WORKSHOP ON INTERNATIONAL MOBILE TELECOMMUNICATION (IMT) FOR MARINE ATONS

Wasserstraßen- und Schifffahrtsverwaltung des Bundes

WSV.de

WORKSHOP REPORT

01 to 05 September 2025

Federal Waterways and Shipping Agency

Karlsruhe, Germany

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REPORT OF THE WORKSHOP

ON INTERNATIONAL MOBILE TELECOMMUNICATION (IMT) FOR MARINE ATONS

EXECUTIVE SUMMARY

The Workshop on International Mobile Telecommunication (IMT) for Marine AtoNs was held between the first and fifth of September 2025 at the Federal Waterways and Shipping Agency (WSV) in Karlsruhe, Germany.

The workshop was well-attended, with 46 participants from 18 countries.

The workshop participants considered the various presentations that were given, and the work conducted in the WGs, and it was concluded that:

- IALA should play a key role in representing marine Aids to Navigation (AtoN) within the 6G development process, ensuring the maritime domain's unique requirements are considered.
- Engagement with 3GPP via ETSI is required to incorporate maritime perspectives, particularly for ship-to-X communications, AtoN communication, waterway information exchange, and safety-related information.
- Use cases, operational coverage zones, preconditions, service flows, post-conditions, challenges, and potential requirements must be clearly defined to guide 6G feature development.
- Detected operational coverage zones include inland/ports (OCZ1), close to coast (OCZ2), and far from coast (OCZ3), each with distinct challenges such as coverage, service continuity, and prioritisation.
- Identified challenges for 6G implementation include ensuring continuous service across operators, service prioritization (QoS), coverage, and cost efficiency.
- Potential maritime use cases for 6G include support for MASS, broadcast voice communication, communication with and between AtoNs, Position, Navigation and Timing (PNT), redundancy for existing systems, and intelligent AtoNs with advanced positioning and data exchange capabilities.
- Expectations for 6G network providers include sufficient Internet connectivity, gateways with QoS, resilience to interference, cyberattacks, and authentication of providers.
- Maritime-specific conditions such as sea state, weather influence, and channel characteristics must be addressed in system design and reliability requirements.
- Technical services like Traffic Clearance, Route Exchange, and Navigational Warnings were analyzed, highlighting challenges such as coverage, service availability, high ship density, and prioritization.
- IMT-2020 (5G) can support maritime services, including video-streaming, IoT applications, VTS, and AtoN monitoring, but requires careful consideration of public vs non-public networks and network slicing for QoS guarantees.
- Procurement strategies should prioritize coverage, reliability, interoperability, and SLAs, with phased rollouts starting with pilot areas like ports and VTS before wider coastal adoption.
- Private and hybrid networks are recommended for critical zones and coastal coverage, balancing control, cost, and efficiency.
- Organisational measures are essential: governance accountability, workforce capacity building, integration into national digital strategies, structured knowledge sharing, and IALA guidance.
- Cybersecurity, legacy system interoperability, lifecycle costs, and technology obsolescence must be managed through standards-based, backward-compatible solutions.
- Preparing for IMT-2030 (6G) requires early adoption in ports and VTS for leadership and efficiency, with phased or later adoption for wider coastal coverage.
- IALA's strategic role includes strengthening influence in standardization, endorsing pilots, supporting global training via WWA, and building global capacity for 6G technologies and regulations.

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Report of the Workshop
on International Mobile Telecommunication (IMT) for Marine AtoNs

1. INTRODUCTION

The workshop on International Mobile Telecommunication (IMT) for Marine AtoNs was held from September 1 to 5, 2025, at the Federal Waterways and Shipping Agency (WSV) in Karlsruhe, Germany. 46 participants from 18 countries participated in the Workshop, plus three members of the IALA Secretariat.

The Chair of the Workshop was Hideki Noguchi, and the Secretary was Alisa Nechyporuk. The logistics and technical programme workflow for the event was organised by Jan-Hendrik Oltmann, senior strategic adviser to the Head of the Traffic Technologies Department of the Waterways and Shipping Agency (GDWS) of the Federal Waterways and Shipping Administration (WSV).

The event was kindly hosted by the Federal Waterways and Shipping Administration (WSV).

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2. SESSION 1 – WELCOME AND INTRODUCTIONS

Hideki Noguchi, IALA DTEC Committee Chair, chaired this session.

2.1 Welcome and introduction to the waterway and Marine AtoN domains of the host country, Germany – Roman Weichert (BAW), Thomas Wagner (WSV)

Roman Weichert, head of the Department of Inland Waterways and deputy director of the host organisation, the Federal Waterways Engineering and Research Institute (BAW), sent a warm wish for a successful and enjoyable workshop, expressing the hope that the setting at BAW would inspire productive discussions and foster international collaboration.

He emphasised that the Federal Waterways Engineering and Research Institute (BAW) is a scientific institute affiliated with the Federal Ministry of Transport. As part of its role, it provides technical and scientific services to both the Ministry and the Federal Waterways and Shipping Administration (WSV), particularly in the field of waterway engineering.

The BAW regularly hosts international guests, but the current week-long event—attended by numerous participants from around the globe—is considered especially significant.

The institute's responsibilities include assessing infrastructure across a portfolio of approximately 2,300 structures, offering expertise through interdisciplinary teams in fields such as hydraulic engineering, navigation, geotechnical and structural engineering. The BAW operates at the forefront of science and technology, with an emphasis on practice-oriented, holistic approaches.

Thomas Wagner, Head of the Traffic Technologies Department of the Waterways and Shipping Agency (GDWS), welcomed participants to the workshop, highlighting its importance as a platform for international collaboration in the field of maritime and inland waterway telecommunications. The event brings together technical and user experts to share insights, foster innovation, and build cross-border cooperation to enhance safety, efficiency, and sustainability in maritime navigation.

He encouraged participants not only to gain professional inspiration but also to enjoy the cultural, social, and culinary experiences Germany offers. Expressed gratitude to the Federal Waterways Engineering and Research Institute (BAW) for hosting and supporting the event. Thanked the organisers, session chairs, and speakers for their contributions.

He made the general overview of the organizational structure and key responsibilities of the WSV, which is responsible for the operation, maintenance, and development of Germany's waterways infrastructure, covering both maritime and inland waterways and managing 7,300 km of navigable inland waterways and 23,000 km² of maritime waterways (North and Baltic Seas).

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

Omar Frits Eriksson, IALA Deputy Secretary-General, kindly welcomed everyone to the workshop and emphasized the significance of holding this workshop in Karlsruhe, a hub of engineering excellence, and praised the high level of ambition reflected in the workshop's goals.

He highlighted the shift from traditional systems like GMDSS to advanced, IP-based mobile technologies such as 5G and 6G. These technologies enable real-time data exchange, smart navigation aids, and integration with satellite and terrestrial networks. The speaker praised Germany’s leadership in digital infrastructure and called for global cooperation in developing secure, connected, and resilient maritime systems.

Omar noted key challenges, including spectrum availability, legacy system integration, and cybersecurity risks. Particular attention was given to the potential for developing nations to leapfrog legacy systems using mobile networks. The workshop aims to produce recommendations for IALA, ITU, and IMO to guide future standards and strategies. Participants were encouraged to contribute to shaping the digital future of navigation. The event was described as a cornerstone for aligning technical innovation with regulatory progress in the maritime sector.

2.3 Workshop aim and objectives, Hideki Noguchi – IALA DTEC Committee Chair

Hideki Noguchi welcomed participants to the workshop and expressed his happiness to see the interest that the event has garnered, with more than 50 experts and stakeholders with a keen interest in the IMT technologies.

Hideki then provided the audience with a short introduction of his position as Chair of the IALA DTEC committee and the Chair of NCSR Working group 2 in IMO.

He expressed his appreciation to the German Federal Waterways and Shipping Agency, the Federal Waterways Engineering and Research Institute, and the main idea creator of the Workshop, Jan-Hendrik Oltmann.

2.4 Workshop introduction, Jan-Hendrik Oltmann – Federal Waterways and Shipping Agency (WSV)

Jan-Hendrik Oltmann, welcomed participants and outlined the structure and objectives of the event, emphasizing a top-down and bottom-up approach to digital transformation in maritime communication. A key focus is on integrating real-time, IP-based data transmission systems—such as 5G/6G—to support new maritime services and S-100 data products. The workshop explores the International Mobile Telecommunications (IMT) family as a potential solution for seamless, secure ship-to-shore communication as a potential carrier of the connectivity part of the Services-Data-Connectivity (SDC) stack.

The SDC stack is a system architectural representation of the work programmed by IMO which was introduced and explained: "Services" are in particular the "Maritime Services in the context of e-navigation" (as defined by IMO MSC.1/Circ.1610 as revised), "Data" are in particular the data models/products as defined in the "S-100 World", and "Connectivity" comprises all components needed to transport data (including digital voice) from shore to ship, ship to shore, and ship to ship by a connectivity broker entity (e.g. Maritime Connectivity Platform (MCP)), radio communication protocols (such as SECOM) and radio link carrier technologies (such as IMT family) – the latter of which being the focal point of the workshop.

Sessions are expected to address technical requirements, digital infrastructure, connectivity, and cybersecurity, while also showcasing working 5G maritime systems. This means, that the workshop addresses the most foundational part of the whole of the SDC stack, namely the carrier for any and all data and functionality to be exchanged shore to ship, ship to shore, and ship to ship in the maritime domain. Compare Session 4 for more detail.

The workshop also aims to create a unified IALA information document to guide global maritime connectivity strategies. Social and cultural activities, including a technical excursion and workshop dinner, foster collaboration. The coordinator of the Workshop emphasized the urgency of aligning global standards to meet the IMO's 2030 digital goals. Overall, the workshop is positioned as a foundational step toward future-proofing maritime navigation.

2.5 Technical excursion, hands-on demonstration of 5G technology, workshop program and list of participants

At the technical excursion, participants rotated through BAW's live running water simulation of a part of the river Rhine for planning and assessing waterway engineering measures to the river, as well as through an inland waterway vessel ship-handling simulator.

In addition, hands-on demonstrations of 5G technology were given to participants to support Session 6 presentations (see below).

A list of participants can be found in Annex A.

The workshop programme can be found in Annex B.

3. SESSION 2 – THE CHALLENGE: INTRODUCING IMT TECHNOLOGIES / RISING TO THE CHALLENGE AND TO THE OPPORTUNITIES: APPLICATION EXAMPLES

This session was chaired by Dennis Khoo, Chief Technology Officer, Director (Maritime Systems and Technology) in the Maritime and Port Authority of Singapore (MPA) and DTEC Vice-Chair.

3.1 Using IMT as the sole means for all communications needs of a maritime island community – Giang Hoang Hong, Director General of the Inland Water Transportation Department of Vietnam

Giang Hoang Hong, representative from the Director General of the Inland Water Transportation Department of Vietnam, in summary, emphasised that Vietnam is actively exploring and piloting IMT-2030 (6G) technologies while continuing to expand its use of 4G and 5G in critical sectors. The country is aligning its efforts with national priorities, including smart infrastructure, environmental management, and digital transformation in maritime and logistics.

He noted that IMT-2030 technologies are currently in the research and pilot testing phase in Vietnam. Key focus areas include transportation, maritime, remote healthcare (e.g., remote surgery), traffic monitoring, and autonomous vehicles. Technologies such as AI, IoT, and low-latency networks are being applied to develop smart ports, real-time vessel tracking, and automated container yard operations. IMT-2030 holds great potential for advancing smart, safe, and connected maritime ecosystems in Vietnam. Success depends on international collaboration, technological support, and capacity building. Vietnam is committed to early preparation and seeks global partnerships to close the technological gap and ensure effective deployment.

3.2 Using IMT's features in public safety communications – Hyounhee Koo, SyncTechno Inc.

Hyounhee Koo's presentation focused on the role of location-based technologies and wireless communications in enhancing public safety, particularly through international standardization efforts such as those led by the ITU (International Telecommunication Union) and 3GPP.

Hyounhee mentioned that the ITU-R plays a significant role in shaping wireless communications standards for disaster management and public safety. Resolution 55 highlights the importance of wireless systems in early warning, mitigation, and relief operations. ITU continues to support the development of IMT (International Mobile Telecommunications) systems for public safety use, including in maritime domains.

Hyounhee explained that integration of these technologies requires regulatory frameworks at the national level. Governments should define policy requirements, integrate emergency alert systems with telecom networks, and ensure interoperability and compliance with international standards.

Public safety communications are transitioning toward integrated, standardized solutions enabled by IMT technologies. The development of features for alerting, geolocation, and mission-critical services is accelerating, but regulatory alignment, government involvement, and inter-sector collaboration are crucial to ensure effective implementation—especially in domains like maritime safety.

3.3 IMT technologies in other modes of transport – a survey – Jan-Hendrik Oltmann, WSV

Jan-Hendrik Oltmann's presentation explored how IMT technologies (such as 5G) are being applied in the railway and automotive sectors, with a focus on what lessons and practices can be adapted to the maritime domain. Emphasis was placed on systems thinking, structured architecture, user requirements, and technology adaptation.

The Future Railway Mobile Communication System (FRMCS), developed by the International Union of Railways (UIC), is a comprehensive system concept, not just a technology upgrade. Key principles: System-wide connectivity: connecting onboard users (trains) with ground-based systems; Simultaneous handling of voice, data, and video; Reference architecture: defining roles, interfaces, and migration paths (from legacy to future systems); Emphasis on well-defined user requirements and migration planning. A similar architecture and requirement-driven approach could be developed to support future ship-to-shore and ship-to-ship communications.

In addition, he introduced the developments at the domain of Connected automated vehicles (CAV) as described in terms of use cases and requirements in Report ITU-R M.2534 as well as in ITU-R's report on Cellular-Vehicle-to-Everything (C-V2X) (Report ITU-R M.2520), and that there can be an analogy drawn between the other modes and maritime. He highlighted also the development of a direct mode (PC5 Mode 4) at C-V2X, where "vehicles autonomously select transmission resources based on sensing the environment and perform time synchronization using GNSS. There is no involvement of the cellular network in this mode." (M.2520-0, intro text to Figure 3).

He emphasised the lessons for the maritime domain as:

- Systemic architecture: Maritime stakeholders should develop a reference architecture similar to FRMCS and C-V2X models; a validated analogy model between CAV/C-V2X and maritime was given.
- Requirement definition: Formal user requirements (similar to rail/automotive sectors) are needed to support technology-driven evolution.

- Legacy transition: Plan for phase-out of older technologies (e.g., VHF voice) and define a migration path.
- Use-case templates: Rail and auto sectors use formal templates to describe communications scenarios, which can be adapted for maritime use.
- Standards synergy: Leverage existing 3GPP and ITU work instead of reinventing solutions—maritime stakeholders should select, adapt, and specialize where needed.

Jan-Hendrik explained that the rail and automotive sectors offer mature, structured approaches to implementing IMT technologies, with clear frameworks, stakeholder models, and functional specifications. By drawing analogies and adopting similar processes, the maritime domain can accelerate the integration of modern communication systems, thereby improving safety, efficiency, and future readiness.

3.4 IMT applications for remotely operated and/or autonomous vessels – Early Results and Prospects of MASS Trials in Italy – Paolo Pagano, CNIT Laboratory

Paolo Pagano, Head of the Technology Transfer Research Sector and Director of the CNIT Laboratory at the Port of Livorno, presented early results and prospects of the MASS trials in Italy. The Port of Livorno, a mid-sized historical port and gateway to Tuscany, is emerging as a pioneer in digital transformation and maritime automation. The port is playing a key role in developing and testing 5G-based autonomous shipping technologies, contributing to global standardization and cybersecurity efforts. The Port of Livorno, located along the TEN-T SCANMED corridor and known as the "door of Tuscany," is a mid-size historical port handling both passengers and a wide range of freight, including containers, Ro-Ro, dry, liquid, and break bulk. It features a freight village with car stocking facilities for up to 25,000 vehicles and is managed under a unified port network authority that also includes the ports of Piombino and Elba.

Since 2015, Livorno has hosted a laboratory for innovation in port and maritime technologies, operating under framework agreements with the Port Authority and the National Coast Guard. It forms part of the National Laboratory of Photonic Networks and Technologies in Pisa and contributes to CITEM, the Livorno Center for Innovation and Technology for the Blue Economy.

Livorno has emerged as a pioneer in the application of 5G to maritime operations. Through the 5G MASS initiative, a prototype Remote Operation Centre (ROC), a retrofitted autonomous test vessel, and dedicated port infrastructure have been developed to support real-time digital ship-port interaction. This work contributes to the evolving IMO regulatory framework for Maritime Autonomous Surface Ships (MASS), which is currently outlined in the draft MSC 110/WP.8 document led by Sweden. The MASS Code is expected to follow a phased rollout, with voluntary adoption in 2025–2026, an experience-building phase from 2026–2028, and mandatory application by 2030–2032.

Cybersecurity is a central aspect of the Livorno 5G MASS architecture. The system is built on a secured private 5G network. Access and authorization are managed through an OpenID Connect-compliant framework (RFC 6749 and 6750). Communication is encrypted in transit using SECOM (IEC 63173-2), and data is securely stored in an isolated tenant within the port’s experimental private cloud.

Autonomous or unmanned shipping is a highly regulated, fully digital domain requiring robust international standards. The experience in Livorno highlights both the potential and the challenges ahead, including issues related to network performance, port layout, ROC operations, and cybersecurity infrastructure. Italy’s early deployment of 5G-enabled maritime automation systems positions it at the forefront of this global shift. However, there remains a strong need for comprehensive international standardization to be achieved during the experience-building phase.

4. SESSION 3 – RISING TO THE CHALLENGE OF EMERGING DEMANDS OF THE MARITIME SERVICES AND ‘REAL-TIME’ DATA PRODUCTS

This session was chaired by Richard Aase from the Norwegian Coastal Administration.

4.1 Rising to the challenge of Vessel traffic services (MS1) and S-212 data product (VTS digital services) – Wim Smets, Agency for Maritime and Coastal Services, Belgium

Wim Smets, a representative from the Belgian Agency for Maritime and Coastal Services, presented ongoing efforts to modernize Vessel Traffic Services (VTS), which are shore-based systems responsible for managing and monitoring vessel movements in ports and coastal areas. These systems are crucial for enhancing maritime safety, improving traffic efficiency, and minimizing environmental risks.

VTS operations rely on a wide range of data, including inputs from onboard sensors (radar, optical systems), shore-based stakeholders, and direct communication with ships. However, much of this data is still not fully digitalized or standardized, creating challenges for real-time coordination and decision-making.

To address this, a guideline on VTS digital communications is being developed by the VTS Committee's Working Group 1. This document aims to define operational VTS functions in a digital context and serve as a foundation for developing technical solutions.

The technical development is anchored in two frameworks:

- The S-100 framework (IMO) provides a structure for modeling maritime data but is limited in supporting real-time exchange.
- The S-200 framework (IALA) supports the VTS domain specifically, with the S-212 standard under development to address VTS-related information exchange.

S-212 is being designed to reuse and integrate existing data models, such as S-421 for route exchange. It currently supports the Traffic Clearance Service, while Route Exchange and other upcoming services rely on pre-existing standards. Additional services like the VTS Information Service and Under Keel Clearance (UKC) are under construction or planning, with UKC expected to use S-129 as a foundation.

The current version of S-212 is 0.7.4, and efforts are underway to publish version 1.0 and expand the model where feasible. Ongoing governance is essential to ensure service coordination and avoid redundancy.

Looking ahead, key priorities include:

- Finalizing the guideline on digital communications
- Developing additional VTS services
- Publishing S-212 version 1.0
- Ensuring interoperability between ship and shore systems
- Promoting stakeholder engagement, particularly with shipowners and mariners

Effective communication infrastructure is also vital. While the specific technology is flexible, the solution must be secure, fast, reliable, cost-effective, and scalable. The Maritime Connectivity Platform (MCP) is one potential option, but other alternatives are also being considered.

Ultimately, the success of digital VTS services depends not only on technical development but also on broad adoption across the maritime sector, ensuring tangible benefits for both ships and shore-based authorities.

4.2 Rising to the challenge of Sea Traffic Management, JITA, fleet management, and other applications of S-421 (IEC 63173-1) – Olli Soininen, Fintraffic VTS

Olli Soininen, Head of Programs from Fintraffic VTS, delivered a presentation highlighting two ongoing European projects focused on the implementation of digital maritime services, particularly those built on the S-421 route exchange standard and aligned with the broader S-100 framework.

The first project, Nelson, is a publicly funded, 36-month initiative involving stakeholders from Finland, Sweden, and Spain. Its objective is to operationalize existing IALA services, particularly the Route Exchange and Traffic Clearance Services, using the Maritime Connectivity Platform (MCP) for secure and standardized communication. The project will also test these services in real-world operations involving remote VTS centers and shipping companies, particularly in the Baltic and broader Atlantic regions.

Nelson includes building a robust communication infrastructure, including 5G, satellite, and VDES connectivity. It aims to integrate VTS and ship systems using these communication layers and validate how the services perform operationally. A key part of the initiative is exploring how remote pilots can interact with standardised VTS services in a decentralised environment, reducing dependency on local systems.

The second initiative is a private-sector-driven project focusing on Just-in-Time (JIT) Arrival and Virtual Arrival services. The project aims to help ports and shipping companies plan and adjust ship arrivals more efficiently, reducing fuel consumption and emissions. It leverages operational data and regulatory demands to optimize voyages dynamically, creating economic and environmental benefits.

This project is being developed as a contractual sandbox involving over ten million euros in private investment. It includes more than 70 ecosystem members—ports, insurers, banks, and technology providers—and will cover over 60 ports in the Baltic Sea. A key goal is to demonstrate how digital trade documentation and operational optimization can be enabled using existing data and digital infrastructure.

Both projects emphasize the need for secure, real-time, standardized communication between ships and shore systems and build on existing standards rather than inventing new ones. They also highlight the importance of integrating technical capabilities with regulatory and commercial frameworks to ensure industry-wide adoption.

In summary, these two projects aim to operationalize the digital services being developed by IALA and the maritime community, turning theoretical frameworks like S-421 into practical, scalable solutions that improve efficiency, reduce emissions, and support regulatory compliance.

4.3 Rising to the challenge of Under Keel clearance management and S-129 UKCM – Jason Rhee, OMC International

Jason Rhee presented on the importance of reliable communication in Under Keel Clearance (UKC) Management and the operational implementation of the S-129 product specification was highlighted. The presentation focused on how digital services can improve navigational safety, operational efficiency, and environmental performance, particularly in sensitive or remote maritime regions like the Torres Strait.

UKC management, which aims to ensure a vessel maintains sufficient clearance beneath the keel, can be approached via two models: static and dynamic. The static model relies on predefined depths and tide tables but lacks flexibility in changing conditions. In contrast, dynamic UKC management uses real-time vessel data, environmental conditions, and hydrodynamic modeling to provide tailored, risk-based clearance assessments. This allows vessels to optimize routes, maintain safety, and reduce emissions.

The Torres Strait example was used to show how a dynamic UKC Management Service (UKCM) has been operational since 2011. The system collects various data inputs—such as ship stability, draft, speed, tide, and weather—processes them ashore, and provides real-time UKC guidance to pilots and mariners. Given the Strait's remoteness, reliable connectivity (e.g., via AIS base stations and satellite links) is essential to keep UKCM services functional and up-to-date.

A major challenge raised was the need for secure, real-time, bi-directional communication between vessels and shore systems, especially as UKCM services evolve to deliver S-129-compliant datasets. S-129 is an IHO standard under the broader S-100 framework and defines how UKC information should be structured and displayed on ECDIS and other navigation systems.

However, the current data distribution infrastructure—largely built for traditional ENCs—does not adequately support real-time delivery or integration of S-129 data. This creates limitations for dynamic services, which depend on frequent updates (potentially every minute) based on changing vessel and environmental conditions.

Furthermore, it's recognized that S-129 services may not be best aligned with the current NS-12 (Publication Service) in the IMO's Maritime Service Portfolio. Alternative or complementary service alignments—such as with real-time environmental or port coordination services—may better reflect the operational nature of S-129 data.

The presenter proposed ongoing industry collaboration to reconsider the service alignment and data exchange mechanisms needed to support full-scale adoption of S-129. A paper has been submitted to the IHO's S-100 and Nautical Information Provision Working Groups to further this discussion.

Effective UKC management and successful S-129 implementation depend on reliable, secure, and near real-time data exchange. UKC is essential for safe and efficient navigation, especially in constrained or sensitive waters, and S-129 provides the framework to deliver this information directly to onboard systems.

To maximise its benefits, a robust communications infrastructure is needed to ensure accurate, up-to-date data. As the industry advances, reconsidering maritime service alignment will help support safe and efficient digital navigation.

4.4 Rising to the challenge of Aids to Navigation Service (MS2) and Navigational Warnings (S-124) – Cheryl Marshall, Canadian Coast Guard

Cheryl Marshall provided an overview of Canada's ongoing efforts to digitalize aids to navigation (AtoN) and navigational warnings, as part of the country's broader E-Navigation strategy. This strategy is guided by the Canadian E-Navigation Road Map, which is developed and updated annually in collaboration with various federal departments and maritime industry stakeholders. The roadmap identifies priority initiatives and highlights operational services already in place.

Canada's E-Navigation Portal plays a central role in this strategy. It offers a wide range of maritime data and services that support voyage planning and operational safety in Canadian waters. The portal includes information such as AIS-based virtual aids to navigation, channel monitoring, weather alerts, navigational warnings, and application-specific messages. It serves both as an operational tool and as a catalog of maritime data services.

A significant focus of the presentation was on real-time data and collaboration. Through partnerships with marine pilots, research institutions, and government agencies, Canada is leveraging smart buoys and AIS technologies to provide near real-time weather and environmental data to mariners. These efforts are particularly important in challenging environments such as the Canadian Arctic, where maintaining traditional AtoNs can be extremely difficult due to geographic remoteness, harsh weather, and limited infrastructure.

The presentation highlighted several ongoing challenges. These include managing regional differences in operations, maintaining traditional aids while transitioning to digital systems, and ensuring that new S-100-based services meet both regulatory and technical requirements. For example, the transition to the S-100 framework, including S-101 for ENCs, S-124 for navigational warnings, and S-129 for under-keel clearance (UKC), demands high-quality, well-structured data. Business rules and data validation are essential, and national alignment is needed to ensure consistency across systems. Legacy system integration and GNSS resilience were also noted as ongoing concerns.

On the regulatory front, the presenter noted that current guidance is still evolving. Concerns have been raised about overlapping standards, such as between S-124 and GMDSS, and the risks of over-reliance on real-time data. The need for flexible, forward-looking regulations that support new technologies while safeguarding mariner safety was emphasized. Limited bandwidth and data transmission capacity to vessels, especially in remote areas, remains a barrier to full adoption of S-100 services.

To address the lack of commercial tools capable of visualizing the Coast Guard's full suite of S-100 products, Canada has developed an internal S-100 testing tool. This application allows developers to visualize and test products such as S-123, S-124, S-127, and S-129, helping ensure proper formatting, attribute use, and interoperability before integration into navigation systems. While this tool is not intended for navigation, it plays a critical role in product development and quality assurance.

The presentation also described Canada's current trials of S-124 data in the St. Lawrence River, involving both internal testing and external stakeholder engagement. Canada has developed an export function for S-124 data from its NAVWARN system and publishes weekly updates of static S-124 data for a designated trial zone. Early feedback from these trials has highlighted challenges with system integration, encryption, and user interface design. There have also been calls for more training. On the positive side, users expressed appreciation for the dynamic data layers and showed strong interest in continuing to explore the use of both S-124 and S-129.

In conclusion, several lessons learned were shared. Visualization has helped identify weaknesses in business rules and highlighted the need for high-quality, consistent data. Integrating with legacy systems has proven complex, and early training of personnel has been shown to be essential. Delivering real-time information requires reliable, low-latency connections, which can be achieved with IP-based systems, though cybersecurity remains a concern. Canada's efforts reflect a coordinated, multi-agency approach to implementing S-100 standards and demonstrate a strong commitment to enhancing maritime safety, operational efficiency, and environmental protection through digital transformation.

5. SESSION 4 – RISING TO THE CHALLENGE OF EMERGING DEMANDS OF DIGITALISATION OF WATERWAYS

This session was chaired by Taoufik El Bacha from Saab TransponderTech.

5.1 Rising to the challenge at Smart AtoNs operations, remote monitoring of AtoNs, vessel crowd monitoring of waterway – Jonas Lindberg, SPX Aids to Navigation

Jonas Lindberg, Senior Product Manager from SPX Aids to Navigation, focused on Enabling Digital Waterways: Smart Visual AtoNs and the harmonized IALA IoT Protocol.

This report explores how the adoption of modern communication technologies can significantly improve the safety, reliability, and availability of visual Aids to Navigation (AtoNs). The discussion is structured around four key areas: the evolution of technology, driving factors, a strategic path forward, and concluding reflections.

Over the past five decades, technology has dramatically transformed the maritime domain. Visual AtoNs have evolved from basic automatic lanterns to smart, connected systems capable of real-time data exchange. Advances in wireless communication, simulation, and AI have enabled faster, more efficient, and more reliable development. Today, compact IoT modules offer global connectivity, low power consumption, and seamless integration, making remote monitoring a standard feature rather than a costly addition.

Three main factors are shaping the next generation of visual AtoNs:

- Smart Devices: Modern electronics are smaller, more efficient, and capable of delivering advanced functions with minimal energy use. Visual AtoNs can now act as smart sensors, reporting not only their status but also position, environmental conditions, and potential collisions.
- Communication Technologies: Radio technologies have matured significantly, offering future-proof global solutions with sufficient range and data capacity for continuous AtoN monitoring.
- Standardization and Harmonization: While some stakeholders have built proprietary systems, a lack of standardization has resulted in fragmented and incompatible projects. Harmonization is essential for large-scale implementation and cross-vendor interoperability.

To fully realize the benefits of connected visual AtoNs, smart technologies, robust communications, and standardized protocols must be brought together. This will allow for a scalable, interoperable network of AtoNs that can be deployed across diverse environments and by multiple manufacturers.

A significant step forward is the recent introduction of the IALA Harmonized IoT Protocol. This protocol:

- Defines communication methods for smart AtoNs;
- Standardizes device onboarding;
- Ensures secure data exchange across systems.

It lays the foundation for a unified digital ecosystem, enabling collaboration across manufacturers, authorities, and users. By adopting this protocol, the AtoN community can transition from isolated systems to a connected, future-proof network.

The maritime world is entering a new era of smart, connected visual AtoNs. The key to unlocking this potential lies in collaboration and standardization. The new IALA IoT protocol offers a path toward scalable, secure, and interoperable deployment. As the community embraces these advancements, we have a real opportunity to significantly improve maritime safety and operational efficiency—creating digital waterways that are smarter, safer, and ready for the future.

5.2 Rising to the challenge for a whole inland waterway on the example of the Danube river/waterway – Gergerly Mezo, RSOE

Gergerly Mezo presented on the inland waterway navigation on the Danube and shared valuable insights into the ongoing digitalisation efforts in the region. The Danube, spanning 400 kilometers within their jurisdiction, serves as a vital international waterway that, while lacking a maritime sea, shares many challenges and technologies with the broader maritime sector.

The speaker emphasized the commonalities between inland and maritime navigation, particularly the use of AIS technology adapted for inland waterways. They highlighted the significance of digitalization in improving navigation safety, efficiency, and integration with other transport modes.

Their organization provides River Information Services (RIS) in compliance with European Union directives, offering charts, AIS data, electronic reporting, and notices to skippers. Their RIS Centre operates 24/7, equipped with radars, cameras, and sensors, similar to maritime VTS centers, but focused on inland navigation along the Danube, which flows through major urban areas such as Budapest.

The speaker underscored the strategic importance of inland waterway transport as a green and efficient mode that must be seamlessly connected with maritime, rail, and road transport. Digitalization efforts are driven by the need for smart infrastructure maintenance, smart vessels, and multimodal connectivity. A significant driver for smart vessel technology is the shortage of qualified crew, prompting developments in remote control and automation.

Security concerns, especially in light of geopolitical tensions affecting the region, have elevated the importance of cybersecurity and reliable positioning systems. The speaker noted the need for integrated smart transport and logistics solutions, supported by harmonized standards from organizations such as UNECE, the Central Commission for Navigation on the Rhine (CCNR), the Danube Commission, and European standardization bodies.

A key innovation presented was the use of IoT-based LoRa communication for buoy monitoring and barge tracking along the Danube. This solution proved more cost-effective than traditional AIS tracking, allowing for real-time monitoring and synthetic AIS signals for navigational visibility. Pilots involving LoRa trackers for non-powered barges are underway, supported by European Union projects.

Additionally, the speaker described a joint electronic ship reporting system currently used by eight Danube countries, enabling vessels to submit voyage and cargo data once for acceptance across all member countries. This platform simplifies reporting processes and is being considered for expansion to neighbouring countries.

The presentation also included advances in high-accuracy positioning, with collaborative projects utilising the European EGNOS system to enhance navigation safety during port manoeuvres, bridge passages, and accident investigations. Finally, the development of the

Inland Multi-System Shipborne Radionavigation Receiver (I-MSR) was highlighted as a future direction to support smart and automated inland navigation.

In conclusion, the speaker conveyed that while inland waterways operate on a smaller scale than maritime systems, the challenges and technological opportunities are closely aligned. The integration of advanced digital services, harmonization of standards, and collaboration between inland and maritime sectors are essential for the future of efficient and safe inland navigation.

5.3 Rising to the challenge from the operation of the SDC stack's connectivity layers themselves: part 1 – Technical Services and their demands (introducing relevant IALA Guidelines) – Hanjin Lee, KRISO and Thomas Christensen, DMC International; part 2 – Maritime Connectivity Platform's including the Maritime Service Registries' demands (introducing relevant IALA Guidelines) – Jin Hyoung Park, Aivenautics

This session focused on addressing the increasing technical demands of waterway digitalization, particularly through the lens of the S-100-based digital infrastructure known as the SDC (Services - Data - Connectivity) stack (compare introduction in Session 1, last presentation). The discussion was framed across three presentations, each exploring a key component of maritime digital connectivity and service integration.

Thomas Christensen from DMC, opened with an overview of the technical services required to support emerging digital maritime operations. He emphasized the critical role of the connectivity layers within the SDC stack in enabling reliable, interoperable maritime data exchange.

Thomas Christensen of DMC set the stage for a technical exploration of the growing demands of digitalisation in maritime waterways. He introduced the concept of technical services as a foundational element in the development of the SDC stack – a framework essential for enabling machine-to-machine communication in e-navigation systems.

Thomas Christensen emphasized that technical services support the broader maritime digitalisation process by providing the structured, standardized exchange of data between systems. This work aligns with the IMO's e-navigation strategy, particularly as formalized in IMO Resolution MSC.467(101), which outlines both Maritime Service Descriptions and Technical Service Specifications, and explains their relationship to data models (such as S-100 Product Specifications).

Further expanding on the standards landscape, Christensen referenced IALA Guideline G1128, which defines three key levels of technical service specifications:

- Service Specification – A high-level, technology-neutral description linked to a reference data model.
- Service Design – A detailed implementation plan using specific technologies.
- Service Instance Description – Information about a real-world deployment of the service, including endpoints and coverage.

He also pointed to MSC.1/Circ.1610/Rev.1, which provides high-level use-case descriptions and identifies associated technical services. These services are built upon international standards such as IEC 63173-2 (SECOM), which defines IP-based service designs with a focus on secure, interoperable communication.

Finally, Christensen underscored the critical role of the Maritime Connectivity Platform (MCP), which provides the infrastructure for both secure authentication and identity management (via the Maritime Identity Registry, MIR) and service discovery (via the Maritime Service Registry, MSR). Both components are integral to the SECOM framework and essential for real-world implementation of interoperable maritime digital services.

His introduction provided a comprehensive technical context that framed the deeper dives in subsequent presentations, highlighting the need for harmonized standards, secure data exchange, and scalable infrastructure in the future of digital waterway operations.

Hanjin Lee from KRISO, continued with a detailed look at the growing demands on technical services as digitalization progresses. He highlighted challenges in system integration, latency, and service availability—particularly in ensuring that various digital layers remain synchronized and resilient under real-world maritime conditions.

In his presentation, Hanjin Lee introduced Korea's Smart Navigation Project as a case study to illustrate the practical implementation of technical services and the demands associated with maritime digitalisation. The project aimed to deliver seamless, integrated navigation services for vessels operating in Korean waters. It was based on the IHO S-100 data framework and various associated product specifications.

One of the key technical challenges addressed in the project was interoperability across different systems and nations. The need to manage communication protocols, data standards, and identity verification led to the adoption of the Maritime Connectivity Platform (MCP). Authentication was implemented using X.509 certificates, administered by Korea's Ministry of Oceans and Fisheries.

To advance global compatibility, Korea is launching a new initiative to test internationally aligned services between Korea and Europe using a real-world testbed for demonstration voyages. These trials aim to validate SECOM, MCP elements, and secure identity services under live conditions.

A new legal framework is being established, with full implementation of the SECOM-based exchange functionality expected by 2029. This complements ongoing standardisation efforts by IHO, IALA, and IEC, with continued development of service-specific guidelines such as IALA G1128.

Korea's Smart Navigation experience highlights the practical integration of evolving standards into national systems while paving the way for international interoperability and harmonised maritime digital services. Looking ahead, Korea is launching a new initiative to develop and test globally compatible services through international demonstration voyages between Korea and Europe. These trials will serve to validate MCP, SECOM protocols, and identity services in a real-world setting. A new regulatory framework is also being prepared, with full deployment of SECOM-based information exchange expected by 2029.

In conclusion, the Smart Navigation Project highlights Korea's commitment to advancing maritime digitalisation by integrating emerging global standards while adapting them to local needs. This experience not only supports national development but also contributes significantly to the goal of international interoperability in maritime services.

Jin Park from AIVeNautics, concluded the session by addressing the Maritime Connectivity Platform (MCP) and its role in managing Maritime Service Registries. He emphasized the importance of standardized and discoverable digital maritime services, noting that registry demands are increasing as more services are integrated into global digital infrastructure. His presentation stressed the need for robust, scalable solutions to maintain service reliability and trust across stakeholders.

The presentation explored the evolving connectivity layers within maritime digitalisation, focusing on the relationship between the IEEE 11073 SDC standard and the Maritime Connectivity Platform (MCP). The speaker highlighted how the SDC standard enables secure, real-time, bidirectional communication between maritime systems, ensuring dynamic interoperability and reducing system integration errors.

SDC provides a layered architecture for device communication, supporting transport protocols like gRPC and MDPWS. These can be mapped to MCP components—specifically the Maritime Identity Registry (MIR), Maritime Messaging Service (MMS), and Maritime Service Registry (MSR). These layers support secure identity management, resilient message transfer, and service discoverability across maritime domains.

MIR ensures trusted identities through PKI and MRN-based authentication. MMS provides store-and-forward messaging for reliable data transfer, even in low-bandwidth conditions. MSR enables local and global service discovery, allowing ships to access navigation warnings and other critical services based on location and operational need.

The presentation concluded with a demonstration setup showing interaction between MCP components and SECOM-based services, validating real-world functionality. Overall, the framework promises secure, scalable, and interoperable maritime communication aligned with international standards.

Together, the session underscored the urgent need for harmonized standards, scalable architecture, and global cooperation.

6. SESSION 5 – RISING TO THE CHALLENGES AND OPPORTUNITIES OF UNDERSTANDING THE IMT FAMILY IN THE CONTEXT OF ITS APPLICATION TO MARITIME SHORE INFRASTRUCTURE

This session was chaired by Olli Soininen, Head of Programs from Fintraffic.

6.1 Reflecting on IMO's state of work on the 'guidance' for the 'unified global framework' and of the role of IMT family for IP-based connectivity therein – Julius Moeller (AMSA)

Julius Moeller, Senior Advisor Digitalisation and Communications from AMSA, represented the ongoing work supporting the implementation of the S-100 framework, focusing on real-time data exchange, the limitations of existing maritime data infrastructure, and how emerging connectivity solutions—particularly IP-based technologies—can bridge the gap. It also discusses the role of IMT (International Mobile Telecommunications) in supporting future maritime communication needs.

The presentation begins with a familiar analogy: while we regularly stream high-definition movies via smartphones using the internet—even while traveling—real-time streaming of navigational data at sea remains a challenge. Yet, from a technological standpoint, this challenge is not insurmountable. The necessary infrastructure already exists; the issue lies in how data is currently managed, distributed, and regulated in the maritime sector.

One of the key focal points is the difference in data requirements among S-100 products. Not all need to be updated in real-time. For example, electronic navigation charts (ENCs) are typically updated on a weekly basis, much like receiving DVDs instead of streaming content. This means that for certain products, high-speed internet at sea is not critical. However, other products—such as S-124, which covers navigational warnings—do require rapid, possibly real-time updates. For these, a robust, modern data service is essential, similar to the role Netflix plays in the entertainment industry.

The current navigational data distribution architecture is built around the S-57 ENC format and delivered through Electronic Chart Display and Information Systems (ECDIS), typically using shore-to-ship transmission via RENCs and commercial resellers. This model is not designed for real-time data, nor does it support bidirectional communication, limiting the ability for ships to send data back to shore. It also excludes non-hydrographic stakeholders who are now involved in S-100 data production, such as Maritime Safety Authorities and AtoN (Aids to Navigation) providers.

A real-world use case illustrating these challenges is S-124. This product involves distributing time-critical navigational warnings to vessels. These are currently shared using legacy systems like GMDSS and NAVTEX, which are not compatible with S-100 datasets. Additionally, the existing ENC infrastructure is too slow and rigid to meet the real-time demands of S-124. There is currently no unified framework for harmonizing the delivery of S-124 in real-time across different systems.

Recent developments, however, are promising. A 2023 survey revealed that over 85% of the global merchant fleet already has internet connectivity, and that number is now estimated to be between 85% and 90% or higher. In response, the IMO has agreed to develop an IP-based global connectivity framework, beginning with decisions made at MSC 109 and formalized into action at NCSR 12. The aim is to establish a reliable, secure, and scalable infrastructure to support S-100 ECDIS and related services.

To summarize, several key criteria have been identified for this new IMO Global Connectivity Framework. It must enable real-time data exchange, such as for S-124, and support bidirectional communication—for example, allowing shore authorities to receive data sets like S-212 from ships. The framework must comply with existing maritime regulations, including the ECDIS performance standards. Importantly, it should incorporate new S-100 stakeholders beyond hydrographic offices, and adopt open standards to promote fast adoption, cost-effective implementation, and interoperability. Security and reliability must be built-in, supporting fault-tolerant architectures with fallback solutions.

The decision to adopt IP-based connectivity is foundational to this approach. IP offers the flexibility to work across different types of networks—cellular, satellite, or hybrid—without being tied to specific service providers, unlike GMDSS. This enables the use of goal-based architectures with redundancy and high availability, while continuing to use GMDSS as a fallback until the new system is proven stable.

Regarding the role of IMT, the presentation clarifies that there is no conflict between IP and IMT. Rather, IP is a general-purpose protocol used for internet and data connectivity, while IMT represents a set of optimized technologies—such as 4G and 5G—designed for high-density, mobile, and low-latency environments. IMT networks typically use IP at their core, meaning IMT is effectively one specific category of IP-based technology. IMT also brings additional features such as well-defined Quality of Service (QoS) parameters and support for mission-critical services, making it especially relevant in complex maritime environments like ports or coastal areas.

As the maritime industry transitions toward next-generation navigation under the S-100 framework, a scalable, reliable, and inclusive data distribution system is critical. By adopting an IP-based connectivity framework, leveraging technologies like IMT, and incorporating new stakeholders, the sector can move beyond the limitations of legacy systems. This will enable not just real-time data exchange but also a more dynamic, secure, and resilient maritime information ecosystem.

6.2 A guide to the IMT family as represented in ITU documents from within the maritime domain – Jan-Hendrik Oltmann, WSV

Jan-Hendrik Oltmann explained that the International Mobile Telecommunications (IMT) family, as defined by the International Telecommunication Union (ITU), comprises several generations of mobile communication technologies. These include IMT-2000 (3G), IMT-Advanced (4G), IMT-2020 (5G), and the forward-looking IMT-2030+ (6G and beyond). The evolution of these systems is designed to support the increasing demand for higher data rates, improved reliability, lower latency, and greater device density. IMT-2020, or 5G, currently serves as the foundation for ongoing deployments and is of particular relevance to emerging maritime applications.

ITU outlines three primary promises for IMT-2020, which are particularly applicable to the maritime sector. Enhanced Mobile Broadband (eMBB) facilitates high-speed data transfer, enabling operations such as UHD video streaming, cloud-based work environments, and smart infrastructure both onshore and offshore. Massive Machine-Type Communications (mMTC) supports the deployment of dense sensor networks along waterways and on vessels, enabling real-time data transmission, as demonstrated by applications like direct vessel-to-waterway sensors. Ultra-Reliable and Low Latency Communications (URLLC) is crucial for mission-critical maritime scenarios, including remotely controlled ships, virtual vessel traffic services (VTS), smart aids to navigation (AtoNs), positioning and timing provision (PNT), and autonomous vessel operations.

These capabilities are designed to enhance communication and automation in both vessel-to-shore and vessel-to-waterway interactions. The flexible deployment models of IMT-2020, described in ITU-R Recommendation M.2101, accommodate various environmental conditions. Macro deployment scenarios are well-suited for extensive coastal and offshore coverage, using base stations on towers or rooftops. Micro deployments, on the other hand, focus on smaller areas like ship interiors, ports, or harbor facilities, where antennas may be mounted on poles or integrated into indoor systems.

The detailed specifications for terrestrial radio interfaces under IMT-2020 are covered in ITU-R Recommendation M.2150-1 (2022). These specifications ensure that various communication technologies can operate seamlessly within a single standardized framework, promoting interoperability across maritime and terrestrial domains.

The IMT system architecture also supports heterogeneous radio access through a flexible approach known as HetNet (Heterogeneous Radio Access Network). This architecture incorporates multiple radio access technologies (RATs) within a unified Radio Access Network (RAN) and Core Network (CN). As a result, maritime networks can integrate diverse technologies—ranging from conventional LTE or 5G to maritime-specialized communication systems—over various physical links. This flexibility supports both voice and non-voice applications onboard vessels, at port facilities, and in offshore operations.

IMT-2020 is not intended to replace existing maritime communication systems but to complement and extend them. It can be integrated with maritime specialties such as AIS/VDES, GMDSS (modernized), NAVTEX/NAVDAT, MF-DGNSS, and VHF systems. These existing systems can coexist with IMT-based services, benefiting from the improved performance, interoperability, and digital modernization that the IMT framework brings. This integration spans both terrestrial and satellite domains, ensuring global connectivity for vessels.

The ITU's timeline for IMT-2020 development, shown in Recommendation M.2083, highlights a phased approach. Initial vision and requirements were established around 2012, followed by standard development and enhancement activities through the second half of the decade. System deployment began around 2020 and continues today, supported by spectrum implementation processes initiated at major regulatory conferences like WRC-15 and WRC-19. The deployment of IMT-2020 systems is expected to continue evolving, with future enhancements paving the way for IMT-2030 and beyond.

In conclusion, the IMT family, especially IMT-2020, provides a robust and flexible framework for advancing maritime communications. ITU's recommendations offer detailed technical guidance and architectural models that support a wide range of maritime applications, from broadband connectivity and sensor integration to autonomous vessel navigation and mission-critical communications. As the maritime sector moves toward digital transformation, the IMT framework will play a vital role in ensuring reliable, scalable, and interoperable communication across vessels, ports, and waterways.

6.3 The relevance of common generic architecture(s) for shore infrastructures for IMO's aspirations – Michele Fiorini, Leonardo

Michele Fiorini focused on e-Navigation as a strategic initiative to improve maritime safety and efficiency by harmonizing the collection, exchange, and analysis of marine information onboard and ashore. It relies on three pillars: systems engineering for harmonized user requirements, the IALA e-Navigation stack for architectural analysis, and alignment with the IHO Registry to ensure compatibility.

Successful implementation requires viewing shipboard systems, shore systems, communications, and data structures as a whole. The CMDS provides a conceptual model for harmonizing data exchange, while distinguishing between data modelling (conceptual integrity) and data encoding (machine-readable formats) ensures reliable information flows. Standardized technical interfaces are essential for interoperability.

The IALA e-Navigation stack follows a layered architecture:

- ISHR: harmonized stakeholder requirements.
- UOPS: unified operational presentation for shore-based operators.
- IHDM: harmonized data model to ensure consistency.
- MDEF: application-level encoding format.
- CSSA: common shore-based architecture enabling service interoperability.

Operational services (e.g., VTS, pilotage, SAR) are supported by technical services (systems, data models, communications). IMT systems serve as the physical layer supporting Maritime Service Portfolios.

S-100-based standards and the IHO GI Registry ensure global consistency and prevent conflicts in overlapping data domains.

Fiorini pointed to the fact that these concepts have been incorporated in valid IALA documentation and gave the respective references. He concluded that e-Navigation requires a harmonized, system-engineering-driven approach, with the IALA stack ensuring traceability from user needs to technical implementation. By integrating data models, technical services, and operational procedures, e-Navigation can deliver global interoperability, safety, and efficiency.

6.4 The potential integration of 5G satellite network in the maritime domain by electronically steered antenna – demonstration and outlook – Chen Binbin, Singapore University of Technology and Design (SUTD); Muneaki Ogawa, Principal Architect, Team Manager of Universal NTN Strategy (JSAT); Johnson Tay, Head of Business Development (VIAVI)

The presenting team is formed by the Singapore University of Technology and Design (SUTD) through its Future Communications Programme (FCP), together with SKY Perfect JSAT and VIAVI Solutions. This partnership brings together academic expertise, satellite operators, and technology providers to explore the convergence of 5G and satellite networks for maritime communications. The maritime industry has always relied on robust connectivity to ensure safety, efficiency, and competitiveness. However, traditional terrestrial systems face clear limitations once vessels move beyond coastal areas, leaving ships dependent on satellite links with limited integration into next-generation 5G infrastructures. The collaboration therefore addresses a critical challenge: how to extend the benefits of 5G into the maritime and oceanic domain by combining terrestrial and non-terrestrial networks into a seamless and resilient communications framework.

The convergence of 5G and satellite networks is happening on multiple levels. First, it represents the convergence of two industries—satellite communications and telecommunications—bringing together their complementary strengths. Second, there is a convergence of user terminals, with innovations in chipsets, communication modules, and electronically steerable antennas enabling flexible and adaptive connectivity. Third, convergence extends across access networks, as multi-orbit satellite systems, High Altitude Platform Stations, and UAVs are integrated with terrestrial networks to form a hybrid and layered communications environment. Finally, the convergence includes the core networks and systems themselves, where cloudified network functions and service-based architectures create a unified, agile, and scalable backbone for future global communications.

For the maritime sector, this convergence carries particular significance. It enables entirely new use cases that were not possible before, many of which are already being explored in Singapore with the support of the Maritime & Port Authority of Singapore and the Infocomm-Media Development Authority. Examples include Remote Assisted Pilotage Advisory to guide vessels safely in complex waterways, Maritime Autonomous Surface Ships that rely on resilient and high-bandwidth connectivity, drone-based ship-to-ship and shore delivery services, and telemedicine solutions that bring healthcare expertise to crews at sea. These applications are made feasible through economies of scale, driven by the global momentum behind open, fast-evolving standards that ensure interoperability and rapid deployment of new technologies.

The vision behind this effort is to provide stable, high-capacity, and low-latency communication for vessels at sea, offshore platforms, and port operations. By using satellite-based Non-Terrestrial Networks together with advanced 5G standards, the project allows services once confined to land-based infrastructures to reach far into international waters. This opens up opportunities for real-time monitoring of ships, enhanced safety systems, digitalization of port logistics, and more sustainable shipping practices through optimized routing and fuel management. It also plays an important role in strengthening resilience, ensuring that maritime communications remain operational even when terrestrial systems face disruption. For Singapore, as a global maritime hub, this initiative directly supports strategic national priorities. It aligns with the dual goals of capturing economic opportunities in high-value technology sectors and safeguarding national resiliency through advanced, secure communication systems.

The collaboration was highlighted in a live demonstration at the Osaka World Expo, where an end-to-end 5G New Radio Non-Terrestrial Network connectivity trial was conducted over a GEO satellite in the Singapore Pavilion in May 2025. This demonstration showcased the technical feasibility of real-time 5G satellite integration for maritime applications, making it clear how the concept can move from research to practice and eventually to large-scale deployment.

The Singapore University of Technology and Design stands at the center of this initiative. As an autonomous public university, SUTD is recognized globally for excellence in telecommunications, security, and advanced engineering. It is also the world’s first Design AI University, placing design thinking and artificial intelligence at the core of its approach. In 2021, SUTD was chosen by the National Research Foundation and the Infocomm-Media Development Authority to host Singapore’s national Future Communications R&D Programme. This programme began with an initial investment of around US$50 million and has since grown into a national platform to explore the future of communications technologies, including 5G, 6G, and their extensions into space and maritime domains. From its inception, the programme has engaged closely with the Maritime & Port Authority of Singapore, ensuring that research directions and demonstrations are aligned with industry needs and government strategies. The engagement reflects two key drivers: first, the pursuit of economic capture by developing technologies where Singapore has the capacity to compete and succeed globally; second, the strengthening of national resiliency by ensuring reliable and secure communication infrastructures for critical sectors like maritime.

Looking ahead, the outlook for this initiative is promising. By continuing to focus on maritime communications, an area where Singapore has natural strengths and significant international influence, the collaboration between SUTD, SKY Perfect JSAT, and VIAVI Solutions is set to play a defining role in shaping the future of global maritime connectivity. The work already accomplished demonstrates that convergence of 5G and satellite is not only possible but increasingly essential, and Singapore is well-positioned to lead this transformation from both a technological and strategic standpoint.

7. SESSION 6 – RISING TO THE CHALLENGES AND OPPORTUNITIES OF UNDERSTANDING IMT 'HANDS ON' AT SELF-GOVERNED IMT CAMPUS NETWORKS

This session was chaired by Lisa Underberg, representative from the Institute of Automation Technology (ifak), Germany.

Session 6 focused on the complex path from the promise of IMT technologies to their actual deployment in industrial and maritime contexts. The chair, Lisa Underberg of the Institute for Automation and Communication (ifak e.V.), guided the discussion through four presentations that moved from a critique of 5G hype, through lessons from industrial applications, to practical steps for implementation, and finally to an informed outlook on IMT-2030/6G. Together, the contributions highlighted the importance of requirement-driven design, systematic testing, and early stakeholder engagement for both industrial and maritime communication systems.

7.1 IMT-2020/5G – a victim of its own hype? How to correctly interpret and apply the 'key performance triangle' – in general and when applied to the wet domain – Lisa Underberg, ifak

Lisa Underberg opened the session by critically examining how IMT-2020/5G has often been overpromised and misunderstood, leading to frustration among stakeholders who expected "one technology to solve everything." She explained that the so-called "key performance triangle"—comprising enhanced mobile broadband (eMBB), massive machine-type communication (mMTC), and ultra-reliable low-latency communication (URLLC)—should not be misinterpreted as a simultaneous guarantee of all features in a single system. Instead, just as different vehicles serve different transport needs (trucks for capacity, buses for passengers, cars for speed), 5G applications must prioritise which part of the triangle is most relevant.

Applied to the maritime or "wet" domain, this perspective is especially crucial. A remote pilotage advisory service may require ultra-low latency and reliability, while on-board video surveillance for safety relies on broadband throughput. Expecting both at once without trade-offs leads to unmet expectations. By drawing attention to this reality, Lisa encouraged stakeholders to approach 5G with realistic application-specific requirements rather than abstract promises.

7.2 Real IMT-2020/5G applications at Industry 4.0 - Learning from digitalisation at industry regarding communications – Sarah Willmann and Lisa Underberg

The second presentation shifted focus to real industrial applications, where Industry 4.0 provides rich lessons for maritime communications. Sarah Willmann and Lisa Underberg shared experiences from private IMT campus networks, which operate independently from public commercial operators. Such networks allow companies to tailor configurations to their specific production environments, addressing both performance and security needs.

Use cases from factories illustrated how 5G connectivity supports machine vision, automated guided vehicles, wireless sensors, and augmented reality applications for maintenance staff. These deployments, however, also exposed challenges: incomplete device readiness, high power consumption, and limited interoperability across vendors. Through systematic requirement specifications, industrial actors were able to overcome many of these obstacles by clearly defining expected performance, schedules, and communication procedures during commissioning.

For maritime stakeholders, the lessons are directly relevant. Ports, shipping companies, and lighthouse authorities face similar requirements for automation, real-time monitoring, and resilient communications. By learning from the digitalisation experience of Industry 4.0, maritime actors can avoid repeating mistakes and accelerate the uptake of IMT-2020/5G in areas such as port logistics, vessel traffic management, and offshore platform operations.

7.3 IMT-2020/5G introduction beyond the buzz words – how to make high-profile radio communications happen – potentially also for AtoN administrations – Sarah Willmann, ifak

Sarah Willmann's second presentation addressed the practical steps required to move beyond slogans and marketing into working radio communication systems. She emphasized that while IMT standards provide the framework, actual deployment depends on systematic testing and validation of devices, networks, and environments. The white paper from 5G ACIA was introduced to illustrate the different types of testing that are potentially of interest to end users: demonstration, interoperability, conformance, certification, performance measurement, and failure diagnosis.

For administrations responsible for Aids to Navigation (AtoN), the message is particularly relevant. Navigational safety depends on communication systems that are resilient, standardized, and thoroughly validated. Willmann described how realistic environments must be considered during testing—metallic ship structures, interference from radars, weather conditions at sea—so that performance metrics such as latency, reliability, and coverage are assessed under conditions that reflect operational reality.

She also stressed that simulation alone is not sufficient, as it oversimplifies the complex maritime environment. Instead, live measurement campaigns and, potentially, updates of hard- and software are essential. The example of update from 4G+ to 5G demonstrated that even with technical feasibility, expert knowledge and cross-disciplinary teams remain crucial for achieving reliable deployment.

For maritime administrations, adopting such rigorous approaches ensures that IMT-2020/5G integration is not just a theoretical vision but a dependable operational tool.

7.4 IMT-2030/6G – a practically informed outlook on proposed capabilities and standardization – Lisa Underberg, ifak

The final presentation by Lisa Underberg looked ahead to IMT-2030/6G, a technology still in its formative stages but already attracting global attention. Desired capabilities include the integration of non-terrestrial networks such as satellites, High Altitude Platform Stations (HAPS), and UAVs; joint communication and sensing (JCAS) functions that combine data transfer with environmental awareness; improved positioning accuracy for navigation and logistics; and spectrum-efficient coexistence to enable diverse systems to operate in harmony.

Underberg stressed that 6G is not a distant future to wait for passively. Instead, stakeholders in both industry and the maritime sector must begin now to articulate their requirements, ensuring that they are incorporated into the evolving standards. Platforms such as 5G ACIA demonstrate how industry alliances can influence 3GPP and IEC working groups, ensuring that theoretical capabilities are matched with real operational needs. For maritime actors, early engagement is vital if features such as remote pilotage, autonomous vessels, or drone-based logistics are to be supported in global standards.

The presentation concluded that the success of IMT-2030/6G will depend not only on technological breakthroughs but also on the ability of diverse stakeholders—industry, academia, regulators, and international organizations—to cooperate in shaping requirements, testing methodologies, and certification schemes.

Session 6 highlighted that while IMT-2020/5G has brought significant advances, its success depends on careful requirement specification, rigorous testing, and realistic expectation management. Industry 4.0 demonstrates both the potential and the pitfalls of deploying advanced communication systems, offering valuable lessons for the maritime sector. For AtoN administrations and maritime authorities, the need for validated, resilient systems cannot be overstated, especially given the safety-critical nature of navigation services. Finally, looking toward IMT-2030/6G, proactive participation in standardization processes is essential to ensure that maritime needs are addressed from the outset.

In sum, the session underscored that the journey from standardization to application is long, complex, and demanding, but with the right approach and alliances, IMT technologies can unlock transformative opportunities for both industry and maritime domains.

8. SESSION 7 – RISING TO THE CHALLENGES AND OPPORTUNITIES OF AN EVEN MORE POWERFUL FUTURE IMT FAMILY MEMBER, NAMELY "IMT-2030 AND BEYOND" (AKA 6G)

This session was chaired by Dennis Khoo, Chief Technology Officer, Director (Maritime Systems and Technology) in the Maritime and Port Authority of Singapore (MPA).

8.1 Introducing and reflecting on ITU's performance indicators for IMT-2030/6G – Jan-Hendrik Oltmann, WSV

Jan-Hendrik Oltmann explained that ITU published Recommendation ITU-R M.2160 in November 2023, setting out the framework and objectives for "IMT-2030 and beyond." Building on the foundations of IMT-2020/5G, this new vision expands both the range of usage scenarios and the set of performance indicators. While IMT-2020 revolved around three core scenarios—enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC), and massive machine-type communications (mMTC)—IMT-2030 adds new dimensions. These include integrated sensing and communication, artificial intelligence-assisted communication, ubiquitous coverage with strong integration of satellite and non-terrestrial networks, and support for sustainable development goals through energy efficiency, resilience, and connecting the unconnected.

Performance indicators reflect both enhancement of existing 5G capabilities and the introduction of genuinely new ones. Reliability is expected to increase by one to two orders of magnitude, latency to drop further below 1 ms, mobility support to extend up to 1,000 km/h for e.g. aviation scenarios, and device density to scale up to 100 million devices per km^2. Positioning accuracy, which in maritime today is typically on the order of 100 (coastal waters) to 10 (approaches) metres, is envisaged to reach one to ten centimetres at IMT-2030. This could have profound implications for navigation, vessel traffic management, and the convergence of communication and positioning domains.

From a maritime perspective, the expansion from "massive machine communication" to "massive entity communication" highlights the inclusion of autonomous ships, drones, remote pilotage advisory, and other maritime autonomous systems. Integrating terrestrial and satellite coverage ensures ubiquitous connectivity at sea, while enhanced resilience and AI-driven optimization open possibilities for real-time decision support, predictive maintenance, and telemedicine.

The ITU also emphasizes broader societal objectives. Sustainability, security, resilience, and intelligence are explicitly embedded in the framework, linking technical developments with global priorities such as the UN Sustainable Development Goals. By ensuring seamless global standards, the vision of IMT-2030 aims to create economies of scale while avoiding fragmentation between industries such as SatCom and telecoms.

Timelines are ambitious but realistic. By 2030, the first implementations of IMT-2030 are expected, with subsequent maturity and wider adoption after 2035. For the maritime domain, this implies that stakeholders—such as IALA, IMO, or coastal state and port authorities—should begin engaging with these developments now rather than waiting for full deployment. Early experimentation with 5G/6G hybrid networks, campus testbeds, and integration of satellite and terrestrial systems will be key to ensuring the maritime community is positioned to benefit from these advances.

In conclusion, IMT-2030 is not merely an incremental improvement over 5G. It represents a broader rethinking of what global communications can achieve by merging connectivity, sensing, AI, and resilience. For the maritime sector, it offers a pathway to safer, more efficient, and more sustainable operations. The challenge is to translate ITU's high-level vision into concrete applications and requirements that address the realities of the sea.

8.2 The dawn of a new era for Resilient PNT by using IMT (Signals-of-opportunity for R-Mode and by built-in Positioning capability) – Ronald Raulefs, German Aerospace Centre (DLR)

Ronald Raulefs presented that modern shipping is critically dependent on Global Navigation Satellite Systems (GNSS), particularly GPS, for both positioning and timing. These signals underpin a wide range of vessel systems, including ECDIS, AIS, radar synchronization, and navigation clocks. However, ships are increasingly exposed to GNSS interference, whether through unintentional disruption, deliberate jamming, or spoofing. This vulnerability poses serious risks, including collisions, groundings, and disruption of operational processes. Recent conflicts and documented interference incidents highlight the urgent need for resilient alternatives.

One promising solution is Ranging Mode (R-Mode), a terrestrial positioning system that transmits time-synchronized ranging signals using existing maritime radio infrastructure. R-Mode employs multilateration to determine position and can operate on medium frequency (MF) signals as well as on VHF Data Exchange System (VDES) channels. VDES is particularly attractive because it has global spectrum allocation, provides higher bandwidth (100 kHz versus 25 kHz in AIS), and covers coastal and harbor areas. Integrating navigation functions into VDE-TER allows for authentication, additional navigation data, and the possibility of building a standardized, resilient positioning layer inside maritime communications.

The security problem extends beyond GNSS dependency. For example, AIS messages can be transmitted with false identities or positions, and today there is no built-in mechanism to authenticate them. Introducing ranging signals and authentication sequences into maritime communication systems, following concepts already applied in LTE/5G (with Positioning Reference Signals), creates the foundation for trusted and resilient PNT. This aligns with broader developments in IMT-2030/6G, where convergence of communications, navigation, and sensing is a central theme.

Key requirements for maritime resilient PNT include ensuring sufficient range, accuracy, resistance to interference, and reliable load management in the network. Medium-frequency and satellite-based solutions complement terrestrial coverage, addressing geometry and dilution-of-precision issues. Together, these layers provide a hybrid, multi-technology architecture that ensures continuity even when GNSS signals are denied.

This topic is not theoretical. In Q1 2025, ESA launched the MAPS project, focusing on developing and validating multi-layer PNT systems for shipping. Trials and studies already show that bandwidth and authentication are decisive factors: the broader the bandwidth, the higher the positioning resolution, and authenticated signals are crucial to trust the source. Historical analogies, such as the Nelson Monument's time ball or the one o'clock gun in Edinburgh, remind us that timing signals have always required resilience and redundancy. Today, the maritime world faces the same challenge, but in a digital and globalized context.

In conclusion, resilient PNT for shipping must build on multiple layers: GNSS where available, terrestrial R-Mode via VDES and MF, and complementary satellite or non-terrestrial networks. By combining bandwidth, authentication, and hybrid architectures, the maritime sector can reduce its vulnerability and ensure safe and efficient operations at sea. The way forward lies in international cooperation, adoption of open standards, and leveraging ongoing projects such as ESA MAPS to bring resilience from concept to practice.

8.3 Mapping 'features' of IMT standardisation at 3GPP to maritime domain's use cases, taking into account upcoming 6G feature standardisation at 3GPP – Hyounhee Koo, SyncTechno

During her speech, Hyounhee Koo highlighted her extensive contributions to the development of public warning and maritime communication standards over the past decade. From 2016 to 2020, she served as Rapporteur for the 3GPP Enhanced Public Warning System, and from 2020 to 2022, she was Editor for the AWG work on public warning. Since 2023, she has chaired the AWG TG PPDR, focusing on public safety over IMT in the APAC region.

In the maritime sector, she was Rapporteur for 3GPP MARCOM between 2016 and 2018, where she successfully introduced maritime use cases into 3GPP standardization. From 2019 onward, she has represented 3GPP in liaison with IALA, collaborating to ensure maritime perspectives are reflected in IMT standards. Since 2023, she has contributed to the ITU-R report M.2527, introducing maritime usage over IMT-2020 and beyond, and she leads the IALA DTEC Task Group on Marine Aids to Navigation over IMT-2030.

Her current work focuses on defining use cases and service requirements for Marine Aids to Navigation, including regulatory aspects, to ensure maritime stakeholder needs are incorporated into IMT-2030 (beyond 5G) standardization. The categories under consideration include Maritime Buoyage Systems, Positioning, Navigation and Timing, Vessel Traffic Services, and digital maritime services such as Single Window Reporting.

She emphasized the importance of early maritime involvement in 6G standardization, noting that the period of 2024–2025 marks Stage 1, when use cases and requirements are established. Without timely contributions from the maritime domain, it would be difficult to reflect these needs in later stages of technical development.

She also discussed the processes of standardization within 3GPP and ITU-R, explaining how use cases, service requirements, and technical specifications are developed in stages and often require multiple releases to fully address all stakeholder needs. She highlighted that while many maritime use cases rely on radio interface specifications, enabling technologies and application-layer considerations are equally important for successful deployment.

In conclusion, she underscored the significance of global harmonization of communication technologies for maritime digitalization, the crucial role of policymakers in supporting standard adoption, and the need for continued maritime engagement to ensure safe, connected, and resilient operations at sea.

8.4 The work of 3GPP on IMT-2030/6G and the pros/cons of setting up an initiative group for the maritime domain at 3GPP ('Market Representation Partner – MRP') – Minsu Jeon, IALA and Jillian Carson-Jackson, JCJ Consulting

Minsu Jeon provided an overview of IALA's ongoing engagement with 3GPP and IMT-2030 (6G) standardization, emphasizing the growing importance of maritime-specific requirements in global communication standards.

Jillian Carson-Jackson highlighted the strategic question of whether IALA should become a 3GPP Market Representation Partner (MRP) to ensure that maritime needs are systematically integrated into standardization efforts.

She explained that connectivity alone is insufficient for maritime applications; IoT, sensor technologies, and big data are essential complements. SMART AtoN platforms equipped with sensors can collect weather, GNSS, AIS, and environmental data, and, when integrated with IMT-2030, support navigation safety, port efficiency, environmental monitoring, and public warning systems. IALA has maintained liaison with 3GPP since 2018, contributing maritime requirements on coverage and sidelink technologies, reflected in Releases 17 and 18, while also contributing to ITU-R studies on societal and industrial applications of IMT.

The speaker noted that while these contributions demonstrate that maritime requirements can be considered, the sector's influence remains limited without formal representation. She described ongoing efforts to develop an IALA guideline for integrating IMT-2030 into maritime operations, ensuring that legacy vessels and new IMT-enabled ships can operate safely and efficiently. Key use cases include Maritime Buoyage Systems, Positioning, Navigation and Timing, Vessel Traffic Services, and digital maritime services, including Public Warning Service (PWS).

She also addressed the 3GPP concept of "verticals," emphasizing that maritime is a distinct sector whose needs are underrepresented. Becoming a 3GPP MRP would allow IALA to provide market advice, ensure maritime requirements are reflected from the start of each release, and promote regulatory harmonization while supporting technology tailored to maritime safety. The presentation concluded by highlighting lessons from Korean LTE-Maritime trials and emphasizing the need to separate application-level requirements from technical implementation, enabling clearer, more effective standardization processes.

Minsu summarised that:

- IMT technologies are already being used in the maritime environment.
- To harness IMT the maritime industry needs to be fully aware of capabilities.
- IALA continues to develop guidance and use cases – focused on the use by IALA members (AtoN focus).
- There is opportunity for individual agencies to be active in IMT development through 3GPP.

- There are benefits for IALA to being more engaged in IMT developments – but these comes with challenges.

9. SESSION 8 – RISING TO THE CHALLENGES AND OPPORTUNITIES: HERE IS THE PLAN FOR IALA

9.1 Technical discussion forum

Omar Frits Eriksson, IALA Deputy Secretary-General, chaired the Technical discussion forum.

The forum explored the opportunities and challenges of advancing new digital communication technologies in the maritime and inland waterway domains.

A major focus was on mesh networking concepts. While buoys and shore-based infrastructure offer promising platforms for connectivity, participants agreed that vessels themselves are not an ideal foundation due to their mobility and the fragmented ownership of fleets. Large-scale adoption of ship-based mesh systems is expected to take at least 10–15 years unless driven by international regulation.

The discussion also highlighted the critical importance of harmonisation. Many regional or project-based initiatives risk creating a patchwork of incompatible systems. Frameworks such as the Maritime Connectivity Platform (MCP) and common IoT protocols like MQTT were identified as essential tools for achieving interoperability and safe, scalable data exchange.

Another theme was the rising demand for data. Emerging use cases, including streaming, remote monitoring, and video-based services, will dramatically increase bandwidth requirements. Participants emphasized the need for precise requirement definitions, mapped against recognized frameworks such as the "performance triangle," to ensure that standards evolve in line with real operational needs.

On the inland waterways, the forum revisited the long-term vision of autonomous and interconnected transport networks across Europe. Achieving this ambition requires continuous, reliable connectivity not only for vessels but for the entire logistics chain, linking ports, cargo systems, and hinterland transport.

Security and trust also featured strongly. The group recognized the need for a globally trusted digital identity framework to underpin secure ship-shore communications, with proposals drawing on established public key infrastructures and SIM-based authentication. The "last mile" challenge of extending secure connectivity into shipboard systems remains unresolved and will require close cooperation with equipment manufacturers.

Finally, the forum considered the future of IMT-based communications (5G/6G) in the maritime sector. While technically feasible and strategically important, deployment will be costly and depends on solid business cases, spectrum harmonisation through ITU processes, and sustained collaboration. Early adopters, such as Korea and Norway, provided valuable lessons in integrating IMT with navigation and sensor systems, with cybersecurity identified as a key concern.

The forum underlined that the success of next-generation maritime communication systems depends on three interdependent factors:

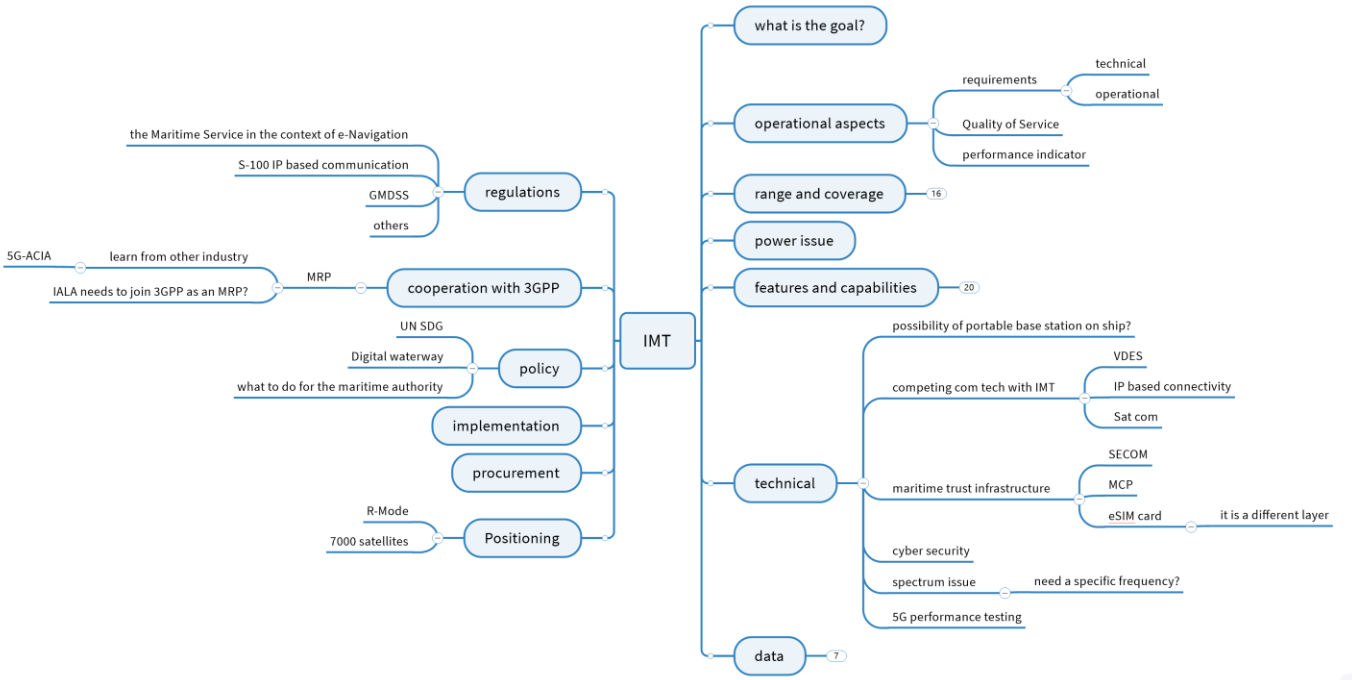
- Clear requirements linked to real operational and economic needs.
- Harmonisation and international collaboration to avoid fragmentation.
- Strong governance frameworks to ensure interoperability, security, and long-term sustainability.

With these in place, technologies such as mesh networking, autonomous inland transport, IMT communications, and harmonised IoT services can transform maritime connectivity into a more resilient and future-proof system.

9.2 Introducing the expected output: Draft IALA information document. Establishing working groups

Minsu Jeon, IALA Technical Director, introduced the ongoing work on the IALA Guideline on IMT-2030, outlining its objectives and scope. He explained that the guideline is intended to provide a structured reference for the application of IMT technologies in the maritime domain, with a focus on supporting future communication, navigation, and digitalisation needs.

He further highlighted the expected output of this work: a Draft IALA Information Document, which will serve as the initial deliverable for circulation, review, and input by participants before progressing the discussions in the Working groups.



During the workshop, Minsu raised the question to participants: Which IMT services, features, and functionalities are most urgent to adopt in the Marine AtoN domain? Examples included NTN coverage, sidelink, ultra-low latency, and advanced positioning.

The question was addressed through a Multimetr survey, the results of which reflected the participants' priorities and perspectives on near-term adoption. The findings were then discussed in plenary and subsequently proposed to the relevant Working Groups for further consideration and follow-up in the development of IMT applications for the maritime sector.

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Which IMT services, features, and funtionalities do you think are most urgent to adopt in the Marine AtoN domain?

The working groups were established, as introduced below:

WG1 – Maritime services, use cases, features	Chair – Wim Smets
WG2 – Technologies	Chair – Ronald Raulefs
WG3 – Procurement and implementation	Chair – Olli Soininen

10. SESSION 9 – SESSION 11 RISING TO THE CHALLENGES AND OPPORTUNITIES TOGETHER – IMT APPLICATION WGS SESSION

Sessions 9 to 11 were held under the theme "Rising to the challenges and opportunities … together!", focusing on the practical development of IMT applications in the maritime domain through the work of three dedicated working groups.

Working Group 1, chaired by Wim Smets, concentrated on maritime services, use cases, and required features. The group discussed how IMT could support safety-critical operations, enhance digital services, and enable new applications for both coastal and deep-sea operations.

Working Group 2, led by Ronald Raulefs, addressed the technological enablers. The discussions examined key aspects of IMT networks, including advanced positioning, non-terrestrial networks, and the integration of multi-orbit satellite systems. Emphasis was placed on identifying the most relevant functionalities for maritime and inland navigation.

Working Group 3, chaired by Olli Soininen, focused on procurement and implementation. The group reviewed potential deployment pathways, business models, and the challenges of aligning investment strategies with regulatory frameworks. Special attention was given to ensuring interoperability and long-term sustainability.

11. SESSION 12 – RISING TO THE CHALLENGES AND OPPORTUNITIES TOGETHER – IMT APPLICATION WGS SESSION: PRESENTATION OF THE RESULTS FROM WGS – WORKSHOP CONCLUSIONS

11.1 WG1 – Maritime services, use cases, features

This WG was chaired by Wim Smets, from the Agency for Maritime and Coastal Services, Belgium.

WG1 had good progress on the topic, and outputs are available in Annexe C.

11.2 WG2 – Technologies

WG2 was chaired by Ronald Raulefs, German Aerospace Centre (DLR).

The group revealed important insights, the outputs are available in Annex D.

11.3 WG3 – Procurement and implementation

This WG was chaired by Olli Soininen, Fintraffic.

The group achieved the constructive procedures for the procurement and implementation of the IMT technologies, the outputs are available in Annex E.

11.4 Findings and observations regarding the capacity building for future IMT family implementation in a 'globally unified framework' – Omar Eriksson, IALA Deputy Secretary-General

Omar Eriksson, IALA Deputy Secretary-General, presented key findings and observations on capacity building for the future implementation of the IMT family within a globally unified framework. He outlined IALA's new status as an Intergovernmental Organization (IGO) and highlighted the growth in membership, including different membership types and increasing engagement from member states. The presentation emphasized IALA's strategic vision and long-term goals, with a particular focus on harmonizing the Maritime Buoyage System (MBS) worldwide.

Omar also described the structured approach of IALA publications, designed to provide clear guidance and technical support to members. The governance framework, including the General Assembly, Council, PAP, and LAP, was explained as essential for coordinated decision-making. Additionally, the World-Wide Academy (WWA) was presented as a key tool to enlighten, educate, and engage the maritime community, fostering capacity building for emerging technologies and IMT deployment. Overall, the session highlighted IALA's commitment to global harmonization, structured guidance, and member-driven initiatives as critical enablers for the successful adoption of future IMT solutions.

11.5 Technical discussion forum

The technical discussion forum focused on the challenges and opportunities for implementing IMT technologies in the maritime domain. Participants highlighted the need to define use cases and requirements carefully, emphasizing that maritime-specific demands are limited in number but high in significance due to the sector's critical role in global trade. Collaboration with other industries and interest groups was identified as a practical approach to leverage existing solutions and accelerate implementation. Concerns were raised about the complexity of establishing communication channels and the lengthy process required to translate requirements into implemented features, stressing the importance of realistic expectations and prioritization.

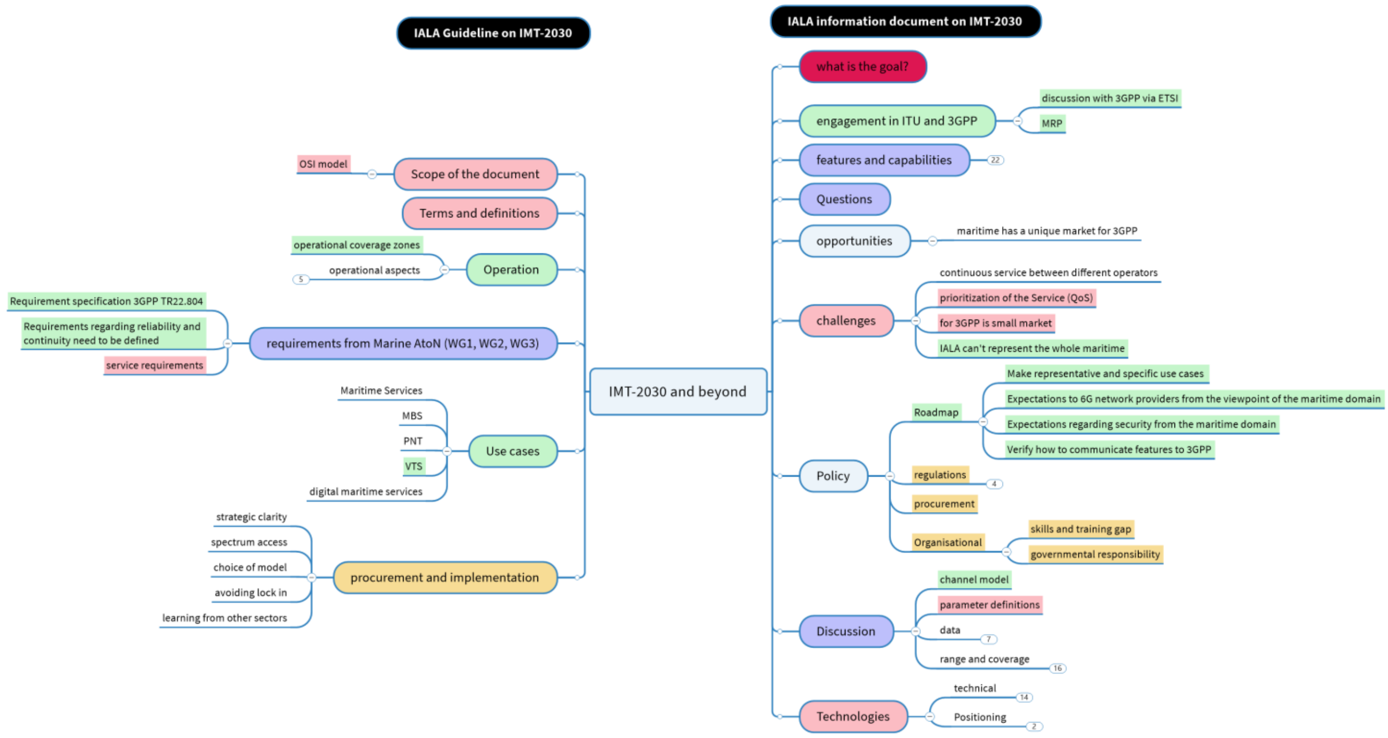
Omar Eriksson presented IALA's evolving status, now as an intergovernmental organization (IGO), and outlined membership types, strategic goals, and governance structures, including the General Assembly, Council, and technical committees. He highlighted IALA's focus on harmonizing marine navigation aids, providing technology-agnostic guidance through standards, recommendations, and guidelines, and supporting capacity building through the IALA Worldwide Academy. This Academy offers training, technical needs assessments, and local support, particularly in developing countries, fostering sustainable skills development and institutional capacity.

The forum concluded that successful IMT adoption requires harmonization across national and international frameworks, close collaboration among stakeholders, and continuous capacity-building initiatives. Emphasis was placed on engaging industry, member states, and training institutions to ensure that innovation in maritime communication delivers practical, safe, and globally aligned solutions.

11.6 The present state of the draft IALA information document on IMT application and other conclusions

Minsu Jeon warmly thanks all the participants, especially the WGs Chairs, for their hard work.

He proposed the structure of the IALA IMT document and explained that this would be the base of the future Guideline on IMT-2030.



Wim Smets asked about the future procedure and how the committees will continue to work on the documents.

Richard Asae raised the question of including the IMT-2030 task in the Work programme of all the committees.

The structure of the IALA guideline on IMT-2030 and IALA information document on IMT-2030 are available in the Annex F and Annex G.

11.7 Rising to the challenge, the way ahead

Omar Eriksson explained the challenges that IALA faces, particularly with the move to a new building.

He explained the progress of the agreement with the French administration and showed the project of the new building.

11.8 Closing remarks – Farewell

Thomas Wagner expressed his gratitude to all workshop participants for their active engagement and contributions throughout the event. He wished everyone a safe journey home and hoped that they would take with them pleasant memories of both the workshop and the city of Karlsruhe.

12. SOCIAL EVENTS AND TECHNICAL VISITS

12.1 Welcome reception at 'Badisch Brauhaus' in Karlsruhe city centre

On Monday evening, following the workshop's opening day, participants attended a warm reception at the Badisch Brauhaus. As ever, this gathering was a great success, and all had the opportunity to taste different food and drink.

12.2 Technical tours

As part of the programme, participants joined an on-site technical tour at the BAW Campus. The visit included a simulation of the Rhine River for waterway engineering and planning, showcasing how advanced modelling supports infrastructure design and navigation safety.

In addition, participants attended a demonstration of a ship-handling simulator for an inland waterway vessel, providing insight into training methods, operational planning, and the testing of vessel manoeuvring scenarios under realistic conditions.

12.3 Cultural tour with Workshop Dinner (Speyer)

Participants joined the preselected cultural activities in Speyer, with two options offered:

- Option A – European History & Culture Tour: A guided city tour covering several sites of interest, concluding at the restaurant.
- Option B – Technik Museum Speyer: A self-guided tour of the museum, followed by a short walk to the restaurant.

Both groups gathered at Restaurant Rentschlers on the banks of the Rhine for the Workshop Dinner at 18:00 sharp. Transportation was provided via bus shuttles from Karlsruhe city centre to Speyer and back.

ANNEX A WORKSHOP PARTICIPANTS

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TECHNICAL PROGRAMME

01-05 September 2025

International Mobile Telecommunication (IMT) Workshop
Application to Marine Aids to Navigation
WSV, Germany

WORKSHOP PROGRAMME

DAY 1 – Monday 01 September 2025

Time	Activity	
08:30 – 09:30	Registration and morning tea/coffee	
09:30 – 11:00	**Session 1 – Welcome and introductions – Is there any challenge?**	**Chair – Hideki Noguchi (JSTRA)**
09:30 – 10:00	Welcome and introduction to the waterway and Marine AtoN domains of the host country Germany	Thomas Wagner (WSV) + Roman Weichert (BAW)
10:00 – 10:20	Welcome from IALA	Omar Eriksson (IALA)
10:20 – 10:40	Workshop aim and objectives	Hideki Noguchi (JSTRA)
10:40 – 11:00	Workshop introduction (incl. introduction to technical tours/cultural tour)	Jan-Hendrik Oltmann (WSV)
11:00 – 11:30	**Break – (coffee/tea)**	
11:30 – 13:00	**Session 2 – The challenge: Introducing IMT technologies / Rising to the challenge … and to the opportunities, too!? Application examples**	**Chair – Dennis Khoo (MPA)**
11:30 – 11:50	Using IMT as the sole means for all communications needs of a maritime island community	Giang Hoang Hong *[recording]*
11:50 – 12:10	Using IMT's features in public safety communications	Hyounhee Koo (SyncTechno Inc.)
12:10 – 12:30	IMT technologies in other modes of transport – a survey	Jan-Hendrik Oltmann
12:30 – 12:50	IMT applications for remotely operated and/or autonomous vessels - Early Results and Prospects of MASS Trials in Italy	Paolo Pagano (CNIT Laboratory) *[remote]*
12:50 – 13:00	**Session 2 Q&A**	
13:00 – 14:00	**Lunch**	
14:00 – 15:30	**Session 3 – Rising to the challenge of … emerging demands of the Maritime Services and 'real-time' Data Products**	**Chair – Richard Aase (NCA)**
14:00 – 14:20	… Vessel traffic services (MS1) and S-212 data product (VTS digital services)	Wim Smets (Agency for Maritime and Coastal Services, Belgium)
14:20 – 14:40	… Sea Traffic Management, JITA, fleet management, and other applications of S-421 (IEC 63173-1)	Olli Soininen (Fintraffic)
14:40 – 15:00	… Under Keel clearance management and S-129 UKCM	Jason Rhee (OMC International)
15:00 – 15:20	… Aids to Navigation Service (MS2) and Navigational Warnings (S-124)	Cheryl Marshall (CCG) *[remote]*
15:20 – 15:30	**Session 3 Q&A**	
15:30 – 16:00	**Break**	
16:00 – 17:30	**Session 4 – Rising to the challenge of … emerging demands of digitalisation of waterways**	**Chair – Taoufik El Bacha (Saab TransponderTech)**
16:00 – 16:20	… at Smart AtoNs operations, remote monitoring of AtoNs, vessel crowd monitoring of waterway, etc.	Jonas Lindberg (SPX)
16:20 – 16:40	… for a whole inland waterway – example Danube river/waterway	Gergerly Mezo (RSOE)
16:40 – 17:00	… from the operation of the Service-oriented Device Connectivity (SDC) stack's connectivity layers themselves:	Hanjin Lee (KRISO) *[remote]* and Thomas Christensen (DMC International)

	Part 1 – Technical Services and their demands (introducing relevant IALA Guideline/s)	
17:00 – 17:20	… from the operation of the Service-oriented Device Connectivity (SDC) stack's connectivity layers themselves: Part 2 – Maritime Connectivity Platform, including the Maritime Service Registries' demands (introducing relevant IALA Guidelines)	Jin Hyoung Park (Aivenautics) *[remote]* and Thomas Christensen (DMC International)
17:20 – 17:30	**Session 4 Q&A**	
18:00 – 20:00	**Welcome reception**	**One-way bus shuttle to 'Badisch Brauhaus' in KA city centre**

DAY 2 – Tuesday 02 September 2025

Time	Activity	
09:00 – 10:30	**Session 5 – Rising to the challenges and opportunities of … understanding the IMT family in the context of its application to maritime shore infrastructure**	**Chair – Olli Soininen (Fintraffic)**
09:00 – 09:20	Reflecting on IMO's state of work on the 'guidance' for the 'unified global framework' and of the role of IMT family for IP-based connectivity therein	Julius Moeller (AMSA) *[Remote]*
09:20 – 09:40	A guide to the IMT family as represented in ITU documents from within the maritime domain	Jan-Hendrik Oltmann
09:40 – 10:00	The relevance of typical generic architecture(s) for shore infrastructure(s) (such as IALA's CSSA in the context of IALA Rec 0140) for IMO's aspirations	Michele Fiorini (Leonardo)
10:00 – 10:20	The potential integration of 5G satellite network in the maritime domain by electronically steered antenna – demonstration and outlook	Chen Binbin, Muneaki Ogawa, Johnson Tay (SUTD, JSAT, VIAVI)
10:20 – 10:30	**Session 5 Q&A**	
10:30 – 11:00	**Break**	
11:00 – 12:30	**Session 6 – Rising to the challenges and opportunities of … understanding IMT 'hands on' at self-governed IMT campus networks**	**Chair – Lisa Underberg (ifak)**
11:00 – 11:20	IMT-2020/5G – a victim of its own hype? How to correctly interpret and apply the 'key performance triangle' – in general and when applied to the wet domain	Lisa Underberg
11:20 – 11:45	Real IMT-2020/5G applications at Industry 4.0 - Learning from digitalisation at industry regarding communications	Sarah Willmann (ifak) and Lisa Underberg
11:45 – 12:10	IMT-2020/5G introduction beyond the buzz words – how to make high-profile radio communications happen – potentially also for AtoN administrations	Sarah Willmann
12:10 – 12:20	IMT-2030/6G – a practically informed outlook on proposed capabilities and standardization	Lisa Underberg
12:20– 12:30	**Session 6 Q&A**	
12:30 – 13:30	**Lunch**	
13:30 – 15:00	**Session 7 – Rising to the challenges and opportunities of … an even more powerful future IMT family member, namely "IMT-2030 and beyond" (aka 6G)**	**Chair – Dennis Khoo (MPA)**
13:30 – 13:50	Introducing the and reflecting on ITU's performance indicators for IMT-2030/6G	Jan-Hendrik Oltmann
13:50 – 14:10	The dawn of a new era for Resilient PNT by using IMT!? (Signals-of-opportunity for R-Mode and by built-in Positioning capability)	Ronald Raulefs (DLR)
14:10 – 14:30	Mapping 'features' of IMT standardisation at 3GPP to maritime domain's use cases, taking into account upcoming 6G feature standardisation at 3GPP	Hyounhee Koo (SyncTechno)
14:30 – 14:50	The work of 3GPP on IMT-2030/6G and the pros/cons of setting up of an initiative group for the maritime domain at 3GPP ('Market Representation Partner – MRP')	Minsu Jeon (IALA) and Jillian Carson-Jackson (JCJ Consulting) *[remote]*
14:50 – 15:00	**Session 7 Q&A**	
15:00 – 15:30	**Break**	
15:30 – 17:30	**Session 8 – Rising to the challenges and opportunities … here is the plan for IALA!** **- Technical discussion forum and the expected outputs of the workshop**	**Chair – Omar Eriksson**
15:30 – 17:00	Technical discussion forum	Plenary
17:00 – 17:30	Introducing the expected output: Draft IALA information document Establishing working groups	Minsu Jeon

18:00 – 20:00	**Technical tour - Simulation of the Rhine River for waterway engineering Planning** **Technical tour – Demonstration of a ship handling simulator for an inland waterway vessel** **Technical tour – Presentation of a live experiment of cutting-edge waterway machinery**	**On-site BAW Campus**

DAY 3 – Wednesday 03 September 2025

Time	Activity	
09:00 – 10:30	**Session 9 – Rising to the challenges and opportunities … together! - IMT application WGs session**	
09:00 – 10:30	WG1 – Maritime services, use cases, features	**Chair – Wim Smets**
	WG2 – Technologies	**Chair – Ronald Raulefs**
	WG3 – Procurement and implementation	**Chair – Olli Soininen**
10:30 – 11:00	**Break**	
13:00 – 14:00	**Lunch**	
11:00 – 17:30	**Session 10 – Rising to the challenges and opportunities … together! - IMT application WGs session**	
11:00 – 17:30	WG1 – Maritime services, use cases, features	
	WG2 – Technologies	
	WG3 – Procurement and implementation	
15:00 – 15:30	**Break**	
18:00 – 20:00	**Free evening**	

DAY 4 – Thursday 04 September 2025

Time	Activity	
09:00 – 13:00	**Session 11 – Rising to the challenges and opportunities … together! - IMT application WGs session**	
	WG1 – Maritime services, use cases, features	
	WG2 – Technologies	
	WG3 – Procurement and implementation	
	Outcome – Discussion + finalise WG contribution to information paper	
10:30 – 11:00	**Break**	
13:00 – 13:45	**Lunch**	
13:45 (sharp) – around 22:00	**<u>Cultural tour with Workshop Dinner (Speyer)</u>** **As preselected by participants upon registration** - **<u>A) European History & Culture Tour</u> (guided tour in city to several sites of interest; end of tour = restaurant)** - **<u>B) Technik Museum Speyer</u> (self-guided tour in museum premises) + short foot walk to restaurant for Workshop Dinner – be at restaurant Rentschlers at 18:00 (sharp)!**	**Bus shuttle to Speyer + Tours A/B + restaurant Rentschlers on the banks of the Rhine + return bus shuttle to Karlsruhe city centre**

DAY 5 – Friday 05 September 2025

Time	Activity	
09:00 – 12:00	**Session 12 – Rising to the challenges and opportunities … our joint achievements so far!** **- Presentation of the results from WGs – Workshop Conclusions**	**Chair – Omar Eriksson**
09:00 – 09:15	WG1 – Maritime services, use cases, features **– Results**	(Chair WG 1)
09:15 – 09:30	WG2 – Technologies **– Results**	(Chair WG 2)
09:30 – 09:45	WG3 – Procurement and implementation **– Results**	(Chair WG 3)
09:45 – 10:00	Findings and observations regarding the capacity building for future IMT family implementation in a 'globally unified framework'	Omar Eriksson
10:00 – 10:30	Technical discussion forum	Plenary
10:30 – 11:00	**Break**	
11:00 – 11:30	The present state of the *draft IALA information document on IMT application* and other conclusions	Minsu Jeon
11:30 – 11:50	Rising to the challenge … the way ahead	Omar Eriksson
11:50 – 12:00	Closing remarks - Farewell	Thomas Wagner
12:00 – 13:00	**Light lunch**	

ANNEX C WG1 OUTPUTS – MARITIME SERVICES, USE CASES, FEATURES

1. Define IALA maritime vertical

IALA should play a key role in representing the voice of marine AtoN within the 6G development process. While it is acknowledged that IALA cannot represent the entire maritime sector, its contribution remains vital to ensure that the unique needs and perspectives of marine navigation are adequately reflected.

Action item:

IALA Secretariat to start discussion with 3GPP via ETSI on how to include the voice of the Maritime domain, especially in marine aids to navigation, in 6G development.

In the IALA scope:

- Ship to X communication;
- Communication with and between AtoN's;
- Waterway information exchange;
- Safety-related information.

2. Determine 6G features

Scheme to determine 3GPP features (ref. 3GPP TR 22.804 V16.3.0 (2020-07))

1. Describe use case
2. Operational coverage zones
3. Preconditions
4. Service flows (who contacts whom)
5. Post conditions
6. Challenges to 6G system and beyond
7. Potential requirements

The following Technical Services were looked into:

- Traffic Clearance (uses S-212);
- Route Exchange (uses S-421);
- Navigational Warnings (uses S-124).

See ANNEX A for the detailed scan of the above-mentioned Technical Service Specifications.

3. Detected 6G features

a. Operational coverage zones

- OCZ 1: Inland/ports
    - Inside the baseline defined by UNCLOS (S-130/S-23)
- OCZ 2: Close to coast
    - Outside baseline defined by UNCLOS
    - Inside A1 area defined by SOLAS (line of sight)
- OCZ 3: Far from coast
    - Outside A1 area defined by SOLAS
    - Inside A2 to A4 area defined by SOLAS

b. Challenges to 6G system and beyond

- Continuous service between different operators (roaming)
- Prioritization of the service (QoS)
- Coverage
- Cost efficiency (effects of scale)

4. Roadmap to express the needs of IALA to 3GPP

a. Make representative and specific use cases

During the work of WG1, the following potential use cases were identified, including some potential challenges for the development of 6G (no priority defined)

- Support for MASS
    - Importance of QoS
    - Very high data rate (for example, multiple cameras need to be connected to a remote operation centre)
- Broadcast communication for voice (digital VHF)
    - Low latency
    - Device to device
    - Quality of codec (sound)
    - Broadcast to a specific group of users
    - Simplex/duplex functionalities
    - Broadcast to a geographic area
    - Hybrid situation with ships equipped with digital VHF and ships without digital VHF => NOT 3GPP matter
- Communication with and between AtoN's
    - Very low power consumption
    - Data rate fit to purpose (e.g. streaming videos, sensors, …)
    - Fallback options regarding communication
    - Advanced positioning
    - Broadcast to a geographic area
- Position Navigation and Timing (PNT)
    - Accuracy of the calculated position fit for purpose (e.g. berthing operations <cm, MASS, AtoN's < m)
    - Degree of independence of GNSS timing
- Redundancy for existing systems like:
    - Back-up for VDES and/or vice versa
    - Replacement for AIS (encryption available)
    - Augmenting VHF with digital voice communication
    - Virtual AtoN's
- Intelligent AtoN's using e.g. AtoN information exchange (S-125), hydrological information, meteorological information, oceanographic information, …
    - Advanced positioning
    - Device to device communication
    - Low power consumption
    - Broadcasting

b. Expectations to 6G network providers from the viewpoint of the maritime domain

- Sufficient connection to Internet (gateway with sufficient capacity)
- Gateway to other systems with possibly QoS

c. Expectations regarding security from the maritime domain

- Resilience against radio channel interference
    - Spectrum used by existing systems on board of ships => handled by ITU
- Self-monitoring the quality of the connection

- Resilience against cyber attacks
- Authentication of 3GPP network providers

d. Verify how to communicate features to 3GPP

- Analyze definitions and concepts used by 3GPP and make the translation to the IALA domain
- Reference 3GPP TS 22.104 V19.2.0 (2024-06)
- Define the numbers for the characteristic parameters

Things to take into account for IALA:

- Channel model for marine environments
    - Specific conditions regarding marine environments
    - Influence of weather conditions
    - Sea state
    - …
    - => not a challenge for 3GPP, should be addressed generally as a matter of priority
- Requirements regarding reliability and continuity need to be defined

ANNEX – Technical Services checked for 6G features

1. Traffic Clearance service

- Describe use case
    - See Technical Service Specification document for Traffic Clearance.
- Operational areas
    - OCZ 1 / 2
- Preconditions
    - Both sides need to be equipped with the proper equipment
    - Equipment is switched on
- Service flows
    - Ship to MCP service lookup (bi-directional)
    - Ship to Route exchange service (bi-directional)
- Post conditions
    - VTS and Ship can exchange information regarding traffic clearance
    - Ships received the information correctly
- Challenges for the 6G system and beyond
    - Coverage
    - Potentially high density of ships
    - Service availability
    - Prioritization of the service
- Potential requirements
    - Not looked into for now

2. Route Exchange service

- Describe use case
    - See Technical Service Specification document for Route Exchange.
- Operational areas
    - OCZ 1/2/3

- Preconditions
    - Both sides need to equipped with the proper equipment
    - Equipment is switched on
- Service flows
    - Ship to MCP service lookup (bi-directional)
    - Ship to Route exchange service (bi-directional)
- Post conditions
    - Route information is exchanged between ship and VTS
    - Ship and VTS received the information correctly
- Challenges for the 5G system
    - Coverage
    - Service availability (depends on where ship is in its journey)
    - Potentially high density of ships
    - Prioritization of the service
- Potential requirements
    - Not looked into for now

3. Navigational Warning service
    - Describe use case
        a. See Technical Service Specification document for Navigational Warnings.
    - Operational coverage zones
        - OCZ 1 / 2/3
    - Preconditions
        - Both sides need to equipped with the proper equipment
        - Equipment is switched on
    - Service flows
        - Ship to MCP service lookup (bi-directional)
        - Ship to Navigational Warning service (bi-directional)
    - Post conditions
        - Competent authority can disseminate navigational warnings
        - Ships received the information correctly
    - Challenges for the 5G system
        - Coverage
        - High availability
        - High reliability
        - Potentially high density of ships
        - Prioritisation of the service (QoS)
        - Continuous service between different operators (roaming)
    - Potential requirements
        - Not looked into

ANNEX D WG2 OUTPUTS – TECHNOLOGIES

The group analysed the potential of IMT-2020 (5G) and the future IMT-2030 standard to support various maritime services, excluding mission-critical systems like the Global Maritime Distress and Safety System (GMDSS).

1. Requirements and Technology Considerations

To properly assess the technology, the group distinguish between different types of requirements and network capabilities.
Key Definitions:

- End-to-End Latency: The group define this from two perspectives. From an application view, it's the total delay from data generation to reception and processing. From an IMT provider's view, it's the delay for a data packet to cross only the provider's managed network.
- Comprehensive Parameters: A communication system's requirements should be described by a comprehensive set of parameters. This includes influencing quantities (e.g., number of devices, data length) which define the operating conditions, and characteristic parameters (e.g., data rate, latency) which describe the required performance.
- Communication Patterns: 3GPP documents define several communication types, including deterministic periodic (messages at regular intervals with strict guarantees), aperiodic deterministic (event-triggered messages with strict guarantees), and non-deterministic (traffic where timeliness is not critical).

2. Maritime Use Cases

The group review numerous maritime services, many of which can be supported by IMT-2020. Key examples include:

- Services like Vessel Traffic Service (VTS), aids to navigation (AtoN), and port support.
- Video-streaming applications such as telemedicine, remote pilotage, and incident management support.
- Maritime Internet of Things (IoT) for monitoring aids to navigation.
- Positioning services that could serve as an alternative to GNSS in port areas.

3. IMT-2020 (5G) Technology

IMT-2020 is built on three main service categories that can be tailored to different applications:

1. Enhanced Mobile Broadband (eMBB): Focuses on high data speeds and capacity, suitable for applications like high-definition video streaming for telemedicine or remote pilotage.
2. Ultra-Reliable and Low-Latency Communications (URLLC): Designed for critical applications needing extremely high reliability and low delay, such as remote pilotage or live navigational hazard assistance.
3. Massive Machine-Type Communications (mMTC): Enables connecting a vast number of low-power devices, ideal for Maritime IoT applications like monitoring waterway conditions or equipment status.

4. Identified Challenges

A primary challenge identified is the choice between using public and non-public (private) networks.

- Public Networks are operated by mobile network operators (MNOs) and offer wide coverage and easy access. However, bandwidth is shared, which can lead to congestion, and there are no performance guarantees.
- Non-Public Networks are dedicated to a specific enterprise or area (like a port), offering full control, guaranteed performance, and enhanced security. The downsides are higher initial cost, complexity, and limited spectrum access.

A key concern for maritime applications is the potential for network congestion from public users on shared networks. The document suggests that network slicing, which creates virtual networks with guaranteed QoS on a shared physical infrastructure, could be a scalable solution, though real-world experience is lacking. Another proposed idea is for the maritime community to seek exclusive spectrum for IMT networks at a future World Radiocommunication Conference (WRC).

5. Summary

The document concludes that IMT-2020 is likely to be capable of supporting the maritime services listed in IMO MSC.1/Circ. 1610/Rev.1, including demanding video-streaming and IoT applications.
The key outcomes and proposed actions for the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) are:

- Inform the International Maritime Organization (IMO) that IMT technology likely fulfils the requirements for many maritime use cases.
- Initiate a discussion on how to ensure reliable network access, whether through exclusive spectrum, a focus on non-public networks, or the implementation of network slicing.
- Define a guideline for its members to adopt the terminology of 3GPP to ensure clear and harmonized communication when specifying requirements.

ANNEX E WG3 OUTPUTS – PROCUREMENT AND IMPLEMENTATION

1. Context & Aim

Working Group 3 (WG3) addressed the procurement, implementation, and organisational aspects of introducing International Mobile Telecommunication (IMT: 4G, 5G, 6G) into the maritime domain, particularly for Aids to Navigation (AtoN) and Vessel Traffic Services (VTS).
The maritime sector faces unique challenges, including safety-critical operations, complex regulations, high costs, and the need to integrate with legacy systems. WG3 sought to develop practical, actionable guidance for IALA members on safe, harmonised, and cost-effective adoption.

2. Procurement Considerations

- Performance priorities: Coverage and reliability take precedence over throughput. Latency should be acceptable but less critical than in other sectors.
- Spectrum access: Maritime uptake is constrained by competition with mobile operators, rigid national licensing, and cross-border interference.
- Deployment models:
  - In-house: Sovereignty/control, but high cost and skills demand;
  - Outsourced: Lower CAPEX, reliance on SLAs;
  - Hybrid: Shared investment, balance of control and efficiency.
- Private/local networks: Attractive for ports and VTS areas, but costly and fragmented. Hybrid approaches are more viable for coastal coverage.
- Lessons from 4G/5G pilots: Private networks often depend on operators; APN connectivity is a practical compromise.
- Procurement strategy: Define SLAs/KPIs rigorously; avoid lock-in through early engagement and standards alignment.
- Influence of other sectors: Aviation/rail (public procurement governance), automotive (cross-industry influence), public safety (SLAs).

3. Organisational Aspects

- Governance: Authorities remain accountable, even when outsourcing.
- Capacity & training: Telecom expertise is limited; workforce upskilling is essential.
- Integration into national strategies: Maritime IMT should be a distinct vertical in digital strategies;
- Knowledge sharing: IALA should coordinate structured exchanges.
- Role of IALA: Provide best-practice guidance, define minimum operational requirements, and represent maritime in ITU/3GPP forums.

4. Implementation Challenges

- Phased rollouts: Start with pilots (ports, VTS) before coastal expansion.
- Legacy interoperability: Maintain AIS, NAVTEX, DSC, VHF alongside IMT with gateways.
- Cybersecurity: Requirements embedded from procurement through operation; continuous monitoring.
- Lifecycle costs: Hidden costs include training, integration, cybersecurity, OPEX.
- Technology lifecycle: Obsolescence risks managed by standards-based, backward-compatible solutions.
- Joint procurement: Effective for common equipment but limited by national regulations.

5. Preparing for IMT-2030 (6G)

- Strategic timing:

    - Early adoption: Efficiency and leadership, but higher risks/costs.
    - Late adoption: Mature solutions, but risk of lagging behind.
    - Recommended: Phased approach.
- IALA's role: Strengthen influence in standardisation, endorse pilots, support training via WWA.
- Capacity building: Prepare administrations globally for 6G with knowledge of technologies, procurement, and regulations.

6. Conclusions

- WG3 emphasises a proactive but balanced approach:
- Challenges: Spectrum conflicts, high costs, limited expertise, legacy integration.
- Models: Private networks in critical zones; hybrid models for wider coverage. Recommendations:
    - Define procurement around coverage, reliability, interoperability, and SLAs.
    - Pursue phased rollouts starting with pilots; plan for lifecycle costs.
    - Integrate IMT into national strategies; build organisational capacity through IALA.
- Strategic direction: Early adoption in ports/VTS; phased/late adoption for coastal coverage. IALA must ensure maritime requirements are represented internationally.

ANNEX F IALA GUIDELINE ON IMT-2030

1. Scope of the document

Defines the purpose of the guideline — how IMT-2030 features can be applied in Marine AtoN.

1.1. OSI model

Reference to how IMT functions align with the OSI communication model.

2. Terms and definitions

Common terminology used in IMT-2030 and maritime AtoN.

3. Operation

Explains how IMT technologies operate in maritime settings.

3.1. Operational coverage zones

Definition of coastal, port, and oceanic coverage areas.

3.2. Operational aspects

Practical factors for deployment.

3.2.1. Requirements

Technical: coverage, latency, interoperability, security.

Operational: ease of use, integration into VTS, AtoN, and bridge systems.

3.2.2. Quality of Service

Definition of maritime-specific QoS (availability, reliability, resilience).

4. Requirements from Marine AtoN (WG1, WG2, WG3)

Inputs gathered from IALA working groups.

4.1. Requirement specification 3GPP TR22.804

Reference to existing 3GPP requirements document.

4.2. Reliability and continuity

Defining required service levels for maritime safety.

4.3. Service requirements

Expected capabilities to support AtoN services.

5. Use cases

Examples of applying IMT to maritime services.

5.1. Maritime Services – General overview.

5.2. MBS – Maritime Broadcast Services.

5.3. PNT – Positioning, Navigation, and Timing.

5.4. VTS – Vessel Traffic Services.

5.5. Digital maritime services – Broader e-navigation services.

6. Procurement and implementation

Guidance for members on adopting IMT.

6.1. Strategic clarity – Defining goals before implementation.

6.2. Spectrum access – Regulatory considerations.

6.3. Choice of model – Options (public, private, hybrid networks).

6.4. Avoiding lock-in – Ensuring vendor neutrality.

6.5. Learning from other sectors – Adopting best practices from non-maritime industries.

ANNEX G IALA INFORMATION DOCUMENT ON IMT-2030

1. What is the goal?
Purpose of the paper: policy-oriented, forward-looking.

2. Engagement in ITU and 3GPP
IALA's role in external organizations.

2.1. Discussion with 3GPP via ETSI – Current liaison channels.

2.2. MRP – Considering IALA's formal role.

3. Features and capabilities
Overview of IMT-2030 functions.

3.1. New

Coverage: global NTNs.

Sensing: environmental and situational sensing.

AI: predictive services.

Sustainability: energy efficiency.

Interoperability: with legacy systems.

Positioning: 1–10 cm accuracy.

3.2. Existing

Review of features from 5G/Rel-17/18 (security, reliability, latency, etc.).

4. Questions
Open questions for members and stakeholders.

5. Opportunities
Strategic advantages for maritime participation.

5.1. Maritime unique market – Special role of shipping in global trade.

6. Challenges
Barriers to adoption and engagement.

6.1. Continuous service between operators – Seamless handover.

6.2. Prioritization of services (QoS).

6.3. Small market size for 3GPP.

6.4. Representation limits of IALA.

7. Policy
Future strategies.

7.1. Roadmap – Steps for maritime engagement.

Use cases, expectations from providers, security needs, communication with 3GPP.

7.2. Regulations – Relevant frameworks (e-Navigation, S-100, GMDSS, others).

7.3. Procurement – Policy aspects of buying and deploying.

7.4. Organisational – Skills, training, responsibilities.

8. Discussion
Technical and policy discussion points.

8.1. Channel model – Maritime-specific propagation models.

8.2. Parameter definitions – Key technical terms.

8.3. Data – Mapping maritime datasets (S-201, S-212, S-210, etc.).

8.4. Range and coverage – 4G, 5G, 6G scenarios, AtoN networks, NTN costs.

9. Technologies
Complementary and competing technologies.

9.1. Technical – Portable base stations, VDES, IP, Satcom, trust infrastructure (MCP, SECOM, eSIM), cybersecurity, spectrum, performance testing.

9.2. Positioning – R-Mode, satellite constellations.

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