed based on the mind map. It was stressed that it is difficult to estimate the duration of processes and time schedules after the end of currently ongoing projects.

12. WORKSHOP CLOSING

12.1 The way forward for R-Mode, Michael Hoppe

Micheal Hoppe commented that there are still a number of open questions that need to be resolved:

- There is still technical risk.

- Acceptance – people still think GNSS is good enough, do we really need back up.

- Time line – there is a momentum for R-Mode with good ideas being validated in test projects, but we need to be fast if we want to develop it into an operational system.

- Regulation and standardization – need all of the international organisations to complete the processes in a timely way.

We now have a consolidated implementation roadmap which should serve to address the open questions. Of particular note, is the evolving acceptance and awareness from users and regulators.

The timeline of the history of R-Mode and the pathway for the future developments is very important.
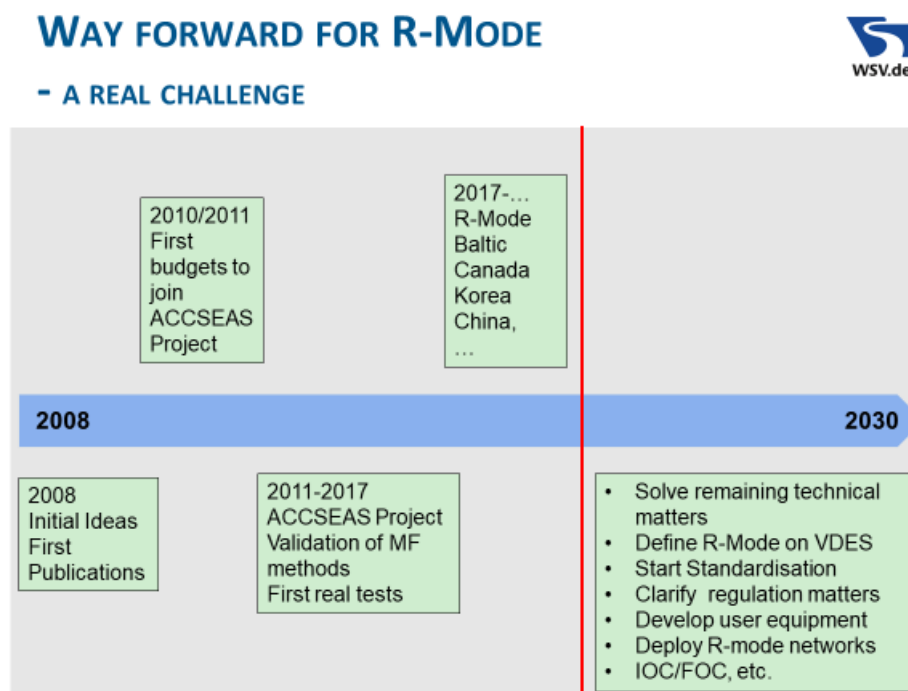
The momentum must be maintained and we must move onwards with the remaining matters as we progress towards 2030.

A large number of stakeholders are already involved with R-Mode. In the IMO, a performance standard is already in place, resilient PNT is a high priority risk control option in the e-Navigation framework. An information paper and presentation to relevant IMO committees could help to raise awareness further.

At the ITU, support is needed for new modulation schemes and new VHF frequencies need to be accepted, the first steps in this are already underway.

Within IALA, the work undertaken on R-Mode within the technical committees needs to be supported and the inclusion of R-Mode in the position paper on the development of marine aids to navigation services maintained. Further workshops and events related to R-Mode would be welcomed as would assistance in the promotion of the system and serving as a platform for the sharing of test bed results.

IALA is a central player and could provide valuable support with respect to liaising with other international organisations and standardisation groups.

Research institutes and manufacturers are also very important. They should continue efforts to develop R-Mode implementation on MF and VHF and also work on error mitigation solutions. Consideration should also be given to the development of suitable equipment for both shipboard and shore use.

Maritime administrations also need to be engaged with respect to the regulatory and standardisation work. They need to be encouraged to implement R-Mode on the coastlines especially in critical areas. Furthermore, administrations should be encouraged to cooperate and work together to implement regional systems.

In summary, awareness for GNSS independent positioning will increase with higher dependence on PNT data onboard ship. R-Mode could play an important role to provide Resilient PNT if all stakeholders work hand in hand. R-Mode may be deployed in different ways in different regions (contingency/ backup or even redundant to GNSS).

12.2   Closing remarks, Francis Zachariae, Secretary-General, IALA

Francis Zachariae thanked all participants for their hard work over the week and IALA considers this work to be extremely important. There was excellent feedback to the post about the workshop on LinkedIn which further highlights this importance.

The conclusions of the workshop are very positive, especially that there is an international recognition that the use of GNSS alone is insufficient. However, there may not yet truly be this international recognition amongst all stakeholder groups, and this is something that we need to continue to work on. With respect to R-Mode, we need to be sure that the whole maritime world is fully convinced that there is a need for this alternative system. We need to convince everyone concerned that GNSS is vulnerable, especially as we move towards automation and potentially unmanned vessels.

These challenges require cross committee coordination in IALA. ENG should continue its positive work, ENAV needs to be engaged with respect to VDES and ARM with respect to user requirements and product specifications.

A platform for sharing testbed results is important. There are a lot of significant projects either underway or completed and we need to ensure we effectively share the results of these and build upon each other's successes and challenges. There is a dedicated space on the IALA website for this and an associated Guideline has been published to facilitate harmonised reporting.

An information paper to the IMO, at a suitable time and to the relevant committees would serve to raise the profile of R-Mode with all member States and other organisations representing major maritime sectors.

12.3   Closing remarks, Stefan Geweis

The workshop has proved to be very valuable in helping us to exchange ideas, learn and work towards reaching our goals. We are now at a good starting point on the road towards the standardization of R-Mode. It is very much hoped that this momentum can be maintained in the forthcoming ENG and ENAV Committee meetings.

Challenge to convince the people of the vulnerabilities with GNSS and of the benefits of R-Mode. Many sectors are already aware, transport, finance and utilities are aware they depend on a single system. Perhaps we should look at more liaisons with other user groups?

It was a successful meeting due to the hard work of the steering committee members and the IALA Secretariat for making the workshop. Mr Gewies wished everyone a safe journey home and looked forward to seeing all participants again in IALA HQ or another place to continue the discussions we have started this week.

ANNEX A   WORKSHOP PARTICIPANTS

Name	Position	Organisation	Country
Richard AASE	Senior Engineer	Norwegian Coastal Administration	Norway
Jesper BACKSTEDT	System Engineer	Swedish Maritime Administration	Sweden
Stefan BOBER	Senior Engineer Radio Technologies	Federal Waterways & Shipping Administration	Germany
Ronan BOYLE	Director of eNavigation & Maritime Services	Commissioners of Irish Lights	Ireland
Krzysztof BRONK	Acting Head of Wireless Systems & Networks	National Institute of Telecommunications	Poland
Michel COUSQUER	Head of Navigation and Positioning Systems Department	Direction des Affaires Maritimes/CEREMA ENF	France
Jean DELISLE		Canadian Coast Guard	Canada
Peter DOUGLAS	Navigation Manager	Northern Lighthouse Board	Scotland
Cato Giil ELIASSEN	Product Manager, Navigation and Infrastructure	Kongsberg Seatex AS	Norway
Simon GASKIN	Secretary-General	International Association of Institutes of Navigation (IAIN)	UK
Stefan GEWIES		German Aerospace Center (DLR)	Germany
Lars GRUNDHOFER		German Aerospace Center (DLR)	Germany
Niklas HEHENKAMP		German Aerospace Center (DLR)	Germany
Kaisu HEIKONEN	Senior Technical Advisor	Finnish Transport Infrastructure Agency	Finland
Xavier HERNOË	Nautical Expert	Direction des Affaires Maritimes	France
Michael HOPPE	Senior Engineer, Radio Navigation	Federal Waterways & Shipping Administration	Germany
Ahmad Rizuan HUSSIN		National Hydrographic Centre	Malaysia
Harold KIFFER	GPS Division Chief	US Coast Guard	USA
Young-jae KIM		Ministry of Oceans and Fisheries	Republic of Korea
Hyun KIM		Ministry of Oceans and Fisheries	Republic of Korea
Young Ju KIM		Ministry of Oceans and Fisheries	Republic of Korea
Dirk KOWALEWSKI		NavXperience GmbH	Germany
Ringo LAKEMAN	Senior policy adviser	Ministry of Infrastructure and Water Management	Netherlands
Philip LANE	Technical Officer	Comité International Radio Maritime	UK

Werner LANGE		Lange Electronic GmbH	
Etienne LEROY	Techical Engineer	CEREMA	France
Chenyang LI		China Maritime Safety Administration - Dalian Maritime University	People's Republic of China
Ognyan MUKAREV		Bulgarian Ports Infrastructure Company	Bulgaria
Lee NEVILLE	Qualification R&D Engineer	Securitats N.V.	Belgium
Thoralf NOACK	Head of Department Nautical Systems	German Aerospace Centre (DLR)	Germany
Tiit PALGI		Estonian Maritime Administration	Estonia
Sang-Hyun PARK	Principal Researcher	Korea Research Institute of Ships & Ocean Engineering (KRISO)	Republic of Korea
Xiaoming PENG	Head of Department	A*STAR-12R	Singapore
Mahesh PRASAD NIMARE	Deputy Director	DGLL	India
Ronald RAULEFS	Researcher - Institute of Communications and Navigation	German Aerospace Centre (DLR)	Germany
Carsten RIECK		RISE	Sweden
Jorgen ROYAL PETERSEN	Senior Engineer Aids to Navigation	Danish Maritime Authority	Denmark
Jan SAFAR	R&D Engineer	GLA Research and Development (GRAD)	UK
Michael STRANDBERG	Project Manager	Danish Maritime Authority	Denmark
Xiaowen SUN		China Maritime Safety Administration - Dalian Maritime University	People's Republic of China
Kim Chuan TEE	Manager	Maritime and Port Authority of Singapore	Singapore
Maik UHLEMANN		Alberding GMBH	Germany
Jeffrey VAN GILS	Senior Advisor	Ministry of Infrastructure and the Environment	Netherlands
Markus WIRSING		German Aerospace Centre	Germany
Roslee Mat YUSOF	Director of Safety of Navigation	Light Dues Board Peninsular Malaysia, Marine Department	Malaysia

ANNEX B   SPEAKER BIOGRAPHIES

Ringo Lakeman: e-Navigation and Resilient PNT

Ringo Lakeman served as a Maritime Officer at Nedlloyd Lines from 1987 to 1993, and consequently held several functions ashore (mainly in the field of ship planning) for the same shipping company.

In 1998 he joined the Netherlands Shipping Inspectorate, originally as inspector (later senior inspector) to move to the function of senior adviser (nautical) in 2004 for this organization.

In 2013 he joined the Ministry of Infrastructure and the Environment (now Ministry of Infrastructure and Water Management) to serve as a senior policy adviser in the Directorate for Maritime Affairs.

Since 2005 he represents the Netherlands in several international meetings, of which most in the International Maritime Organization. In this field he served as head of delegation of the Netherlands in many sub-committee meetings, and chaired several working groups.

In 2013 he became vice chairman of the IMO COMSAR Sub-Committee (Radiocommunications and Search and Rescue), to become vice chairman of the IMO NCSR Sub-Committee (Navigation, Communication and Search and Rescue) in 2014.

Since 2016 he serves as chairman of the IMO NCSR Sub-Committee.

Since 2016 he is involved in the topic of autonomous shipping, and contributed significantly in putting the issue on the agenda of the IMO.

Simon Gaskin: GNSS vulnerability - Mariners need for a back-up

Has been the Secretary General of the International Association of Institutes of Navigation since October 2015.

Now retired, Simon was a career Naval Officer in the Royal Navy for 37 years, specialising in Navigation. He spent the majority of his career at sea, serving in most types of warship including operational duty in 1982 and 2002. He commanded HMS CYGNET and was Navigation and Operations Officer in the Antarctic Patrol Ship, HMS ENDURANCE. His last appointment was as the marine navigation equipment and ship's bridge human element adviser to the Defence Equipment and Support agency. After joining the Retired list he did some consulting on marine navigation projects before closing his company in 2016. He is an Assistant Editor for the Journal of Navigation.

Simon is a Freeman of the Honourable Company of Master Mariners, a Fellow of both the Royal Institute of Navigation and the Nautical Institute, and a Member of the Institute of Seamanship. He also sits on two committees of the British Standards Institute.

Michael Hoppe: Early work on R-Mode

Michael Hoppe received his diploma as a radio engineer in 1990. Since 1991 he has been working for the German Federal Waterways and Shipping Administration. He is responsible for the field of radio navigation systems for maritime and inland waterways applications. Michael Hoppe is a member of various national and international working groups dealing with development and standardization of integrated PNT systems. Since 1998 he has been a member of the IALA in various technical committees. At present he is acting as vice chair of the PNT WG within the IALA Engineering Committee.

Jan Šafář: R-Mode in the North Sea region

Dr Jan Šafář is an R&D Engineer working for the Research and Development Directorate of the General Lighthouse Authorities of the United Kingdom and Ireland (GRAD). His areas of expertise include GNSS and complementary positioning, navigation and timing systems, such as eLoran and R-Mode. He has also been closely involved with the development and international standardization of the VHF Data Exchange System. Jan is a member of the Digital Communications Working Group of the IALA e-Navigation Committee, the AIS Working Group of IEC TC80, the Royal Institute of Navigation and US Institute of Navigation.

Stefan Gewies: R-Mode in the Baltic Sea region

Stefan Gewies is a Scientist working for the German Aerospace Center in the Institute of Communications and Navigation. He is there Head of the Working Group Maritime Services of the Department of Nautical Systems and Project Manager of an international project that aims to build an R-Mode testbed in the Baltic Sea. His current research focus is on terrestrial maritime navigation systems using signals-of-opportunity. Stefan is a member of the Radionavigation Services Working Group of the IALA ENG Committee.

Sun Xiaowen: AIS Autonomous Positioning System (AAPS) in China

Sun Xiaowen is a lecturer of Information Science and Technology College at Dalian Maritime University, China. She is a team manager of VDES R-mode group at Dalian Maritime University. She is also a technical director of Liaoning Key Laboratory of traffic safety and communication technology. She received the Ph.D. degree in Dalian Maritime University in 2012. She is mainly engaged in the research of AIS R- mode, VDES R-mode and GNSS positioning and navigation technology.

Sang-Hyun Park: R-Mode in the Republic of Korea

Dr. Sang Hyun PARK is a director of Maritime PNT Research Centre at the Korea Research Institute of Ships & Ocean Engineering (KRISO). The Maritime PNT Research Centre is in charge of research and development of marine PNT-related research projects promoted by the South Korean government, and serves as a technical advisor for the government to establish technical policies. He has been involved in lots of radio navigation-related research projects such as a vessel berthing system using GNSS, DGNSS reference stations and integrity monitors, eLoran system, etc. His current research interests focus on resilient PNT systems for maritime safety.

Jean Delisle: R-Mode in Canada

Jean began his career in the private sector as a physics technologist. He then joined the public service and has held various electrical and electro-optical engineering positions with Defense Research & Development Canada (Valcartier). He has occupied progressively more senior roles as service head (DRDC) and regional director of the former Québec region in the Canadian Coast Guard (CCG). After the region merger, he was appointed as the national director of the Alternate Service Delivery of buoy tending. As the project progressing, he fulfilled the national Shore Electronic & Informatics Manager position. Jean holds a Diploma in Physics, a Bachelor of Electrical Engineering and Master of Business Administration from Université Laval. He is also a chartered Engineer.

Carsten Rieck: Timing for R-Mode base stations

Carsten Rieck, time metrologist at RISE Research Institutes of Sweden. He has a background in Computer Science, Digital Communication and Geodesy. He has been working with time keeping for about 20 years, with research concentrating on time and frequency transfer methods in the microwave and optical domain. He has special interest in IP network timing.

Stefan Bober: VHF Data Exchange System (VDES)

Stefan Bober is a senior engineer within the Traffic Technologies Centre of the German Federal Waterways and Shipping Administration.

Since 1987 he has been working on radio aids and transponder techniques for Vessel traffic Services (VTS) and River Information Services (RIS). He has been involved in several projects concerning radio transponder and AIS and is engaged in the AIS and VDES standardisation process for maritime and inland waterways applications. Stefan Bober is actively involved in the planning and development of the German AIS Services.

Stefan Bober is member of various national and international working groups dealing with development and standardisation of AIS and radio communication systems. He is member of the AIS and Communication WG within the IALA e-Navigation Committee, chair of IEC AIS WG and chair of the European expert group for Vessel Tracking and Tracing for Inland Navigation.

10, rue des Gaudines – 78100 Saint Germain en Laye, France
Tel. +33 (0) 1 34 51 70 01 – Fax +33 (0) 1 34 51 82 05 – contact@iala-aism.org
www.iala-aism.org

International Association of Marine Aids to Navigation and Lighthouse Authorities
Association Internationale de Signalisation Maritime