Report on the Workshop on future radionavigation and radiocommunication systems

WORKSHOP REPORT

09 to 13 February 2026

Northern Lighthouse Board

Edinburgh, United Kingdom

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International Organization for Marine Aids to Navigation

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Executive Summary

The workshop on future radionavigation and radiocommunication systems was held between 09 and 13 February 2026 in Edinburgh, United Kingdom.

The workshop was well attended with 78 participants from 24 countries.

The workshop participants considered the various presentations that were given, and the following were concluded:

- Considering the significant increase in navigational risk due to GNSS interference and AIS spoofing, IALA should encourage a safe navigation environment through the promotion, development, and implementation of resilient maritime PNT and radiocommunication services, in cooperation with relevant international bodies.
- More resilient PNT and radiocommunication technologies are available now, and in the near future, IALA should assist its members to prepare, implement, and operate these technologies through IALA publications.
- The IMT technology family, as of today (4G, 5G, terrestrial, and space), offers substantial radio communication capabilities readily applicable to the maritime domain. The firmly planned availability of 6G by 2030 will add many gradual improvements in many relevant regards to 5G, including PNT and IoT; however, the maritime domain should not wait until 6G to engage with the IMT technology family.
- Despite significant development in radionavigation and radiocommunication technologies, physical AtoN remains a primary means for navigation and is essential for resilience.
- IALA should proactively monitor the rapid evolution of satellite technologies and prepare for the utilization of emerging satellite services, especially Low Earth Orbit (LEO)and 5G/6G non-terrestrial networks (NTN) to improve maritime safety and resilience.
- There is no harmonised way of detecting and reporting PNT service interferences. IALA should consider conducting a Workshop on this topic and inviting all relevant stakeholders, alongside the ongoing development of the IALA Guideline on GNSS interferences.
- E-navigation maritime services (Initial descriptions of maritime services in the context of e-navigation MSC.1/Circ. 1610/rev1) should be reviewed and revised, taking specifically into account the introduction of the Resilient PNT service, and the task added to the IALA Work Programme.
- Several terrestrial radionavigation systems are being developed, such as eLoran, R-Mode, etc.; IALA should consider conducting a Workshop on interoperability and harmonisation of these systems.
- The required performance, e.g., bandwidth, latency, etc., for the emerging e-navigation services is unknown; therefore, IALA should consider collecting the needs and creating a method to estimate the required communication means for specific services in each region.
- The development of countermeasures against AIS spoofing is urgent, and authentication of AIS has been developed; in this regard, IALA should consider “a strategy” to encourage widespread implementation for both ship and shore.

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1. INTRODUCTION

Northern Lighthouse Board (NLB) hosted a workshop in Edinburgh from 09 to 13 February 2026, as the need for consideration and discussion on future radionavigation systems and radiocommunication systems was recognised since emerging digital technologies could be used for both radionavigation and radiocommunication as one system, e.g., VDES R-mode, Galileo return link service.

78 participants from 24 countries participated in the Workshop, including six members of the IALA Secretariat and IALA WWA.

2. SESSION 1 – WELCOME AND INTRODUCTIONS

This session was chaired by Hideki Noguchi, Chair of the Workshop and IALA DTEC Committee. The Secretary was Alisa Nechyporuk, and the Northern Lighthouse Board organised the logistics for the event.

Workshop Chair clarified that the workshop was not originally his initiative. It had been planned by Michael Hoppe, the former Chair of the Radio Navigation Working Group of the PNT Committee. Mr. Hoppe was well known and respected within the community for his dedication to radionavigation and his efforts in maintaining strong professional connections in this field. Sadly, he passed away a few years ago. The workshop is therefore dedicated to his memory and contributions.

2.1 Welcome from the host, Mike Bullock – Northern Lighthouse Board (NLB)

The IALA Workshop on future radionavigation and radiocommunication technologies was officially opened in Edinburgh by Mike Bullock, Chief Executive of the Northern Lighthouse Board. He opened the workshop by welcoming participants and outlining essential safety procedures. Clear instructions were provided regarding evacuation routes, assembly procedures, badge access, security protocols, first aid arrangements, and building regulations. Safety was emphasised as the highest priority throughout the event.

He then formally welcomed participants on behalf of the Northern Lighthouse Board (NLB) and highlighted the significance of hosting IALA in Scotland's capital. The United Kingdom's strong support for IALA was noted, including active participation in governance, committees, and research activities. The visit was also described as an opportunity to raise awareness of the vital role of marine aids to navigation in ensuring safe waters globally.

An overview of the week's programme was provided, including a visit to the NLB's newly commissioned vessel *Pole Star* and an evening reception aboard the Royal Yacht Britannia.

Mike Bullock concluded with a brief introduction to the Northern Lighthouse Board, established in 1786 and headquartered in Edinburgh since 1829. As one of the three General Lighthouse Authorities of the United Kingdom and Ireland, alongside Trinity House and the Commissioners of Irish Lights, the NLB is responsible for Aids to Navigation in Scotland and the Isle of Man. The organization employs approximately 200 staff and operates an extensive network of lighthouses, buoys, and support vessels.

Participants were encouraged to engage fully in the programme and to approach the NLB team for any assistance during their stay.

2.2 Welcome from IALA, Omar Eriksson – IALA Deputy Secretary-General

Omar Eriksson, IALA Deputy Secretary-General, welcomed participants to the Workshop on Future Radionavigation and Radiocommunication Systems. He expressed sincere appreciation to the Northern Lighthouse Board and to Mike Bullock for hosting the event and for their warm welcome.

He highlighted that the workshop serves not only as a technical meeting but as a strategic forum to address the evolving infrastructure that underpins safe, efficient, and resilient maritime operations. Over the five-day programme, participants expect to examine both legacy systems and emerging technologies, reflecting the rapid transformation of the maritime domain driven by digitalization, automation, satellite expansion, GNSS vulnerabilities, spectrum challenges, cyber resilience, and developments in autonomous shipping.

IALA Deputy Secretary-General underlined key strategic questions concerning interoperability, system resilience, global harmonization, and equitable access to innovation. He emphasized that the diversity of expertise present—regulators, technologists, industry representatives, researchers, and operational users—creates a strong foundation for holistic and forward-looking solutions.

The Technical programme addresses regulatory frameworks, VDES and AIS evolution, satellite-based systems, terrestrial back-up solutions, emerging communication technologies, and quantum navigation research, culminating in working group discussions aimed at developing actionable outcomes.

In conclusion he stressed that resilience—technological, operational, regulatory, and global—must remain the central objective in shaping the future of maritime navigation and communication systems. He encouraged active engagement and collaboration throughout the week and expressed confidence in a productive and forward-looking workshop.

2.3 Workshop scope and purpose, Hideki Noguchi (JSTRA)

Hideki Noguchi, Chair of the Workshop, outlined the scope and objectives of the Workshop on Future Maritime Radionavigation and Radiocommunication Systems.

Radionavigation and radiodetermination were defined as the use of radio waves to determine position, velocity, or other characteristics of an object for navigation purposes, including obstruction warning. Radiocommunication was described as telecommunication by means of radio waves. With increasing digitization, single radio systems can now simultaneously carry navigation data (e.g., timing signals) and communication content (e.g., text messages), as demonstrated by AIS Message 12 (addressed safety-related message), AIS Message 17 (DGNSS broadcast binary message), and VDES R-Mode applications.

The presentation highlighted significant changes in the radio environment, including rapid digital transformation, the availability of multi-system and multi-frequency solutions, and increasing GNSS interference. These developments directly impact Aids to Navigation (AtoN) and Vessel Traffic Services (VTS) authorities.

The workshop aims to:

- Guide AtoN and VTS authorities, service providers, and manufacturers in planning and investment for future systems.
- Identify operational requirements for future maritime radionavigation and radiocommunication services.
- Analyze technical, regulatory, and operational challenges.
- Clarify IALA's role in supporting these developments.

Two working groups were established:

WG1 – Maritime Radiocommunication (MarCom)

Expected outputs include identification of future system requirements and gaps, proposals for updated IALA guidance, recommendations for revisions to the Maritime Radiocommunication Manual, development of a new guideline draft describing integrated operational use cases from detection to S-100 information delivery, and key messages on resilience, interoperability, and regulatory alignment.

WG2 – Maritime Radionavigation (MarNav)

Expected outputs include identification of future system needs and resilience strategies, proposals for updated IALA guidance on radionavigation, recommendations to ENG regarding updates to the World-Wide Radionavigation Plan (WWRNP), and clarification of the continued role of terrestrial systems in an increasingly GNSS-dependent environment.

Overall, the presentation positioned the workshop as a strategic step toward strengthening resilience, integration, and future readiness in maritime radio-based navigation and communication systems.

Presentations from the Workshop can be found on the IALA fileshare.

A list of participants can be found in Annex A.

The full programme of the workshop can be found in Annex B.

2.4 WWA updates on Capacity building, Vincent Denamur – IALA WWA Dean

Vincent Denamur – IALA WWA Dean presented Goal 2 of the IALA Strategic Vision, which aims to ensure that all coastal States contribute to a sustainable and efficient global network of Marine Aids to Navigation (AtoN) through capacity building and the sharing of expertise.

Central to this objective is the World-Wide Academy, established in January 2012 as the vehicle through which IALA delivers training and technical assistance. The Academy is independently funded, enabling it to provide services regardless of IALA membership status. Its mission is to support coastal States that require strengthened national and institutional capacity to deliver AtoN services in accordance with international standards.

The Academy delivers training programmes, including the Level 1.4 Model Course, currently under review by DTEC and the ENG Committee. Emerging priority topics include resilient Positioning, Navigation and Timing (PNT), digitalisation, and maritime radionavigation and radiocommunication, as addressed in IALA Standards S1030 and S1060. A possible training session is envisaged in 2026 for a Black Sea country.

The speaker highlighted that while radionavigation and radiocommunication are specifically addressed in dedicated standards, they underpin all seven IALA Standards. In today's rapidly changing environment—characterised by digital transformation, climate change, geopolitical shifts, and budget constraints—coastal States face increasingly complex challenges. A widening gap is emerging between countries able to adopt digital solutions quickly and those lacking the necessary institutional capacity.

Key concerns identified include GNSS disruption, incomplete or outdated nautical charts, deficiencies in Maritime Safety Information (MSI) issuance, weak coordination mechanisms, insufficient radiocommunication infrastructure, and limited staffing and workflow capacity. In some cases, authorities can draft navigational warnings but lack reliable broadcasting capability. These implementation gaps often overshadow discussions about advanced technologies.

The speaker emphasised that beyond technology, three critical enablers determine success:

- People – adequate skills and technical capacity;
- Money – sustainable operational funding;
- Governance – clear accountability and institutional frameworks.

Failure to address these factors has led to so-called "white elephant" projects—costly infrastructure investments that fail to deliver sustained operational benefits due to weak management, lack of oversight, or insufficient local capacity.

Effective governance was identified as a decisive success factor. Essential elements include:

- A designated national authority responsible for originating and coordinating MSI with 24/7 capability;
- Formal processes for message authentication, logging, and incident investigation;
- Strong procurement evaluation, contract management, and performance monitoring mechanisms;
- Clear accountability in public–private partnership arrangements, ensuring that maritime administrations retain oversight under SOLAS obligations;
- The ability to independently verify that outsourced or contracted services meet required performance standards.

The presentation concluded by stressing that technological advancement must be matched by institutional strength. Sustainable safety improvements depend not only on systems and equipment, but on governance clarity, capacity development, and long-term operational resilience.

3. SESSION 2 – REGULATORY CONSTRAINTS AND TECHNICAL CAPABILITY

Stefan Bober, from the German Federal Waterways and Shipping Administration (WSV), chaired this session.

3.1 Overview of Maritime Spectrum Regulations and Gaps – China Transport Telecommunications and Information Center (CTTIC)

Falong Liu delivered a presentation addressing the evolving landscape of maritime radionavigation and radiocommunication within the broader framework of international cooperation and technological transformation.

He highlighted the rapid pace of digitalization in the maritime domain and the increasing integration of navigation and communication functions within shared radio systems. Emphasis was placed on the importance of resilience, interoperability, and spectrum efficiency in a context of growing GNSS vulnerabilities and expanding satellite and terrestrial communication infrastructures.

Mr. Liu underlined the need for coordinated international standards and regulatory alignment to ensure that emerging technologies are implemented safely and consistently across regions. He also stressed the importance of balancing innovation with reliability, ensuring that new systems complement existing infrastructure and support uninterrupted maritime safety services.

Concluding his remarks, he encouraged strengthened collaboration among administrations, industry, and international organizations to address technical challenges and to build a robust, future-ready maritime radionavigation and radiocommunication ecosystem.

The presentation outlined the scope and action of a regulatory study concerning the VHF maritime mobile band. The study focuses on spectrum sharing and compatibility between new digital voice and data technologies and incumbent services that currently hold primary allocations in the same or adjacent frequency bands. It also examines spectrum requirements, transitional arrangements, and potential adjustments within the VHF maritime mobile band to accommodate technological evolution.

Based on the results of these studies, the proposed action is to consider possible regulatory changes within the framework of the Radio Regulations (RR), without introducing new allocations under Article 5. The objective is to advance digital voice and data technologies within the Maritime Mobile Service (MMS) while ensuring protection of existing services and maintaining orderly spectrum management.

3.2 Experience from VDES and AIS: Regulatory Adaptation for New Technologies – Hideki Noguchi (JSTRA)

Hideki Noguchi explained that AIS is currently a mandatory carriage requirement under SOLAS Chapter V. The development of the VHF Data Exchange System (VDES), which expands AIS capabilities and includes terrestrial and satellite components, required significant regulatory adjustments.

A key challenge was securing appropriate frequency allocations through the ITU World Radiocommunication Conferences (WRC-15 and WRC-19). Although terrestrial frequencies were approved earlier, satellite allocations were more complex and remain secondary rather than primary allocations, limiting integration into GMDSS.

At IMO level, discussions addressed whether VDES should amend SOLAS Chapter V (navigation safety) or Chapter IV (radiocommunications). After extensive debate and correspondence group work, the decision was to amend Chapter V rather than Chapter IV, due to GMDSS frequency and regulatory constraints. The process required amendments to numerous IMO instruments, as AIS is referenced in more than 40 resolutions and guidelines.

Workshop Chair emphasized that introducing even a “small” technological enhancement can take over a decade due to the need for coordination between IMO, ITU, and Member States, as well as alignment with performance standards and associated codes.

3.3 Experience from SBAS: Regulatory adaptation for marine radionavigation – Hideki Noguchi (JSTRA)

Hideki Noguchi referred to SOLAS Chapter V, Regulation 13, which requires Contracting Governments to provide aids to navigation as traffic volume and risk justify, and to Regulation 19.2.1.6.

Although GNSS carriage is mandatory, earlier IMO instruments, including Resolution A.1046(27) (2011) – Worldwide Radionavigation System (WWRNS), did not clearly address augmentation systems. That resolution established procedures and requirements for GNSS recognition, building on Resolution A.915(22) concerning future GNSS policy.

At NCSR 12 (2025), augmentation systems were formally considered within the WWRNS framework. The Committee concluded:

- Augmentation systems were not intended to be part of GNSS recognition, as they are methods of improving GNSS performance.
- Resolution A.915(22) required GNSS recognition because GNSS receivers are subject to mandatory carriage requirements.
- Requiring IMO recognition for every augmentation system would have significant regulatory implications.
- Resolution A.1046(27) lacked clarity regarding the requirements augmentation systems should satisfy.

As a result, NCSR drafted and finalised a proposed revised annex to Resolution A.1046(27), to be issued via MSC resolution.

Key Outcomes:

- The WWRNS includes global and regional radionavigation systems and may include corresponding augmentation systems.
- Augmentation systems do not require formal IMO recognition, but they must meet defined operational requirements.
- The term *radionavigation system* may refer either to a stand-alone system or to a combination of a radionavigation system and an augmentation system.
- Augmentation systems may also provide integrity monitoring and malfunction notifications for radionavigation systems.

Turning to Satellite-Based Augmentation Systems (SBAS), Hideki Noguchi noted that while systems such as EGNOS and regional augmentation services are operational, SOLAS and the IMO World-Wide Radionavigation System (Resolution A.1046) historically did not explicitly reference augmentation systems.

A proposal led by Australia and EU Member States initiated work on developing performance standards for dual-frequency, multi-constellation GNSS receivers with SBAS capability. This required clarification of whether augmentation systems themselves needed formal IMO recognition, similar to GNSS constellations.

After discussion, it was agreed that SBAS and GBAS do not require individual IMO recognition. However, Resolution A.1046 was updated to incorporate augmentation systems within the broader framework of the World-Wide Radionavigation System. Work is now progressing on performance standards for shipborne receivers.

4. SESSION 3 – USERS' VIEW ON RADIONAVIGATION AND COMMUNICATION

This session was chaired by Phillip Day, Northern Lighthouse Board (NLB).

4.1 ARM perspective on MARCOM – R. David Lewald (U.S. Coast Guard)

R. David Lewald from the U.S. Coast Guard presented the ARM perspective on maritime communications, combining operational experience with reflections on modernization and digital transformation. He began with a personal account from his time as a buoy tender captain during the Deepwater Horizon response, illustrating how incomplete or outdated marine safety information could have resulted in grounding. This example underscored that the delivery of reliable navigation information is not only a professional obligation but a matter of operational safety with real consequences.

He identified several drivers shaping the evolution of maritime communications, including digitalisation, expanded AIS and VDES capabilities, increased reliance on GNSS, cybersecurity concerns, and the need for interoperability and harmonisation. He described AIS as a paradigm shift that significantly improved situational awareness by allowing mariners to monitor surrounding traffic more effectively. The integration of digital communications, including weather data and air draught information, has enhanced operational awareness, but he stressed that the key challenge is operationalising these tools effectively. Training for both mariners and service providers remains critical as systems become more complex.

Mr. Lewald provided detailed insights from an eight-year U.S. Coast Guard test programme on remote monitoring of Aids to Navigation. Using satellite communications, the Coast Guard monitored buoy battery performance and was able to remotely adjust light intensity during periods of low solar charging to prevent outages. While the system demonstrated operational benefits and validated predictive maintenance models, it also revealed software limitations and highlighted significant costs, approximately $1,700 per buoy annually. He emphasised that not all buoys require monitoring and that authorities must carefully balance operational vessel costs with digital monitoring investments, prioritising critical aids such as turn buoys.

He cautioned against over-reliance on GNSS despite its transformative impact, noting that visual aids remain essential for redundancy in case of signal disruption. Cybersecurity was identified as a growing concern, particularly regarding the extent of responsibility for shore-based authorities versus shipboard systems. He also addressed environmental and operational efficiencies achieved through LED technology, solarisation, and synthetic buoy materials, while acknowledging associated trade-offs.

The U.S. Coast Guard currently operates more than 500 synthetic AIS AtoN and over 100 virtual AtoN, using them for temporary outages, storm response, ice conditions, and dredging operations. Mr. Lewald concluded that while digital communications and VDES offer significant opportunities for improved safety and efficiency, successful implementation depends on careful cost management, training, cybersecurity awareness, and maintaining appropriate redundancy within the maritime navigation system.

4.2 Digital VTS and the Future of Maritime Connectivity – Olli Soininen (Fintraffic)

Olli Soininen presented the Vessel Traffic Service (VTS) user perspective on digitalisation and future maritime connectivity, drawing on Finland’s operational experience in complex and extreme maritime conditions. He emphasised that while systems may be technically advanced, the end user—particularly the mariner—often perceives VTS primarily as a voice service. The challenge, therefore, is not only technological development but aligning systems with user understanding and operational reality.

He described VTS as a shore-based safety service aimed at improving navigation safety, efficiency, and environmental protection through traffic monitoring, information provision, traffic organisation, and vessel assistance. Although VTS has long relied on digital infrastructure internally, communication with ships remains largely voice-based. However, increasing traffic density, operational complexity, environmental constraints, and the evolution toward e-navigation are driving the need for structured, two-way digital data exchange alongside voice communication.

Mr. Soininen explained that modern VTS relies on interconnected sensor networks, including radar, AIS, cameras, and radio systems. Operators build situational awareness based on integrated data streams, often without direct visual confirmation of traffic. Current limitations include reliance on voice language communication, reactive rather than predictive operations, and fragmented data systems that require operators to mentally integrate information. This model, he noted, will not scale effectively with future traffic growth and automation.

He stressed that digital VTS represents not merely a technical upgrade but a fundamental shift in operational approach. Future systems must support structured, continuous, service-based communication between ship and shore. Harmonization and standardization are essential; ships cannot operate with different communication methods in every port. Any new digital solution must be consistent, interoperable, and ideally mandatory to ensure usability across regions.

Addressing resilience, he highlighted ongoing GNSS disruptions and positioning challenges. Ships frequently require support due to loss or degradation of positioning signals. Integration of multiple sensors, anomaly detection systems, and alternative positioning methods will be increasingly important. Emerging technologies such as AI-supported monitoring and intelligent sensor fusion were identified as tools to enhance predictive capability and risk assessment.

Mr. Soininen also presented findings from a global VTS foresight study conducted in 2024, based on expert input. Two scenarios were analyzed: incremental evolution and radical transformation. The incremental scenario suggests VTS will remain essential, with greater emphasis on communication, monitoring, predictive tools, and cybersecurity. The radical scenario, driven by autonomy and remote operations, would require high-integrity continuous monitoring, real-time data availability for both human operators and automated systems, regional coordination models similar to aviation, and robust cyber resilience.

Across both scenarios, key requirements emerged: improved positioning reliability, multi-source data integration, structured and secure digital communication, continued importance of voice as a safety fallback, and clear governance frameworks. Mr. Soininen concluded that while radical transformation is possible, incremental digital evolution is more likely in the near term. Nevertheless, investments in positioning resilience, communication standardization, and interoperable digital services represent “no-regret” steps toward the future of maritime connectivity.

4.3 Standard Navigation for GNSS Disruption: Bringing Visual Perception Back to the Forefront – Capt Aly Elsayed (AFNI)

Captain Aly Elsayed addressed the growing operational risks associated with GNSS disruption and the need to rebalance navigation practices by strengthening visual perception and traditional navigation skills. Rather than focusing on distant future concepts, he concentrated on the “near future” – the next 10 to 20 years – during which current vessels and systems will still be in operation and exposed to increasing GNSS interference.

He highlighted that GNSS represents a single point of failure when over-relied upon, and recent geopolitical conflicts have demonstrated how easily signals can be disrupted, spoofed, or degraded. Through simulator demonstrations used in Bridge Resource Management (BRM) training, he illustrated how GNSS manipulation can shift a vessel’s displayed position while other targets appear normal, creating a dangerous false sense of security. Such distortions may not be immediately obvious to operators who rely primarily on screen-based information.

Captain Elsayed questioned whether the maritime sector is truly prepared for sustained GNSS disruption. Accident reports and recent cases show increasing instances of degraded positioning, AIS anomalies, and signal manipulation. He stressed that excessive reliance on screens—ECDIS, radar overlays, AIS and other digital systems—has contributed to diminished visual navigation competence. In many cases, navigators trust electronic displays even when visual cues contradict them.

He emphasised the critical difference between “seeing” and “observing.” Observation is an active cognitive process that integrates visual information with mental interpretation and situational awareness. Visual perception, including the ability to recognise landmarks, interpret buoy characteristics in real conditions, judge scale and distance, and mentally map spatial relationships, is essential for safe navigation. These skills are directly linked to situational awareness and can deteriorate without regular practice.

Through a series of short educational videos developed by The Nautical Institute, he promotes training focused on visual perception, mental imagery, and cross-checking between outside observation and electronic instruments. The initiative encourages navigators to visualise routes, anticipate sequences of events, and strengthen visual sequential memory, especially in complex or restricted waters. He underscored that technology should validate what is observed outside the window, not replace it.

Captain Elsayed also warned that reduced physical Aids to Navigation in some regions, combined with heavy GNSS dependence, may weaken resilience. While digitalisation and AIS have significantly improved safety and efficiency, a balance must be maintained. Visual navigation should not be treated as secondary but as a fundamental layer of redundancy.

He concluded that GNSS disruption is no longer theoretical. The industry must act proactively by reinforcing training, improving awareness, and embedding visual navigation competence within curricula and operational practice. The key message was clear: cross-checking, balanced use of technology, and strengthened human perception are essential to maintaining safe navigation in an increasingly disrupted digital environment.

5. SESSION 4 – VHF RADIO NAVIGATION AND COMMUNICATION

Peter Douglas from Northern Lighthouse Board (NLB) led this session.

5.1 VDES as a communication system – Stefan Pielmeier (FLIR TransponderTech AB)

Stefan Pielmeier presented VDES (VHF Data Exchange System) as an integrated maritime communication system, emphasizing its structure, capabilities, and unique value compared to other communication technologies. Drawing on his extensive background in digital radio engineering and maritime standardisation, he explained VDES not as a replacement for AIS, but as an evolution that builds upon it.

He began by clarifying that VDES consists of four components: AIS (unchanged from its current form), Application Specific Message (ASM) channels, terrestrial VHF Data Exchange (VDE-TER), and satellite VHF Data Exchange (VDE-SAT). AIS remains exactly as it is today, operating on its existing channels. The ASM channels provide additional bandwidth for digital data transmission, allowing application-specific messages to be offloaded from AIS channels. These channels support higher data rates and can incorporate authentication, which is essential given AIS's current lack of built-in security.

VDES terrestrial introduces coordinated, managed access similar to mobile telecommunication systems, using designated VHF channels with significantly greater bandwidth than AIS. It enables higher data throughput—up to approximately 30 times AIS speeds—and supports structured data exchange, including route plan exchange, S-100 product distribution, navigational warnings, and GNSS interference reporting. However, Mr. Pielmeier stressed that VDES remains a narrowband system and must be used with careful bandwidth planning. It is not intended to replace broadband internet services but to provide reliable, maritime-dedicated communication for safety-critical data.

The satellite component of VDES extends coverage globally using low Earth orbit satellites. While satellite bandwidth is more limited than terrestrial, it enables wide-area broadcast services, including authenticated AIS messages, route exchange in remote regions, and potential Arctic and high-latitude use cases. Achieving near-real-time global coverage would require a significant satellite constellation, but the concept supports incremental development through multiple providers and harmonised interfaces.

A key theme of the presentation was authentication. VDES allows authenticated AIS and AtoN messages using additional data capacity on ASM or VDE channels. This directly addresses IMO performance standard requirements for AIS authentication. Mr. Pielmeier highlighted that unauthenticated AIS is vulnerable to spoofing, and VDES offers a practical pathway to improve trust and cybersecurity without abandoning existing AIS infrastructure.

He also addressed spectrum coordination and resource management. VDES uses coordinated slot allocation mechanisms, including broadcast "bulletin boards" from shore stations or satellites, informing vessels how communication resources are assigned. Guidelines under development within IALA aim to support infrastructure planning and cross-border coordination.

Mr. Pielmeier presented VDES as uniquely suited to maritime needs because it operates on internationally allocated maritime frequencies, supports ship-to-ship and ship-to-shore communication independent of commercial subscriptions, and is governed through open international standards under ITU and IMO frameworks. Unlike commercial satellite or cellular systems, VDES does not inherently require SIM cards or subscription models for safety services.

He concluded that VDES provides a harmonised, authentication-capable, maritime-dedicated communication infrastructure supporting services such as authenticated AIS, virtual AtoN, GNSS disruption reporting, route exchange, S-100 product distribution, and potential R-Mode positioning. While not a broadband solution, VDES offers a resilient, open, and internationally governed communication system tailored to the safety and operational requirements of the maritime domain.

5.2 VDES R-Mode – Ronald Raulefs (DLR)

Ronald Raulefs presented VDES R-Mode as a terrestrial backup navigation solution designed to enhance maritime resilience against GNSS disruption. Framing his presentation with a historical example from Edinburgh—the time ball and 1:00 gun used for ship chronometer synchronisation—he illustrated how navigation has always relied on diversified systems. The core message was clear: resilience requires independent, complementary positioning systems.

The motivation for R-Mode is the increasing vulnerability of GNSS. Spoofing and jamming incidents have been observed in multiple regions, including the Baltic Sea, Eastern Mediterranean, and other operational areas. Since GNSS provides both positioning and timing for many onboard systems, its disruption affects not only navigation but also AIS, communications, and timing-dependent equipment. International bodies including IMO, ICAO, and ITU have recognised the issue, but operational resilience requires technical solutions.

R-Mode (Ranging Mode) is a terrestrial positioning concept that reuses existing maritime radio infrastructure. In the VDES implementation, synchronised shore base stations transmit specially designed ranging signals. Ships receive signals from multiple base stations and compute their position through multilateration. Unlike communication coverage, which relies on connection to a single base station, R-Mode requires reception from several stations simultaneously. Coverage is therefore determined by geometry and line-of-sight conditions.

VDES R-Mode benefits from the globally allocated maritime VHF spectrum and can coexist with communication services. It uses the VDES time-division multiple access (TDMA) structure, where ranging sequences are embedded into standard time slots (26.67 ms). Depending on operational conditions, the number of ranging sequences per second can be scaled. In case of GNSS disruption, the system can dynamically prioritise ranging over data payload to improve positioning accuracy.

Performance investigations demonstrated that update rates significantly influence positioning accuracy. Higher ranging update frequencies allow simpler tracking filters, while reduced update rates require more complex filtering algorithms. Testing in Berlin Harbour confirmed that real-time positioning using VDES R-Mode is feasible, including authenticated position reporting via VDES terrestrial channels.

A demonstration network was established in the Baltic Sea with three shore base stations equipped with enhanced monitoring capabilities. These include GNSS timing monitoring, RF signal observation, and cross-monitoring between stations. This architecture allows investigation of integrity monitoring and resilience, including detection of spoofing or jamming events. Research is also exploring “uplink R-Mode,” where shore stations use vessel transmissions to verify reported vessel positions.

In addition to terrestrial VDES R-Mode, work is underway on integration with MF R-Mode (operating in the 300 kHz band) and potential satellite-assisted ranging concepts. While terrestrial systems cannot provide full ocean coverage, they are intended to serve coastal waters, port approaches, and restricted areas, aligning with previously defined IMO backup PNT performance requirements.

Standardisation activities are progressing on two tracks. Within ITU, discussions are underway to prepare potential spectrum regulatory changes at WRC-31, as current maritime VHF allocations do not formally include radionavigation as a primary service. Within IMO, a draft performance standard for R-Mode has been initiated, covering both MF and VDES implementations. Proposed performance targets include positioning accuracy better than 100 metres and timing accuracy better than 100 nanoseconds, along with integrity and availability metrics.

The presenter concluded that VDES R-Mode enhances maritime navigation resilience by providing an independent terrestrial PNT capability. However, true robustness will require integration of multiple complementary systems, including MF R-Mode, VDES R-Mode, GNSS authentication, satellite services, and emerging technologies such as 5G-based positioning. The objective is not to replace GNSS but to strengthen maritime navigation through layered redundancy and diversified radio-based positioning solutions.

5.3 VHF digital radio – Jeffrey van Gils (RWS WVL)

Jeffrey van Gils presented the concept and ongoing developments related to VHF Digital Radio as a response to congestion in the maritime VHF voice spectrum. Drawing on operational experience from the Netherlands and the North Sea region, he explained that traditional analogue VHF voice channels have become heavily congested, particularly in dense port and VTS areas. The need for additional capacity, improved spectrum efficiency, and better integration with digital navigation systems has driven interest in digital voice solutions.

The initiative gained momentum after 2019, when practical tests were conducted in Dutch ports using digital PMR technologies (including DPMR and DMR). Technical evaluations and user trials assessed voice quality, range, interoperability, and operational acceptance. Reports were submitted to IMO and ITU, and discussions progressed within the Joint IMO/ITU Experts Group. An urgent work item was later agreed at MSC 110 to develop a transition plan from analogue to digital VHF.

Digital VHF radio offers several advantages. By using narrower channel spacing (6.25 kHz instead of 25 kHz), it can multiply available channel capacity. It enables clearer audio at range, supports signal regeneration without added noise, and allows transmission of small digital data elements such as transmitter identification or short text messages. Digital signals can also be better integrated with onboard systems, potentially linking voice communication with AIS or other navigation data.

However, the transition presents significant challenges. Ships would require new equipment, and migration periods are expected to be long. Cost implications, regulatory updates, and industry acceptance remain key concerns. Voice quality, vocoder selection, intellectual property rights, and compatibility with existing maritime communication standards must be addressed. There are also open questions about cybersecurity, authentication, and whether digital identification features would meet future security requirements.

The presentation highlighted broader strategic considerations. Digital VHF must fit within the evolving maritime communication landscape, alongside AIS, VDES, satellite systems, and IP-based services. Questions were raised about system integration, performance standards, and whether future equipment might combine multiple functions (voice, AIS, data exchange) into unified communication platforms.

In discussion, participants reflected on whether maritime communications should move toward a layered, technology-neutral architecture similar to terrestrial telecom systems, separating applications from underlying transport layers. Concerns were also expressed about cost, dependency on commercial providers, and long-term sustainability of legacy technologies.

Mr. van Gils concluded that digital VHF radio represents a necessary step to relieve spectrum congestion and modernize maritime voice communications, but successful implementation will require coordinated regulatory action, careful migration planning, and alignment with broader maritime digitalization strategies.

6. SESSION 5 – LF/MF/HF RADIO NAVIGATION AND COMMUNICATION

The session was chaired by Gillian Burns from Northern Lighthouse Board (NLB).

6.1 E-Loran – Dr. Jan Safar (UK and Ireland GRAD)

Dr. Jan Šafář presented a compelling case for eLoran as a resilient terrestrial backup to GNSS in maritime navigation. The presentation began with real-world evidence of GNSS disruption: over 3,000 vessels simultaneously appearing in ports they had never visited, compliance systems overwhelmed by false alerts, and bridge crews uncertain which navigation data could be trusted. The message was clear—GNSS interference is no longer theoretical but systematic, escalating, and global.

Three primary threat mechanisms were outlined: jamming, where radio noise blocks authentic satellite signals resulting in “no fix” or erratic positioning; spoofing, where fabricated signals generate false positions or time without triggering alarms; and meaconing, where genuine GNSS signals are recorded and rebroadcast, causing offset errors in position and time. GNSS spoofing has already been detected in 27 Exclusive Economic Zones worldwide. A survey by the Royal Institute of Navigation’s Maritime GNSS Interference Working Group found that 75% of 271 mariners surveyed believe the situation is not improving, highlighting vulnerabilities in SOLAS-mandated equipment dependent on GNSS.

Dr. Šafář argued that maritime infrastructure has become critically dependent on a single, fragile source of Positioning, Navigation, and Timing (PNT). He introduced LORAN’s historical foundation, beginning in 1942 with LORAN-A guiding Allied convoys across the Atlantic. By 1945, coverage extended across 30% of the Earth’s surface with over 70,000 receivers in service. LORAN-C, introduced in 1957, improved range and accuracy, eventually forming a global network of 79 stations. At its peak, LORAN was the world’s most widely used navigation system before being superseded by GPS.

Enhanced Loran (eLoran) retains the same low-frequency physics (100 kHz pulsed ground-wave transmissions) but incorporates modern engineering. High-power terrestrial transmitters organised in chains emit signals that follow the Earth’s curvature, providing coverage up to approximately 1,000 km. Unlike legacy LORAN-C, which relied on master-secondary synchronisation within chains, eLoran stations are tightly synchronised to UTC (≤25 nanoseconds averaged over 10 seconds). This allows “all-in-view” positioning using any available stations and enables pseudoranging based on time-of-arrival measurements rather than hyperbolic time differences. Position and timing are solved simultaneously, reinforcing the “T” in PNT.

Comparative system analysis demonstrated complementary strengths. GNSS offers high accuracy and global coverage but remains vulnerable to interference, even with multi-frequency and multi-constellation receivers. eLoran provides assured availability, jam resistance, and wide-area terrestrial coverage, though it cannot match GNSS precision in benign conditions. Other alternatives such as R-Mode, radar absolute positioning, inertial navigation systems, and dead reckoning provide partial solutions but have limitations in range, maturity, or drift without external updates.

Sea trials provided operational evidence. During the 2008 Pole Star trials, increasing GPS jammer power caused the vessel’s reported position to shift 22 km inland. Sequential failures affected ECDIS, DGPS, AIS, autopilot, radar, gyro compass, GMDSS-DSC, satcom, and heli-deck stabilisation. In the 2013 Galatea trials, low-power jamming produced Hazardously Misleading Information without triggering alarms. However, when eLoran was integrated, interference was detected before position errors occurred, and the vessel seamlessly switched to eLoran-derived positioning. Bridge systems remained operational, and the crew was unaware of the GNSS disruption. The vessel became the first to broadcast AIS positions derived from eLoran.

The presentation concluded that eLoran is a proven, dissimilar, and practically unjammable PNT solution designed to complement—not replace—GNSS. Its independence in infrastructure, frequency band, and failure modes makes it a robust resilience layer for modern maritime systems. Several nations are advancing deployment or testing, including the Republic of Korea, Saudi Arabia, UAE, the UK, and the USA, with international collaboration accelerating.

Dr. Šafář’s central argument was that maritime safety requires layered resilience. eLoran offers a terrestrial, sovereign, and technically mature solution capable of sustaining electronic navigation and communication systems when GNSS fails.

6.2 Advancing the Korean eLoran System: Development Status and New LDC design – Ki-yeol Seo (KRISO)

The presentation detailed the Republic of Korea's progress in advancing its national eLORAN system toward a resilient, nationwide PNT (Positioning, Navigation, Timing & Data) capability aligned with IMO and IALA performance expectations. The Advanced eLORAN (A-eLORAN) programme aims to achieve positioning accuracy below 10 meters, integrity risk below 10^{-5} per three hours, and rapid time-to-alarm performance, while also strengthening national timing synchronization through UTC(KRIS).

The system architecture integrates upgraded high-power transmitters, enhanced timing synchronization using Two-Way Satellite Time Transfer (TWSTT) and Two-Way Low-Frequency Time Transfer (TWLFTT), a Terrestrial Wide-Area Augmentation System (TWAS), and an Integrated Operation & Control System (IOCS+). Transmitter performance has been improved from approximately 50 ns synchronization accuracy to 10 ns (rms), with high-power amplifier configurations exceeding 150 kW ERP and expandable toward 200 kW class operation. The upgraded exciter and pulse generation system supports enhanced signal monitoring, robustness, and compatibility with modern receiver requirements.

A central component of the advancement is TWAS, which integrates measurements from distributed reference stations, incorporates GIS and weather data, and generates wide-area ASF correction maps using AI-based modeling. These corrections are distributed semi-real time and aim to improve positioning accuracy to below 10 meters across extended coverage areas. KRISO currently operates six sites, while the Ministry of Oceans and Fisheries is expanding the network to over thirteen sites by 2026, supporting the roadmap toward nationwide resilient PNT coverage.

The IOCS+ platform connects transmitter stations, differential Loran reference stations, and TWAS servers, enabling centralized monitoring, database management, ASF map handling, and enhanced message distribution. This integrated digital architecture supports full-system supervision and optimized operational control of terrestrial radionavigation infrastructure.

A major technical development presented was the redesigned Advanced Loran Data Channel (LDC), based on a modified 9th pulse structure. The system replaces Reed-Solomon forward error correction with LDPC (640,324) coding derived from WLAN 802.11n principles, significantly improving robustness and data throughput. The effective transmission rate increases to approximately 24.5 bps while incorporating AES-128 encryption for security-sensitive messages. Performance testing demonstrated improved signal-to-noise tolerance and lower bit error rates compared to legacy 9th pulse and Eurofix LDC designs, with measurable gains of 2–5 dB in SNR performance under AWGN conditions. Prototype receiver testing confirmed improved reception sensitivity and robustness.

Planned applications include integrated eLoran/GNSS navigation demonstrations, timing synchronization support for AIS base stations using NTP/PTP equipment, and development of integrated PNT receiver modules for maritime and potentially broader applications. The roadmap envisions expanding from three to five transmitter stations by 2030, strengthening coverage, signal stability, and timing performance.

The long-term vision presented is a nationwide resilient PNT service delivering reliable Positioning, Navigation, Timing, and Data through a dissimilar terrestrial infrastructure that complements GNSS and enhances maritime safety and national resilience.

6.3 DGNSS and MF R-Mode – Stefan Gewies (DLR)

The presentation examined the current status and future role of DGNSS and R-Mode as components of resilient maritime Positioning, Navigation and Timing (PNT), highlighting the transition from legacy differential services toward alternative terrestrial positioning solutions. It emphasized the growing vulnerability of GNSS-dependent maritime systems and the need to reuse existing infrastructure to strengthen resilience.

DGNSS was presented as a maritime radio service specified under ITU-R Recommendation M.823-3 and RTCM 10403.3, with system guidance provided in IALA Guideline 1112. Operating in the maritime MF band between 283.5 kHz and 325 kHz using MSK modulation and ground-wave propagation, DGNSS historically provided code corrections for GPS and GLONASS L1 signals at data rates between 25 and 200 bps, ensuring positioning accuracy around 10 meters and delivering regional integrity information. The average service range is approximately 250 km. However, since the removal of GPS Selective Availability in 2000 and the deployment of multiple modern GNSS constellations and SBAS services, the relative importance of DGNSS has declined. Several countries, including the USA, UK, Japan, Norway and France, have discontinued DGNSS services since 2019. At the same time, DGNSS infrastructure is aging and often prone to technical faults.

The presentation highlighted the increasing prevalence of GNSS interference, including jamming, spoofing and meaconing, particularly in regions near geopolitical conflict areas such as the Baltic Sea, Black Sea, Mediterranean, Red Sea and Persian Gulf. Such interference affects not only navigation but also communications, AIS, ECDIS, GMDSS and bridge systems, increasing operational and environmental risk. Reference was made to IALA Guideline G1180 on Resilient PNT, which recommends reducing dependence on GNSS and adopting complementary positioning sources.

R-Mode was introduced as a terrestrial alternative PNT system that transmits synchronized ranging signals using existing maritime radio infrastructure and applies multilateration to determine vessel position. The concept emerged in 2008, with feasibility studies beginning in 2015 under the ACCSEAS project and subsequent development programs in Germany, the UK, China, the US, Korea, Canada and Romania. Baltic Sea projects between 2017 and 2026 have been central to validation efforts.

Medium Frequency (MF) R-Mode, standardized in IALA Guideline G1187, expands existing DGNSS radio beacons by adding two carrier signals within the spectral nulls of the MSK signal. Distance estimation is based on carrier phase measurements, while the existing data channel alternately transmits DGNSS corrections and R-Mode navigation information. This approach allows reuse of DGNSS infrastructure without disrupting legacy services, enabling cost-effective system upgrades.

Several technical challenges were discussed, including ionospheric sky-wave reflections that reduce night-time performance, transmitter chain instability—particularly within antenna tuning units—and propagation delays over land. Proposed mitigations include improved antenna designs, digital signal processing enhancements, correction maps derived from satellite and measurement data, differential R-Mode techniques, and implementation of transmitter monitoring and control loops.

The Baltic Sea test bed, including the ORMOBASS project, has deployed synchronized MF and VDES transmitters, implemented centralized monitoring and control, and validated coordinated R-Mode signal transmission. Performance predictions and validation measurements indicate positioning accuracies (95%) between 16 m and 38 m during daytime and between 51 m and 86 m at night, with most measurements currently relying on initial GNSS calibration. These results demonstrate that MF R-Mode can support coastal navigation requirements, though performance is influenced by environmental and propagation conditions.

The IALA R-Mode roadmap anticipates gradual implementation toward operational services in selected regions by approximately 2030. The presentation concluded that while DGNSS has lost global relevance as a correction service, its frequency allocations and hardware infrastructure provide an opportunity to deploy MF R-Mode as an urgently needed alternative terrestrial positioning and timing service. Validation campaigns confirm that MF R-Mode can provide coastal positioning performance in the range of 10 to 100 meters, contributing to maritime PNT resilience in an era of increasing GNSS vulnerability.

6.4 NAVDAT – Pierre Mingot (Cerema)

The presentation introduced NAVDAT as a next-generation terrestrial digital broadcast service within the GMDSS framework, designed to complement and progressively enhance NAVTEX by enabling high-capacity digital transmission of Maritime Safety Information (MSI). NAVDAT operates as a coordinated broadcast system, supporting automatic reception and aligned with the IMO e-navigation strategy, particularly the requirement that maritime services be based on the IHO S-100 data model.

NAVDAT functions in internationally allocated frequencies of 500 kHz in the MF band and 4226 kHz in the HF band, with the possibility of additional national or regional allocations in the maritime MF and HF bands.

Unlike traditional NAVTEX, NAVDAT supports the transmission of any type of digital file, including structured S-100 exchange sets, thereby enabling richer data products such as S-124 navigational warnings and other digital maritime services. The system maintains the core GMDSS principle of coordinated broadcast and automatic reception of safety information.

The regulatory and standardization framework for NAVDAT has progressed under IMO developments in GMDSS services. Performance standards are addressed in MSC.569(109) for the reception of MSI and SAR-related information via MF and HF digital navigational data systems. The system is referenced in MSC.509(105)/Rev.1 concerning radio services for GMDSS, and frequencies are included in Appendix 15 for distress and safety communications. Supporting ITU documentation includes Recommendations ITU-R M.2010 (MF), ITU-R M.2058 (HF), and Report ITU-R M.2443-0 providing NAVDAT guidelines. Coordination is ensured through the IMO Terrestrial Broadcast Services Coordinating Panel, encompassing both NAVTEX and NAVDAT, with draft manuals reviewed by the World-Wide Navigational Warning Service (WWNWS) and the Worldwide Met-Ocean Information and Warning Service (WWMIWS).

The French implementation was presented as a practical case study. Coast stations have been installed and commissioned, with sites such as Corsen and La Garde providing national coverage, as illustrated in the station deployment map and antenna photographs. NAVDAT integrates into the Maritime Safety Information service chain of the GMDSS, operating alongside NAVTEX and Enhanced Group Call (EGC). Within the coordinated broadcast services architecture, NAVDAT serves defined service areas with dedicated receivers, similar to NAVTEX but offering expanded digital capability.

In France, NAVDAT is embedded within the broader technical and digital information ecosystem. The national coordinator manages coastal and local navigational warnings, while the NAVAREA II coordinator manages NAVAREA warnings. Information flows through a national nautical information platform and is distributed via multiple channels: NAVTEX (S-53), NAVDAT (S-124 exchange sets), Enhanced Group Call interfaces, and internet-based S-124 distribution via API REST and web mapping services. Coastal navigational warnings in mainland France are broadcast via terrestrial services, while satellite broadcast services and maritime web services complement the distribution framework.

The presentation demonstrated that NAVDAT provides a modern, digital terrestrial broadcast solution capable of transmitting structured S-100 compliant data sets, strengthening the MSI dissemination chain within GMDSS. By combining coordinated broadcast principles with enhanced digital capacity, NAVDAT supports the transition toward e-navigation and integrated maritime data services while maintaining regulatory alignment with IMO, ITU, IEC, IHO, WMO, and IALA frameworks.

7. SESSION 6 – IMT AND OTHER TECHNOLOGY

This session was chaired by Ronald Raulefs from DLR.

7.1 The potential of the IMT technology family, considering the outcome of the IMT workshop 2025 – Jan-Hendrik Oltmann (WSV)

The presentation examined the role of the International Mobile Telecommunications (IMT) technology family—4G, 5G and emerging 6G—as a foundational carrier for future maritime communications in the context of e-navigation and real-time S-100 data exchange. It framed the discussion around the need for resilient Positioning, Navigation and Timing (PNT), real-time connectivity, and implementation of the Services–Data–Connectivity (SDC) stack by coastal administrations by 2029 and beyond.

The maritime domain is increasingly driven by real-time operational requirements, particularly in support of Just-In-Time Arrival (JITA), Vessel Traffic Services (VTS), and harmonized maritime services as defined in IMO resolutions and circulars, including MSC.1/Circ.1595, MSC.1/Circ.1610 Rev.1 (2024), Resolution MSC.467(101), and Assembly Resolution A.1158(32). These instruments call for globally unified frameworks for real-time S-100 data exchange and Internet Protocol (IP)-based connectivity. The outcome of MSC109 emphasized the realization of the full potential of S-100 ECDIS and a globally unified IP-based framework for maritime services, placing connectivity at the center of digital maritime transformation.

The presentation stressed that many port call processes and VTS interactions require timely, often near real-time communication between shore and ship. Constant interaction implies constant connectivity, supported by resilient PNT. The task for coastal states is therefore not limited to defining services and data formats but extends to implementing a capable, scalable communication carrier that supports IP-based real-time exchange, including S-100 world data products and other digital services.

In this context, IMT—defined by ITU as the 4G/5G/6G mobile radio technology family—was identified as the prime candidate for a versatile, IP-capable, real-time terrestrial and satellite "working horse." IMT supports enhanced mobile broadband (eMBB), massive machine-type communications (mMTC), and ultra-reliable low-latency communications (URLLC). These capabilities collectively form what was described as a "magic versatility triangle," allowing optimization for high data throughput, large-scale IoT connectivity, or highly reliable low-latency links depending on system configuration. Importantly, IMT supports both digital voice and non-voice data services within a unified framework.

5G (IMT-2020) was presented as already delivered "on time," with capabilities far beyond what maritime radio systems have historically provided. 6G (IMT-2030 and beyond) is expected to expand these capabilities further, enhancing integration, performance, and flexibility. The emphasis was placed on timely deployment and leveraging mainstream technology development rather than developing isolated maritime-specific systems with limited scalability.

The presentation proposed a migration strategy toward a future maritime radiocommunication scenario built around IMT as the primary carrier, while protecting and supplementing existing systems. AIS must remain protected and be enhanced through VDES as a fallback and protection mechanism. Some legacy systems—such as VHF Channel 16, DSC Channel 70, and MF/HF distress communications—are likely to remain operational for the foreseeable future. A phased migration concept was outlined: "Freeze" (stabilize Appendix 18 allocations), "Transit" (migrate toward IMT as the working horse while maintaining legacy systems and gradually phasing out analogue VHF), and "Revitalize" (long-term modernization, potentially including IMT use within VHF allocations).

The overarching conclusion was that shipowners and coastal states seek to minimize the number of shipboard and shore-based communication systems while maximizing versatility and capability. IMT provides the most powerful and flexible mobile radio communication technology family currently available, with IP capabilities that exceed maritime-specific developments in both present and foreseeable contexts. By embracing IMT as the core carrier and integrating it within the S-100 and e-navigation architecture, maritime administrations can achieve globally unified, real-time digital maritime services supported by resilient connectivity and scalable communication infrastructure.

7.2 IMT 2030 (6G) – Hyounhee Koo (SyncTechno)

The presentation examined IMT-2030 (6G) as a unified communication platform capable of transforming maritime radionavigation and radiocommunication systems, positioning the 2026–2027 period as a strategic window for maritime stakeholders to influence global standards. It addressed the limitations of current fragmented maritime communication systems and outlined how integration into the 3GPP ecosystem could reshape maritime connectivity, sensing, and regulatory alignment.

The maritime challenge was framed around existing communication silos and equipment overload on vessels. Modern ships carry multiple antennas and systems for AIS, VDES, VHF, and various satellite services, resulting in increased maintenance complexity and cost. Many maritime systems are proprietary, limiting interoperability and preventing economies of scale. Additionally, VHF-based systems suffer from bandwidth constraints, restricting high-speed data exchange required for remote vessel monitoring, digital Vessel Traffic Services (VTS), and Maritime Autonomous Surface Ships (MASS). Emerging operational paradigms require hyper-reliable, fail-safe connectivity, seamless integration between land and sea networks, and sensing capabilities capable of detecting vessels and obstacles even in degraded visibility conditions.

IMT-2030 was presented as a unified platform integrating terrestrial networks (TN) and non-terrestrial networks (NTN) within a single global standard. This integration enables seamless roaming from harbor to open ocean using a single chipset capable of supporting 4G, 5G, 6G, and satellite connectivity. Such convergence promises significant reductions in hardware complexity and cost. Beyond connectivity, 6G introduces Integrated Sensing and Communication (ISAC), enabling radio waves to function as radar-like sensing mechanisms. This allows real-time detection of vessels, aids to navigation, and obstacles without additional hardware, thereby enhancing situational awareness in safety-critical maritime environments.

The architecture of IMT-2030 is designed to be AI-native, embedding artificial intelligence within the air interface itself. This enables real-time adaptation to changing maritime propagation conditions, predictive beam management for maintaining stable links on rolling vessels, and self-optimizing mesh networking for remote maritime regions. These features collectively enhance resilience and reliability compared to traditional maritime communication systems.

The presentation emphasized the importance of leveraging 3GPP international standards rather than developing isolated maritime solutions. By aligning with the global mobile ecosystem, maritime stakeholders gain access to large-scale hardware supply chains, continuous security updates, research and development investment, and interoperability across coastal states and equipment vendors. IALA's participation in 3GPP as a Market Representation Partner ensures that maritime requirements are represented as a recognized vertical industry. Within this framework, IALA's DTEC activities are developing user requirements for Marine AtoN and maritime services to influence IMT-2030 specifications directly.

Release 21 of 3GPP was identified as the strategic opportunity. While Release 19 and 20 focus on 5G-Advanced and early 6G study phases, Release 21 marks the beginning of the normative specification phase. Technical requirements established during this period will define the structure of 6G deployment. The presentation stressed that if maritime-specific use cases—such as MASS data cycles, VTS sensing resolution, and high-reliability maritime services—are not formally submitted during this window, the resulting standards will remain land-centric and potentially unsuitable for maritime needs. The message was clear: maritime stakeholders must actively shape the standard rather than adapt passively after commercialization.

Regulatory and policy harmony were highlighted as essential complements to technical standardization. Even the most advanced global standards require spectrum harmonization through ITU-R World Radiocommunication Conferences, adaptive regulation shifting from hardware-based mandates to capability-based frameworks, and alignment of IMO/SOLAS provisions with high-reliability 6G capabilities. Effective implementation requires coordination among international standards bodies, regulators, maritime administrations, and industry actors.

The presentation concluded with a strategic call to action structured around three principles: transition from fragmented communication silos to a unified 6G platform; actively influence Release 21 Stage 1 requirements beginning in mid-2026; and harmonize regulatory frameworks to match technological evolution. IMT-2030 was positioned not merely as a connectivity upgrade but as a transformative infrastructure capable of integrating communication, sensing, AI-driven resilience, and global interoperability into a single maritime communication ecosystem.

7.3 INS and Quantum Navigation - Dr Kevin Sheridan (UK and Ireland GRAD)

The presentation explored the role of Inertial Navigation Systems (INS) and emerging quantum sensing technologies in strengthening Resilient Positioning, Navigation and Timing (R-PNT) for maritime applications, emphasizing complementary sensor integration and GNSS-independent capability development. It clarified that the term INS referred to inertial navigation systems rather than the IMO Integrated Navigation System defined in MSC.252(83).

INS technology was introduced as a self-contained navigation solution based on inertial measurement units (IMUs) composed of gyroscopes and accelerometers. These sensors measure angular rate and specific force, allowing continuous calculation of position, velocity, and attitude (pitch, roll, yaw) without reliance on external signals. INS supports high-rate position outputs—tens to hundreds of hertz—enabling applications such as transferring GNSS antenna positions to reference points, determining sonar signal direction, stabilizing imaging sensors, and bridging GNSS outages through holdover and gap-filling. In integrated configurations, INS operates alongside GNSS and other aiding sources; in resilient scenarios, it can function as a primary position source during signal loss.

However, INS accuracy degrades over time due to error accumulation. The presentation detailed numerous error sources including gyro bias and bias variation, gyro scale factor and misalignment, accelerometer bias and noise, gravity model inaccuracies, environmental effects such as vibration and temperature, mathematical modelling errors, and initialization misalignment. Gyro drift was identified as the dominant contributor to long-term position error. Even small alignment errors can lead to rapid drift; for example, a 0.01° tilt misalignment can produce horizontal drift of approximately 11 km per hour due to gravity projection effects. Long-term unaided inertial accuracy therefore depends critically on sensor grade, alignment quality, gravity modelling, and error compensation techniques. High-grade ring laser gyro systems can maintain useful performance for extended periods but at substantial cost compared with GNSS-based solutions.

The presentation then examined quantum navigation, focusing on Cold Atom Interferometry (CAI) as a potential breakthrough in inertial sensing. Quantum systems exploit stable atomic properties and wave–particle duality, using atom interferometry to measure acceleration with exceptional sensitivity and long-term stability. Unlike mechanical sensors, quantum sensors rely on atomic references governed by unchanging physical constants, offering the potential for significantly reduced drift. However, practical implementation presents substantial challenges including limited update rates (typically around 1 Hz), sensitivity to vibration, wavelength ambiguity, dynamic range constraints, system size, weight, power and cost (SWaP), and the complexity of trapping and cooling atomic clouds. While sensor stability may improve dramatically, full navigation performance still depends on alignment, modelling, and integration with other systems.

The HARLEQUIN-ST (High Accuracy Robust Deployable Quantum Inertial Navigation – Sea Trial) project was presented as a practical demonstration of quantum-enhanced navigation at sea. The system combined a classical INS with a quantum cold-atom interferometer to calibrate accelerometer measurements along the direction of travel. The aim is to reduce inertial sensor drift sufficiently to enable displacement measurements within tens of meters after weeks of unaided operation. The sea trial took place in October 2025 aboard THV Galatea, collecting six days of operational data. The trial demonstrated, for the first time, the use of a grating-based Magneto-Optical Trap (gMOT) for atom interferometry on a maritime platform. Stable atom trapping, optical molasses cooling at microkelvin temperatures, frequency-stable laser systems, and vibration-tolerant operation were achieved under real shipboard conditions. Ruggedization improvements, power stabilization, and system downsizing are planned for subsequent trials.

The presentation concluded that resilient maritime PNT requires complementary sensors and effective data fusion rather than reliance on a single technology. INS provides a proven, self-contained navigation capability attractive for resilience, but long-duration accuracy comes at high cost and remains sensitive to alignment and modelling errors. Quantum sensing offers the potential for unprecedented stability and reduced drift, yet it represents only part of the navigation solution and must be integrated into a broader system architecture. Together, advanced inertial systems and quantum-enhanced sensors form a promising pathway toward GNSS-independent maritime navigation resilience.

8. SESSION 7 – SATELLITE (1)

This session was chaired by Dennis Khoo from Singapore MPA.

8.1 Growing Risks to Maritime Safety – Omar Eriksson (IALA)

The presentation examined the evolving risk landscape in maritime navigation, emphasizing the increasing vulnerability of radionavigation and radiocommunication systems and the need for strengthened resilience measures. It highlighted that shipping operates in a fully globalized environment, where disruptions in positioning or communication systems can rapidly escalate into international safety risks.

The discussion began with an overview of navigational risk and the tools currently available within the IALA risk management framework. These include methodologies such as PAWSA (Ports and Waterways Safety Assessment), the SIRA methodology, IWRAP (IWRAP Mk2 traffic risk modelling), and Bayesian models for probabilistic analysis. Risk is categorized according to three states: acceptable, unacceptable, and tolerable only if reduced to ALARP (As Low As Reasonably Practicable). These tools support evidence-based decision-making when assessing changes in navigational risk arising from environmental, traffic, or technological factors.

A simple conceptual framework was introduced to structure the discussion around three interconnected components: Navigational Environment, Situational Awareness, and Positional Awareness. The Navigational Environment encompasses bathymetry, winds and currents, hazard density, Aids to Navigation (AtoN), traffic volume and distribution, vessel mix, waterway complexity, and available navigable space. Situational Awareness integrates knowledge of hazards and AtoN status, traffic behaviour via AIS and VTS, meteorological conditions, communications and operational instructions, local rules such as Traffic Separation Schemes and pilotage requirements, and digital maritime services including S-100/S-200 products. Positional Awareness concerns knowing the vessel's location with sufficient accuracy, integrity, continuity, and availability, integrating GNSS performance, terrestrial alternatives such as eLoran and R-Mode, augmentation systems including AIS-R and VDES, and resilience measures against jamming and spoofing.

The presentation demonstrated how degradation in positional awareness increases grounding probability, while reduced situational awareness increases collision probability. Safe and anticipatory navigation requires both high-confidence positioning and a predictive understanding of evolving risks. Modern bridge systems rely on multiple sensors and sources, including GNSS, ECDIS, radar, AIS, VTS, and visual cues. However, radionavigation jamming or spoofing, as well as radiocommunication jamming (particularly VHF), can compromise both positional and situational awareness simultaneously, leading to cascading failures across integrated navigation systems.

The urgency of the issue was reinforced by reference to a joint statement issued on 26 January 2026 by 14 coastal States of the North Sea and Baltic Sea region, warning of increasing GNSS interference and AIS manipulation. The statement called upon the international maritime community to recognize GNSS interference as a direct threat to maritime safety and security, ensure vessels have adequate capabilities and properly trained crews to operate safely during navigation system outages, and cooperate in developing alternative terrestrial radionavigation systems capable of operating when GNSS signals are disrupted or unavailable.

The presentation concluded with a clear message that terrestrial alternatives to GNSS are urgently required, and that shore-ship-ship connectivity solutions are operationally ready to support enhanced resilience. Addressing navigational risk today requires coordinated international action, integration of resilient PNT systems, and reinforcement of both positional and situational awareness frameworks to safeguard global maritime safety.

8.2 Galileo return link – Eduardo Diaz (EUSPA)

The presentation described the Galileo Search and Rescue (SAR) service and its Return Link Service (RLS), outlining its operational architecture, maritime applications, performance statistics, and future developments. Galileo SAR represents the European Union's contribution to the international COSPAS-SARSAT system, providing both forward link detection of distress beacons and a unique global return acknowledgment capability via the Galileo Open Service signal-in-space.

Galileo SAR operates through MEOSAR satellites equipped with SAR Repeaters (SARR). These repeaters receive 406 MHz distress signals transmitted by COSPAS-SARSAT-compatible beacons and relay them in L-band to Medium Earth Orbit Local User Terminals (MEOLUTs). The Forward Link Service (FLS) enables detection and localization of distress beacons across the European Coverage Area (ECA) and the Indian Ocean Coverage Area (IOCA), with processing performed by MEOLUT facilities located in Spain, Norway, Cyprus, and

La Réunion. The La Réunion MEOLUT uses an active phased-array system tracking all satellites in view, while European MEOLUTs employ multiple tracking dishes. Location is determined through time-of-arrival (TOA) and frequency-of-arrival (FOA) measurements and relayed to Mission Control Centres (MCCs).

The Return Link Service distinguishes Galileo as the first GNSS constellation capable of globally acknowledging receipt of a distress alert directly via the navigation signal. After beacon detection and localization, the responsible MCC sends a Return Link Message (RLM) request to the Return Link Service Provider (RLSP), located at the Galileo SAR Service Centre in Toulouse. The RLM is embedded in the Galileo Open Service I/NAV message within the E1-B data component. Each odd page of the navigation message contains a 22-bit SAR field, transmitted every two seconds. An 80-bit RLM is delivered in approximately eight seconds and is broadcast through two satellites in parallel, with repetition cycles managed according to COSPAS-SARSAT operational priorities. If acknowledgment is not confirmed, RLM transmission continues for up to 24 hours.

The RLS confirmation informs the distress beacon user that the alert has been received and localized, though it does not confirm that a rescue operation has commenced. Timing performance targets include an expected end-to-end loop of approximately 30 minutes for 95% of activations and a committed Galileo system loop within 15 minutes for 99% of cases. Since 2020, performance levels have been high; in 2022 more than 99.7% of beacons received acknowledgment within five minutes of the RLM request. RLS beacon activations have increased significantly, from seven in 2022 to 654 in 2024, representing 56% of SAR events in 2024. This growth reflects both increasing emergency cases and wider adoption of RLS-enabled beacons.

For maritime distress scenarios, Galileo SAR enhances operational confidence by providing feedback to vessel crews that their distress alert has been detected and processed. The system operates free of charge, supports global coverage, and integrates seamlessly into the COSPAS-SARSAT framework. It strengthens maritime emergency response by reducing uncertainty during critical incidents.

Future developments include Remote Beacon Activation (RBA), enabling Rescue Coordination Centres or authorized entities to activate a beacon remotely through authenticated RLM commands embedded in the Galileo signal. Activation targets include response within two minutes, with authentication provided via the Galileo Open Service Navigation Message Authentication (OSNMA). Another planned evolution is Two-Way Communication (TWC), allowing short, preformatted messages between the distressed party and RCCs. This would enable exchange of information such as type of distress, number of injured persons, and operational guidance, as well as improved false alert management. Both RBA and TWC are planned as global, free-of-charge services with target availability of 99%.

The presentation concluded that Galileo SAR and its Return Link Service provide a significant enhancement to maritime emergency response capability. By combining MEOSAR detection with global satellite-based acknowledgment and planned two-way communication features, Galileo strengthens the reliability, transparency, and effectiveness of search and rescue operations within the international COSPAS-SARSAT framework.

8.3 SBAS as a radionavigation system - Jose-Luis Martin (ESSP)

The presentation provided a comprehensive overview of Satellite-Based Augmentation Systems (SBAS) as a radionavigation solution for maritime applications, explaining system architecture, transmitted data, regulatory framework, operational use, and future evolution.

SBAS is a GNSS Satellite-Based Augmentation System designed to improve the accuracy and integrity of standalone GNSS positioning. It broadcasts augmentation data via GNSS signal-in-space on standard GNSS frequencies, typically in the L1 band. SBAS services are regional or wide-area in nature and currently augment mainly a single constellation, most often GPS. However, the ongoing Dual Frequency Multi Constellation (DFMC) evolution will enable augmentation of multiple constellations such as GPS, Galileo and BeiDou, and provide corrections on at least two frequency bands, for example L1/E1 and L5/E5. Future developments also foresee additional features including authentication, enhanced accuracy and increased resilience to radio frequency interference.

The SBAS architecture consists of three main segments. The Space Segment is formed by geostationary satellites broadcasting augmentation messages. The Ground Segment includes Ranging and Integrity Monitoring Stations (RIMS), Mission Control Centres (MCC), and Navigation Land Earth Stations (NLES). The User Segment comprises SBAS-capable receivers adapted to specific operational domains, including maritime.

SBAS transmits two principal categories of data. First, differential corrections improve positioning accuracy by mitigating satellite orbit and clock errors and by providing ionospheric corrections to compensate for ionospheric delay. Second, integrity information ensures safety-of-life performance by providing timely warnings when system data should not be used for navigation. This includes system-level integrity warnings, GNSS satellite health alerts, and ionospheric alerts. Integrity, in this context, is defined as the ability to provide users with a warning within a specified time when the system should not be relied upon for navigation.

From a regulatory perspective, SBAS is referenced within IMO and IALA frameworks. IMO Resolution A.1046(27) defines operational requirements for navigation in ocean waters, coastal waters, harbour approaches and entrances, and recent amendments allow inclusion of GNSS augmentation systems such as SBAS within the World-Wide Radionavigation System (WWRNS). Resolution A.915(22) recognizes that SBAS improves GNSS accuracy and provides integrity. Resolution MSC.401(95) establishes performance standards for multi-system shipborne radionavigation receivers that combine radionavigation and augmentation systems. Within IALA documentation, Guideline G1152 describes SBAS elements relevant to maritime administrations, including system architecture and service provision. Guideline G1129 details mechanisms for retransmission of SBAS data via DGNSS stations and AIS or VDES, while Recommendation R1022 provides guidance for formal declaration of augmentation services by service providers.

In maritime operations, SBAS is considered both within the IMO WWRNS framework and by IALA as an Aid to Navigation (AtoN). When combined with GNSS, SBAS performance aligns with the most stringent IMO requirements for coastal waters, harbour approaches and entrances. To benefit from increased accuracy alone, vessels must be equipped with SBAS-compatible receivers. To benefit from both accuracy and integrity for safety-critical applications, vessels require SBAS type-approved receivers compliant with IEC 61108-7. SBAS data can be received directly through geostationary satellites via signal-in-space, or indirectly through retransmission by IALA DGNSS stations for local coverage enhancement.

The European implementation of SBAS, EGNOS, includes the ESMAS service (EGNOS Safety of Life assisted service to Maritime Users), the first SBAS service formally declared for maritime use. ESMAS provides open, free-of-charge service across Europe, supporting safe navigation in ocean waters, coastal waters and harbour entrances in line with IMO operational requirements. Corrections and integrity data are broadcast through the signal-in-space in the L1 band via EGNOS GEO satellites. In addition, ESMAS offers integrity warnings through a Maritime Safety Information notification proposal service to inform users of service outages or degradation. Use of ESMAS requires type-approved receivers compliant with IEC 61108-1 and IEC 61108-7 standards.

The presentation also addressed integration of SBAS with maritime radio communication systems. SBAS correction data can be retransmitted via AIS Message 17, originally designed to carry DGNSS corrections in binary format following RTCM standards. With the evolution of VDES, retransmission of SBAS data via ASM, VDE-SAT and VDE-TER channels is under consideration within IALA guideline updates. Future VDES message types may also support SBAS status information and SBAS-related Maritime Safety Information warnings.

The presentation concluded that SBAS plays a critical role in enhancing maritime positioning accuracy and integrity, supporting compliance with IMO requirements, and strengthening resilience of GNSS-based navigation. With DFMC evolution and integration into maritime communication systems, SBAS will continue to contribute to safer and more robust maritime navigation services worldwide.

9. SESSION 8 – SATELLITE (2)

The session was chaired by Hideki Noguchi (JSTRA).

9.1 Inmarsat – John Dodd (Inmarsat)

The presentation outlined the role of Inmarsat, now part of Viasat, in delivering global maritime safety services under the Global Maritime Distress and Safety System (GMDSS), and addressed emerging challenges in Maritime Safety Information (MSI) coordination and regulatory harmonization.

Viasat/Inmarsat operates as a global satellite communications provider with more than 40 years of maritime service experience, supporting aviation, government, maritime and fixed connectivity sectors. Within the maritime domain, Inmarsat provides safety services to merchant shipping, offshore vessels and high-end fishing fleets. Its satellite fleet supports interoperable and resilient on-the-move communications worldwide, forming a critical component of international safety-of-life infrastructure.

In 2024, Inmarsat processed 801 GMDSS distress alerts, highlighting the continued operational relevance of satellite-based distress communications. In addition to reactive distress handling, Inmarsat supports preventative safety measures through extensive Maritime Safety Information broadcasts. Over a five-year average, the system delivered approximately 1,482 MSI messages daily and more than 45,000 MSI messages monthly via Enhanced Group Call (EGC) services. These broadcasts cover navigational, meteorological, search and rescue, piracy and armed robbery warnings across NAV/MET areas worldwide.

The presentation emphasized regulatory foundations under SOLAS Chapter IV, particularly Regulation IV/7.1.4, which requires every ship to carry receivers capable of receiving maritime safety and SAR information throughout the voyage. IMO-recognised EGC services provide global MSI coverage through satellite broadcasts to defined geographic areas, coordinated via the IMO EGC Coordinating Panel. In parallel, terrestrial NAVTEX services broadcast coastal MSI where transmitters are operational, coordinated through the IMO Terrestrial Broadcast Services Coordinating Panel.

However, concerns were raised regarding increasing fragmentation of MSI systems. The growing number of providers and digital platforms can result in inconsistent or contradictory safety-critical data, including weather, navigation warnings and SAR coordination information. Rather than improving situational awareness, this can create cognitive overload for crews, leading to confusion and increased operational risk. The lack of harmonisation between satellite EGC, NAVTEX, NAVDAT and emerging S-100-based services was highlighted as a significant challenge.

Particular attention was drawn to the absence of coordination between certified EGC broadcasters and other MSI transmission systems. NAVTEX does not officially broadcast SAR messages in the same manner as EGC services, and future S-124 navigational warning products are currently focused on navigational information without full alignment with EGC-certified broadcast content. The IMO circular COMSAR.1/Circ.32/Rev.3 on harmonisation of GMDSS radio installations addresses equipment carriage requirements but does not harmonise MSI providers themselves. SOLAS Chapter IV specifies equipment requirements but leaves ambiguity regarding duplication and prioritisation of MSI reception capabilities.

The presentation argued that seafarers must receive reliable, consistent and prioritised safety information to ensure effective navigation and SAR response. The absence of harmonised MSI governance risks undermining the integrity of maritime safety communications.

In response to training and operational challenges, Inmarsat has developed the Safety Training Hub, an open-access platform providing interactive training resources on GMDSS, SafetyNET II, Fleet Safety services and RescueNET operations. These tools support maritime training establishments and aim to improve operational understanding of satellite safety services.

The presentation concluded that while satellite-based GMDSS services remain robust and operationally essential, the maritime community must address fragmentation, harmonisation and cognitive load issues to ensure that safety information systems truly enhance, rather than complicate, bridge decision-making and maritime safety.

9.2 Iridium – Dan Rooney (Iridium)

The presentation outlined Iridium's role in global maritime safety communications and its development of assured Position, Navigation and Timing (PNT) solutions designed to mitigate GNSS denial risks.

Iridium operates a global low Earth orbit (LEO) satellite constellation supporting maritime, aviation, government and IoT markets. In the maritime sector, Iridium services are deployed on four out of five SOLAS vessels and on more than 100,000 fishing vessels worldwide, supporting GMDSS, LRIT, SSAS, vessel monitoring systems, broadband connectivity and emerging autonomous vessel operations. The company maintains global coverage, including polar regions and Sea Area A4, a key differentiator from traditional geostationary systems.

Iridium GMDSS was presented as a fully integrated safety platform delivering GMDSS, LRIT, SSAS and companion services through a single terminal. This integration simplifies onboard installations while providing truly global coverage through the LEO constellation. The system is supported by multiple approved terminal manufacturers and is positioned as a modern alternative within the IMO-recognized GMDSS framework.

A central focus of the presentation was GNSS denial, including the three primary interference mechanisms: jamming, spoofing and meaconing. GNSS signals are inherently weak, making them vulnerable to wideband interference. Spoofing manipulates timing signals to create false positions without triggering alarms, while meaconing rebroadcasts authentic GNSS signals at higher power to create misleading location data. The presentation emphasized the growing global incidence of GNSS interference and the cascading impacts on critical shipboard systems that depend on reliable PNT data, including ECDIS, AIS, GMDSS, dynamic positioning and tracking systems.

Iridium's Position, Navigation and Timing solution addresses these vulnerabilities through Satellite Time and Location (STL) services. Unlike GNSS, Iridium operates high-power LEO signals approximately 1,000 times stronger than GNSS signals, providing enhanced resilience against interference. The Iridium PNT architecture uses secure signal design and unpredictable burst messaging to reduce spoofing risk. Because the system is based on a different frequency band, infrastructure and orbital architecture than GNSS, it provides a dissimilar and independent PNT source.

Iridium PNT service tiers include timing-only solutions and dynamic location services for slow-moving maritime applications, asset tracking, vessel monitoring, route verification and safety-of-life use cases. These services are designed to maintain operational continuity when GNSS is degraded or unavailable.

The presentation also introduced PNT-enabled products, including the PNTGuard system, which provides real-time detection of falsified GPS tracks and displays the vessel's verified position. The solution includes a below-deck unit (BDU), an above-deck antenna unit (ADU) connected to the Iridium PNT service, and integration capabilities for bridge systems and operations centres. Complementary solutions such as the NAL SkyRouter™ and Ground Control RockFLEET Assured platform were presented as part of the broader assured PNT ecosystem, supporting fleet management, command and control, and remote monitoring.

Performance data and real-world test results demonstrated the system's ability to maintain position and timing during GNSS interference scenarios. The solution is positioned as secure PNT when GNSS is unavailable, enhancing maritime resilience and supporting safety-critical operations.

The presentation concluded that GNSS denial is an escalating global threat affecting maritime safety systems, and that resilient, independent PNT solutions are required. Iridium's LEO-based communications and assured PNT services provide a complementary and dissimilar capability to GNSS, strengthening the robustness of maritime navigation and safety infrastructure worldwide.

9.3 Status of the satellite communication systems - Nader Alagha (ESA)

The presentation provided a strategic overview of the global satellite communications (Satcom) ecosystem, highlighting market dynamics, technological trends, resilience challenges and implications for maritime communications.

Satellite communications represent a major segment of the global space economy, accounting for approximately 34% of the upstream and 27% of the downstream space markets. While Satcom is a significant space application, it remains a relatively small component within the much larger global telecommunications ecosystem. Europe accounts for roughly 18% of the Satcom market. The sector is increasingly attracting multinational corporations, with companies such as SpaceX and Amazon entering as satellite operators, and mobile network operators investing in space infrastructure to complement terrestrial coverage. This integration reflects the convergence of satellite and terrestrial communications into a broader connectivity ecosystem.

The economic importance of Satcom was illustrated through a scenario analysis of a one-week loss of satellite services in ESA Member States and Canada. Estimated impacts include losses of up to €19 billion for shipping, €558 million for aviation due to flight cancellations and emissions increases, €90 million for energy infrastructure, and €353 million for consumer services. Approximately 2.2 million people could risk complete loss of connectivity. These figures underline the critical role of satellite systems in maintaining economic continuity and safety.

Business and geopolitical trends indicate rapid expansion of mega-constellations, with scale accessible only to a limited number of global players. The European response includes the institutional IRIS² programme aimed at federating European secure connectivity efforts. Geopolitical shifts emphasize the dual-use nature of space systems and the growing importance of resilience and security capabilities.

Technology trends shaping Satcom include multi-orbit connectivity architectures combining GEO, MEO and LEO systems; integration of terrestrial and non-terrestrial networks (TN-NTN); optical and quantum communications; direct-to-device connectivity; joint communications and sensing; spectrum sustainability; aviation and maritime surveillance; and secure ubiquitous connectivity. These trends reflect the transition toward hybrid and interoperable space-ground architectures.

In the commercial GEO satellite market, annual satellite orders have declined compared to a decade ago due to competition from MEO and LEO constellations. LEO broadband services are reducing demand for large GEO satellites, prompting a shift toward smaller, modular, software-defined satellites with flexible payloads. Government and defence demand now represents a larger proportion of GEO orders, providing greater market stability.

Broadband NGSO constellations are expanding rapidly. SpaceX's Starlink constellation has deployed more than 10,000 satellites, with over 9,000 operational and more than 75,000 vessels reportedly equipped in 2024. Amazon's LEO constellation has begun beta services with 180 satellites launched, while Telesat and Eutelsat OneWeb are advancing deployment plans. Maritime connectivity increasingly relies on these NGSO systems, though operational and regulatory challenges remain.

Direct-to-Device (D2D) satellite connectivity is emerging as a significant growth opportunity, with projected revenues of $30 billion by 2035. Both mobile satellite service (MSS) and terrestrial spectrum are being leveraged to deliver complementary handheld connectivity services, often at consumer price points.

However, mega-constellations face sustainability challenges, including launch bottlenecks and high replenishment costs. Thousands of satellites are scheduled for de-orbit within five years, requiring significant reinvestment to maintain capacity. Regulatory deadlines for deployment add further pressure on operators.

From a maritime perspective, satellite communications must address diverse requirements, including GMDSS safety communications, distress alerting, high-rate broadband data, low-rate operational data, surveillance, suspicious activity detection, e-navigation services and support for Maritime Autonomous Surface Ships (MASS). No single system can meet all use cases; instead, a mix of GEO, LEO, satellite GMDSS providers, AIS, VDE-SAT, COSPAS-SARSAT and emerging 5G/6G non-terrestrial networks is required.

The presentation concluded by highlighting strategic challenges and opportunities in space-based critical communications and domain awareness. Priorities include addressing AIS spoofing and dark vessel detection through technologies such as VDE-SAT and RF sensing; enhancing satellite GMDSS resilience; integrating broadband and safety systems for redundancy; and developing communication architectures aligned with future IMO MASS requirements. Satellite communications are thus positioned as a foundational element of maritime safety, security and digital transformation in an increasingly complex and contested space environment.

10. SESSION 9 – 11 – WORKING GROUPS

10.1 Working Group 1 – MarCom

1. GNSS INTERFERENCE DETECTION, REPORTING AND WARNINGS

The group noted that the topic also is covered by the DTEC task 3.1.3, “Developing a Guideline for Exchanging GNSS Interference Data for Navigational Safety”.

Magnus Nyberg from FLIR Transpondertech AB presented the capabilities of modern GNSS to detect spoofing and jamming, see the presentation in the folder

Olli Soininen from Fintraffic presented a project from Finland where GNSS interference is detected, see the presentations folder, which lead to a more detailed discussion in the group summarized in the following.

The session addressed the development of a guideline for the structured exchange of GNSS interference information to support navigational safety.

We discussed the main operational use cases:

- Ship-to-shore reporting
- Shore-to-ship dissemination
- Ship-to-ship information exchange
- Authority-to-authority coordination

There was support for automated reporting as the preferred approach, minimizing manual workload and enabling near real-time situational awareness. The possibility of anonymized reporting was discussed, where feasible, to encourage participation while still maintaining operational value. At the same time, authentication of messages was identified as essential to ensure trust, integrity, and protection against misuse.

It was agreed that reported information must be standardized to enable interoperability and integration within emerging digital maritime frameworks (e.g. S-100/S-200). A harmonized message structure would allow automatic processing and consistent situational awareness across systems and stakeholders. An example of a possible way to include this in the IMO compendium was presented with the Voluntary Observing Ship (VOS) schema which is similar in character and up for adoption at FAL 50.

The discussion also clarified the difference between existing GMDSS/MSI mechanisms and the proposed guideline. While there is already a requirement to report navigational hazards and GNSS-related issues through GMDSS channels, those systems are primarily designed for safety alerts and textual MSI dissemination. The proposed guideline would instead focus on structured, machine-readable, real-time or forecast-type GNSS interference reporting.

The aviation domain was used as a reference case. Through ADS-B (Automatic Dependent Surveillance–Broadcast), aircraft automatically broadcast their position and operational status. If onboard GNSS detects interference or degraded performance, this status information can be encoded in standardized operational status messages (e.g. DO-260B/ED-102A). The information is automatically transmitted via ADS-B Out (1090ES), allowing air traffic services and nearby aircraft to immediately recognize that data may be unreliable. This creates shared situational awareness without relying on voice reporting.

An equivalent maritime concept could enable vessels to automatically broadcast GNSS interference status or quality indicators, supporting shore services, VTS, nearby ships, and authorities in building a real-time interference picture. The objective is not to replace GMDSS, but to complement it with automated, standardized digital exchange of GNSS interference information, enhancing resilience and navigational safety.

A draft GNSS interference reporting format can be found in the Annex.

2. FUTURE MARITIME COMMUNICATIONS

The group started to identify use cases for future maritime communication needs, led by Axel Hahn.

The group discussed the development of a vision and a roadmap for the maritime communication stack in 10 years and beyond. We agreed that this should be user and application driven and therefore started an analysis of selected applications. The group compiled an initial list of use cases including:

- MS 1 VTS (Route Plan Exchange)
    - Route Plan Exchange Service
    - (Route Cross Check Service)
    - Route Reference Service
    - Route Monitoring Service
- MS 1 VTS (Traffic Management)
- MS 1 VTS (Information Service)
- MS 2 ATON (Virtual AtoN)
- MS 2 ATON (AtoN Monitoring)
- MS 5 Maritime Safety Information
- MS 15 Real Time Hydrographic / Environmental Information
- MS 16 Search and Rescue
- Voice Communication
- Identification / Authentication
- Maritime Traffic Collision Avoidance
- MASS / ROC
- GMDSS (looking at the Use Cases)

A brief collection of requirements was made to be considered by DTEC6 as an initial list for further progressing by DTEC working groups.

Jan Henrik reminded the group about the new DTEC task to create a new guideline on a service connectivity roadmap and IMT (see report of DTEC 5). Additionally, the group discussed about the drafting of a new IALA Guideline on the “Integration and use of IMT-2030 Technologies for Marine AtoN”. The group discussed the impact of IALA’s work onto future use case inputs from IALA to 3GPP in IALA’s role of MRP (Market Representative Partner).

3. INTRODUCTION OF AUTHENTICATION OF AIS TO IMO

The IMO performance standard for VDES states that VDES should be able to authenticate AIS.

IEC TC80 WG 15 is finalizing the development of a 1st edition IEC Standard for VDES mobile station (IEC project number 63514) with an expected publication during 2027-2028. This standard includes a method of authentication of AIS messages.

A way forward to propose this applicable means of a concept of authentication of AIS to IMO could be:

1) 1st input an inf paper to introduce the concept (to NCSR and MSC), no action asked; lunch break presentation of the concept;
2) 2nd input a proposed draft guideline (e.g. new Circular) on how to deal with the concept (measures to enhance maritime security)
3) 3rd input a proposal to introduce the concept as part of SOLAS V

TODO: investigate the mentioning of the "integrity of AIS" in the report of NCSR 10, which might possibly be used as an anchor for inputs. DTEC6 may seek advice from Cafer Ozkan Istanbullu as to when it is to expected that IMO starts the work on the below proposed new output:

NCSR10 REPORT TO THE MARITIME SAFETY COMMITTEE

including a new output on "Identification of measures to improve the security and integrity aspects of AIS" in the biennial agenda of the Sub-Committee and in the provisional agenda of NCSR 11, with two sessions required to complete the output, in order to continue to address the instructions given by the Committee (MSC 105/20, paragraph 2.7, and MSC 106/19, paragraph 2.8.1)

The NCSR 11 report noted that VDES could provide an effective solution through data encryption and authentication.

PKI is currently an open issue which is handled indirectly through the ECDIS requirement to support SECOM, and FAL is working on a strategy towards digitalization including a PKI solution.

When discussing the topic, the group became aware of the following: As of the IMO performance standard for VDES, authentication of AIS is required for all ships who choose to install VDES to fulfil the AIS carriage requirement from 1st of January 2028 on. DTEC6 may seek advice from Cafer Ozkan Istanbullu on the possibility to propose an urgent output to MSC on the topic of PKI.

4. DRAFT EXAMPLE REPORTING FORMAT FOR GNSS INTERFERENCE

Draft Specification — GNSS Interference Report

This document describes the structure and content of the GNSS Interference Report aligned with the IMO Compendium vocabulary and data conventions.

1. shipStaticData (Object)

Provides identifying information about the vessel.

Field	Type	Format	Required	Description
shipName	string	string	Yes	Name of the vessel reporting the incident.
imoNumber	string	^\d{7}$	Yes	The 7-digit IMO number of the vessel.

2. positionReport (Object)

Captures the geographic location and time of the event.

Field	Type	Format	Required	Description
latitude	number	-90 to 90	Yes	Latitude in decimal degrees.
longitude	number	-180 to 180	Yes	Longitude in decimal degrees.
timestamp	string	ISO 8601	Yes	Time of detection, e.g., 2025-03-24T12:34Z

3. interferenceEvent (Object)

Details about the GNSS interference experienced.

Field	Type	Format	Required	Description
gnssConstellation	string	Enum	Yes	GNSS system affected: GPS, Galileo, GLONASS, BeiDou, etc.
signalIdentifier	string	string	Yes	Signal identifier (e.g., PRN, G1, G3).
frequencyBand	string	L1/L2/L5/etc.	Yes	GNSS frequency band impacted.
averageSignalStrength	number	dBHz	Yes	Average measured signal strength.
signalQuality	string	string	Yes	Description of signal quality (e.g., degraded, lost).
interferenceType	string	Enum	Yes	Type of interference: spoofing, jamming, malfunction, etc.
additionalInformation	string	string	No	Extra details about the event (free text).
reportingSystem	string	string	No	Name or type of onboard detection system.

4. Communication Infrastructure

The implementation of the GNSS Interference Report message will utilize MQTT (Message Queuing Telemetry Transport) as the communication infrastructure for data exchange between ships and shore-based systems. MQTT is a lightweight, publish-subscribe network protocol that transports messages between devices with minimal overhead. It is particularly well-suited for maritime environments where connectivity may be intermittent or bandwidth-constrained.

Each GNSS Interference Report will be published to a predefined topic on the MQTT broker, and subscribed shore-based systems will receive the reports for further processing, analysis, or response. Authentication and authorization mechanisms will be in place to ensure secure access to the MQTT broker.

5. REMARKS ON IMT

A. Regarding the introduction of the IMT technology family - starting with what we have today 4G / 5G - as the "working horse" for e-navigation related (but not limited to that, potentially) IP capable communications (and more): new DTEC Task Group on IMT

A.1. Craft an INF paper to NCSR (possibly 2026) to inform NCSR about work started at IALA on this vision; refer to and cite Workshop conclusions related to this.

A.2. Craft a new IMO work item proposal for defining and accepting the IMT technology family as the "working horse" carrier technology for e-navigation with the view that IMO MSC (autumn 2026, where there will be finalised the findings of NCSR regarding the "globally unified IP based framework") will agree to this in one (!) session (as was the case with the IP-based framework submission of Australia et al in December 2024):

- Goal = to have an agenda working item starting at IMO NCSR in 2027;

- Rationale for the urgency (to be presented to IMO MSC autumn 2026): The "globally unified IP based framework" for Maritime Services (in the context of e-navigation) and S-100 data product connectivity was accepted as a matter of urgency by MSC109, and NCSR was commissioned to work on this until 2026 and report to MSC autumn 2006. Thus, by then the SDC stack will have been defined (in principle) in particularly regarding connectivity down to its IP base, namely including MCP (connectivity broker) and SECOM (cyber secure protocol), both relying (!!!!) on an existing IP capable carrier domain framework. On top there are new and substantial demands on navigation and safety related connectivity namely but not limited to the MASS (compare several other presentations of the Edinburgh Workshop). Thus, it can be inferred that the urgency for the "globally unified IP base" prompts an identical urgency for the only carrier available capable to take up the total future load to be introduced to maritime.

NB: The point really is, that existing technology at 4G and 5G can be and should be brought to/adapted to the maritime domain - such a carrier "working horse" does not needed to be invented or designed from scratch.

- Draft TOR for the work item considering both shipboard and shore aspects (co-operative system): shipowners' interests seem to converge with coastal states' interests etc. (refer to presentation at Workshop)

- NB: VDES cannot take the load but will be needed in fall-back terms: AIS protection and augmentation system, with limited capabilities for IP based communications.

- [Potentially also include the SDC-Stack guideline as attachment, which should be ready be then; JHO's other task group]

A.3. Consider impact on capability building at IALA WWA - need for what WWA instrument(s) to be developed!?

B. Regarding "securing visibility of maritime at 3GPP" by presenting IMT 3GPP use cases maritime for 6G: Task Group of Hyounhee Koo.

B.1. INF paper to (next reachable) NCSR (possibly 2026) on the fact that IALA is working on getting the maritime domain seen at 3GPP by means of a MRP + state of work reached on the use cases for maritime: Intro-Letter + Draft Use Case document attached.

B.2. Send an INF paper (or an IALA note even) to the NCSR after that (likely 2027) to validate the use case advance information; with the use case document(ation) attached

C. Steady-state process for Revision of "1610"

C.1 There seems not to be a process defined; however, this is essentially needed.

Rationale: The Maritime Services in the context of e-navigation as represented in "1610" as revised (once in 2024) are the top level entities of the SDC stack and need to be defined in sufficient detail in terms appropriate for digital transformation implied. This has been done to some extent with some MS, but as insight of the participating international organisations grow over time, the "1610" needs to be revised steadily (!) (This is not a short-lived process.)

C.2 Could IALA act as "spider in the web" to that end?

Rationale: IALA developed this document in the past, and with its new standing as an IGO can more easily liaise with other MS domain coordinating international organisations.

C.3. Resilient PNT to become an independent MS3 (again): When such a process has been established, the notion of an independent MS3 Resilient PNT could and should be re-visited in that process!?

Rationale: The original plan of IALA before the last revision (2024) was, to have an independent MS3 on Resilient PNT, but during discussions at IMO this was merged to MS2 AtoN. The Edinburgh Workshop showed that while there are strong (fresh and traditional) contributions from the traditional AtoN domain stakeholders to a Resilient PNT maritime service, it also showed clearly that there are (existing and emerging) technologies being brought to maritime applications in due course, such as IMT (terr/sat) and stand-alone sat constellations, that have not been part of the AtoN domain and will not be part of it in the future. Hence, their joint co-operation in a dedicated MS3 would be appropriate to reflect this situation.

10.2 Working Group 2 – MarNav

The working group reviewed the list of existing PNT related IALA Recommendation and Guidelines. The Working group realised IALA has many documents already available in various conditions which may require review.

Takeaways from presentation and discussion on Monday and Tuesday were evaluated by the WG and concluded that:

- GNSS disruptions no longer hypothetical. Is increasingly seen in various regions and has an adverse impact on maritime safety.
- This necessitates urgent action by coastal administrations to develop and implement mitigation strategies.
- These mitigation strategies include a range of potential systems spanning from maintenance of the existing physical AtoNs, monitoring GNSS disruptions and through the development and adoption of terrestrial navigation systems.

The WG identified the Recommendation R1017 on Resilient Position, Navigation and Timing as best solution to preserve given information from presentations and results of discussions. The WG amended R1017 and generated a draft for further consideration.

The WG identified the Guideline also that is already in revision of IALA ENG committee could be updated with the given information from the presentation and results of the discussions. The WG added comments to “G1180 Ed1.0 Resilient PNT update post ENG21” for further considerations at the next ENG22 committee meeting.

The WG discussed the possible need for a World Wide Radio Navigation Services Manual in line of the Maritime Radio Communications Manual and as a successor of the World Wide Radion Navigation Plan. The

WG composed a possible index with the given information from the World Wide Radion Navigation Plan, presentation and results of the discussions.

The WG discussed given the information given by the presentations and other information available what services AtoN providers could deliver to the seafarer and what we would like to have for the seafarer to make navigation safer. Also discussed that some of the data possible needed for positioning could not be delivered by AtoN providers but might be in the remit of IHO like Bathometry (S-102) data for use on the ship for the echo sounder as mentioned in IMO MSC.1/Circ.1575 (16 June 2017) on the matter of Guidelines for the Shipborne Position, Navigation and Timing (PNT) Data Processing.

The working group asks:

- IALA to forward the draft of R1017 to the next VTS, ARM, DTEC and ENG committee meeting;
- The VTS, ARM and DTEC committee to review the draft and sent for review to the ENG committee;
- ENG committee to review and consolidate the existing PNT related Recommendations and Guidelines and the Task Register;
- IALA to forward the commented document of draft of G1180 Ed1.0 to the next ENG committee meeting;
- After finishing the draft of G1180, ENG committee is asked to send it to PAP;
- ENG committee to review R0129 and the number for the requirements on a backup system;
- IALA to forward the concept index for a World Wide Radio Navigation Services Manual to the next ENG committee meeting for further considerations.

The WG thanks the Northern Lights Board for the arrangements to have a very nice workshop in Edinburgh.

11. SESSION 12 – WORKSHOP CONCLUSIONS

The session was chaired by Hideki Noguchi (JSTRA), Workshop and IALA DTEC Chair.

The participants were invited to comment on the Final Conclusions for the Workshop:

- Considering the significant increase in navigational risk due to GNSS interference and AIS spoofing, IALA should encourage a safe navigation environment through the promotion, development, and implementation of resilient maritime PNT and radiocommunication services, in cooperation with relevant international bodies.
- More resilient PNT and radiocommunication technologies are available now, and in the near future, IALA should assist its members to prepare, implement, and operate these technologies through IALA publications.
- The IMT technology family, as of today (4G, 5G, terrestrial, and space), offers substantial radio communication capabilities readily applicable to the maritime domain. The firmly planned availability of 6G by 2030 will add many gradual improvements in many relevant regards to 5G, including PNT and IoT; however, the maritime domain should not wait until 6G to engage with the IMT technology family.
- Despite significant development in radionavigation and radiocommunication technologies, physical AtoN remains a primary means for navigation and is essential for resilience.
- IALA should proactively monitor the rapid evolution of satellite technologies and prepare for the utilization of emerging satellite services, especially Low Earth Orbit (LEO)and 5G/6G non-terrestrial networks (NTN) to improve maritime safety and resilience.
- There is no harmonised way of detecting and reporting PNT service interferences. IALA should consider conducting a Workshop on this topic and inviting all relevant stakeholders, alongside the ongoing development of the IALA Guideline on GNSS interferences.

- E-navigation maritime services (Initial descriptions of maritime services in the context of e-navigation MSC.1/Circ. 1610/rev1) should be reviewed and revised, taking specifically into account the introduction of the Resilient PNT service, and the task added to the IALA Work Programme
- Several terrestrial radionavigation systems are being developed, such as eLoran, R-Mode, etc.; IALA should consider conducting a Workshop on interoperability and harmonisation of these systems.
- The required performance, e.g., bandwidth, latency, etc., for the emerging e-navigation services is unknown; therefore, IALA should consider collecting the needs and creating a method to estimate the required communication means for specific services in each region.
- The development of countermeasures against AIS spoofing is urgent, and authentication of AIS has been developed; in this regard, IALA should consider “a strategy” to encourage widespread implementation for both ship and shore.

The participants were provided with the Working Group Chars reports, which are available in Annexes C, D, E, and F.

11.1 Closing Remarks

Mike Bullock thanked all participants for their engagement during the week and highlighted that the workshop was a great illustration of IALA in action ie cooperation, collaboration and friendship. He acknowledged the contributions of the IALA team in making the event so successful. Special thanks were given to the workshop committee and Northern Lighthouse Board team staff for their coordination and support. He concluded by encouraging ongoing collaboration and wished safe travels to those returning home.

In his closing remarks, Omar Eriksson reflected on the workshop's success, noting that the chosen format had worked very well. He highlighted that beginning with presentations from top-level experts provided a strong foundation for discussions, followed by productive reflection and mapping of the lessons learned onto IALA’s work. According to him, this approach consistently delivers valuable and sometimes unexpectedly strong outcomes, as evidenced by this workshop.

12. SOCIAL EVENTS AND TECHNICAL VISIT

On Wednesday evening, workshop participants had the opportunity to take part in two memorable events combining technical insight with maritime heritage.

These events enriched the workshop programme by combining professional exchange with direct engagement in vessels representing both operational service and historic maritime tradition.

12.1 Technical Tour visit to NLV POLE STAR

The technical visit was hosted on board the Northern Lighthouse Board newly delivered Hybrid powered buoy tender, NLV Pole Star. Participants were given an overview of the vessel's operational role in maintaining aids to navigation around the coasts of Scotland and the Isle of Man and of the technical and environmental innovation built into the design of the vessel. The visit provided valuable practical context to the workshop discussions on maritime safety, resilient PNT and modern navigation services.

12.2 Workshop dinner on Royal Yacht BRITANNIA

The workshop dinner took place aboard HMY Britannia, the former Royal Yacht with a distinguished history of state visits and diplomatic missions. Hosting the dinner on this iconic vessel offered participants a unique opportunity to network in a setting of exceptional maritime heritage, reinforcing the strong historical and operational links between navigation, safety at sea and international cooperation.

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14. TECHNICAL PROGRAMME

WORKSHOP PROGRAMME

DAY 1 – Monday 2026 – 09 February 2026

Time	Activity	
08:30 – 09:00	Registration and morning tea/coffee	
09:00 – 10:20	**Session 1 – Welcome and introductions**	**Chair – Hideki Noguchi (JSTRA)**
09:00 – 09:20	Welcome from the host	**Mike Bullock (NLB)**
09:20 – 09:40	Welcome from IALA	**Omar Eriksson (IALA)**
09:40 – 10:00	Workshop scope and purpose	**Hideki Noguchi (JSTRA)**
10:00 – 10:20	WWA updates on Capacity building	**Vincent Denamur (IALA WWA)**
10:20 – 10:40	**Coffee Break**	
10:40 – 12:00	**Session 2 – Regulatory Constraints and Technical Capability**	**Chair – Stefan Bober (WSV)**
10:40 – 11:00	Overview of Maritime Spectrum Regulations and Gaps	**Falong Liu (CTTIC) – online**
11:00 – 11:20	Experience from VDES and AIS: Regulatory Adaptation for New Technologies	**Hideki Noguchi (JSTRA)**
11:20 – 11:40	Experience from SBAS: Regulatory adaptation for marine radionavigation	**Hideki Noguchi (JSTRA)**
11:40– 12:00	**Session 2 Q&A**	
12:00 – 13:00	**Lunch**	
13:00 - 13:20	**Session 3 – Users' view on radionavigation and communication**	**Chair – Phillip Day (NLB)**
13:20 – 13:40	ARM perspective on MARCOM	**R. David Lewald (U.S. Coast Guard)**
13:40 – 14:00	Digital VTS and the Future of Maritime Connectivity	**Olli Soininen (Fintraffic)**
14:00 – 14:20	Standard Navigation for GNSS Disruption: Bringing Visual Perception Back to the Forefront	**Capt Aly Elsayed (AFNI)**
14:20 – 14:40	**Session 3 Q&A**	
14:40 – 15:00	**Break**	
15:00 – 15:20	**Session 4 – VHF radio navigation and communication**	**Chair – Peter Douglas (NLB)**
15:20 – 15:40	VDES as a communication system	**Stefan Pielmeier (FLIR TransponderTech AB)**
15:40 – 16:00	VDES R-Mode	**Ronald Raulefs (DLR)**
16:00 – 16:20	VHF digital radio	**Jeffrey van Gils (RWS WVL)**
16:20 – 16:40	**Session 4 Q&A**	
17:00 – 18:30	**Welcome reception**	

DAY 2 – Tuesday 2026 – 10 February 2026

Time	Activity	
09:00 – 10:00	**Session 5 – LF/MF/HF radio navigation and communication**	**Chair – Gillian Burns (NLB)**
09:00 – 09:15	e-Loran	**Dr Jan Safar (TH, GRAD)**
09:15 – 09:30	Advancing the Korean eLoran System: Development Status and New LDC design	**Ki-yeol Seo (KRISO)**
09:30 – 09:50	DGNSS and MF R-Mode	**Stefan Gewies (DLR)**
09:50 – 10:10	NAVDAT	**Pierre Mingot (Cerema)**
10:10 – 10:30	**Session 5 Q&A**	
10:30 – 10:40	**Coffee Break**	
10:40 – 12:00	**Session 6 – IMT and other technology**	**Chair – Ronald Raulefs (TBC)**
10:40 – 11:00	The potential of the IMT technology family, considering the outcome of the IMT workshop 2025	**Jan-Hendrik Oltmann (WSV)**
11:00 – 11:20	IMT 2030 (6G)	**Hyounhee Koo (SyncTechno)**
11:20 – 11:40	INS and Quantum Navigation	**Dr Kevin Sheridan (TH, GRAD)**
11:40– 12:00	**Session 6 Q&A**	
12:00 – 13:00	**Coffee Break**	
13:00 - 14:40	**Session 7 – Satellite (1)**	**Chair – Dennis Khoo (MPA)**
13:20 – 13:40	Growing Risks to Maritime Safety	**Omar Eriksson (IALA)**
13:40 – 14:00	Galileo return link	**Eduardo Diaz (EUSPA)**
14:00 – 14:20	SBAS as a radionavigation system	**Jose-Luis Martin (ESSP)**
14:20 – 14:40	**Session 7 Q&A**	
14:40 – 15:00	**Lunch / Break**	
15:00 – 15:40	**Session 8 – Satellite (2)**	**Chair – Hideki Noguchi (JSTRA)**
15:20 – 15:40	Inmarsat	**John Dodd (Inmarsat)**
15:40 – 16:00	Iridium	**Dan Rooney (Iridium)**
16:00 – 16:20	Status of the satellite communication systems	**Nader Alagha (ESA)**
16:20 – 16:40	**Session 8 Q&A**	

DAY 3 – Wednesday 2026 – 11 February 2026

Working groups

Time	Activity	
09:00 – 16:00	Session 9 – **Establishing working groups**	
	WG1 – MarCom	**Chair – Stefan Pielmeier (FLIR TransponderTech AB)** **Vice-Chair – Stefan Bober (WSV)**
	WG2 – MarNav	**Chair – Jeffrey van Gils (RWS WVL)** **Vice-Chair – Stefan Gewies (DLR)**
10:20 – 10:40	**Coffee Break**	
12:00– 13:00	**Lunch**	
14:30– 15:00	**Coffee Break**	
16:00 – 18:00 **18:30 – 20:00**	**Technical Visit on board a vessel** **Workshop Dinner** ***Leaving the NLB HQ at 15:00**	

DAY 4 – Thursday 2026 – 12 February 2026

Working groups

Time	Activity	
09:00 – 17:00	Session 10 – **Establishing working groups**	
	WG1 – MarCom	**Chair – Stefan Pielmeier (FLIR TransponderTech AB)** **Vice-Chair – Stefan Bober (WSV)**
	WG2 – MarNav	**Chair – Jeffrey van Gils (RWS WVL)** **Vice-Chair – Stefan Gewies (DLR)**
10:20 – 10:40	**Coffee Break**	
12:00– 13:00	**Lunch**	
15:00– 15:20	**Coffee Break**	

DAY 5 – Friday 2026 – 13 February 2026

Time	Activity	
09:00 – 10:00	**Session 11 – WG report**	**Chair – Omar Eriksson (IALA)**
09:00 – 09:20	WG 1 report	**Chair – Stefan Pielmeier (FLIR TransponderTech AB)** **Vice-Chair – Stefan Bober (WSV)**
09:20 – 09:40	WG 2 report	**Chair – Jeffrey van Gils (RWS WVL)** **Vice-Chair – Stefan Gewies (DLR)**
10:00 – 10:20	**Session 11 Q&A/Discussion**	
10:20 – 11:00	**Coffee Break**	
11:00 – 11:40	**Session 12 – Workshop Conclusions**	**Chair – Hideki Noguchi (JSTRA)**
11:00 – 11:20	Summary of Workshop Findings	**Hideki Noguchi (JSTRA)**
11:20 – 11:30	Remarks from the host	**Mike Bullock (NLB)**
11:30 – 11:40	Remarks from IALA	**Omar Eriksson (IALA)**

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