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PROGRESS UPDATE FOR TASK ON DEVELOPING A DISCUSSION PAPER ON DIGITALISATION IN THE SCOPE OF IALA

Summary

This paper provides a progress update for the task to develop a discussion paper on digitalisation in the scope of IALA.

Purpose

DTEC Work Group 2 began its work on the task at DTEC3. A task group was formed and has made good progress on the task thus far. The task group convened an intersessional meeting via virtual Teams on 28 August 2025, from 09:00 to 10:30 UTC. The task group has produced a draft version of the discussion paper, annexed in this submission, and plans to advance the task further at DTEC5.

Action requested of the Committee

The Committee is invited to note the progress of the task and to forward the draft discussion paper to DTEC Working Group 2 for further deliberation.

ANNEX

DISCUSSION ON VISION TOWARDS DIGITALIZATION IN THE IALA DOMAIN

Edition 0.0

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

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

DOCUMENT HISTORY

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

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

CONTENT

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

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1 INTRODUCTION

1.1 Maritime Digitalization

In an increasingly interconnected world, digitalization has emerged as a powerful transformative force affecting diverse sectors, and the maritime industry is no exception. As global trade continues to expand and the demands of the consumer-driven economy evolve, maritime stakeholders are compelled to adapt to rapid technological changes. Digitalization offers unprecedented opportunities to enhance operational efficiency, optimize resource utilization, and improve safety standards. By embracing digital technologies, the maritime sector can potentially unlock significant benefits in streamlining processes, automating tasks, and enabling real-time monitoring and decision-making, which potentially promotes cost savings, productivity gains, and better risk management capabilities.

Digitalization with standardized protocols enhances interoperability, enabling better coordination between Vessel Traffic Service centres, thereby improving navigational maritime safety and security. Digitalization enables the integration of diverse data sources and systems, facilitating communication and collaboration across different stakeholders in the maritime ecosystem. From port operations and vessel traffic management to navigational safety and environmental protection, digitalization empowers maritime stakeholders to collect, analyze, and utilize data more effectively, enabling proactive decision-making and strategic planning. Additionally, digitalization is the fundamental prerequisite for the integration of artificial intelligence (AI) in maritime operations.

1.2 Key Global Trends Driving Maritime Digitalization

Maritime digitalization is being propelled by a confluence of factors that are reshaping the industry landscape. These key drivers are transforming traditional practices and paving the way for innovative solutions to meet the evolving demands of the maritime sector. The drive towards digitalization is fuelled by the desire to enhance operational efficiency, optimize resources, and address challenges in safety, security, and environmental sustainability. As the industry navigates towards a more interconnected and data-driven future, these drivers are instrumental in shaping the course of maritime digital transformation. The key drivers which are broadly discussed in the literature of maritime digitalization includes 1) Rapid digital technology advancements 2) Shift in User Expectations 3) Sustainability 4) Safety of Navigation 5) Globalisation and 6) Need for cost efficiency & productivity. Figure 1 illustrates some of the key motivators of maritime digitalization.

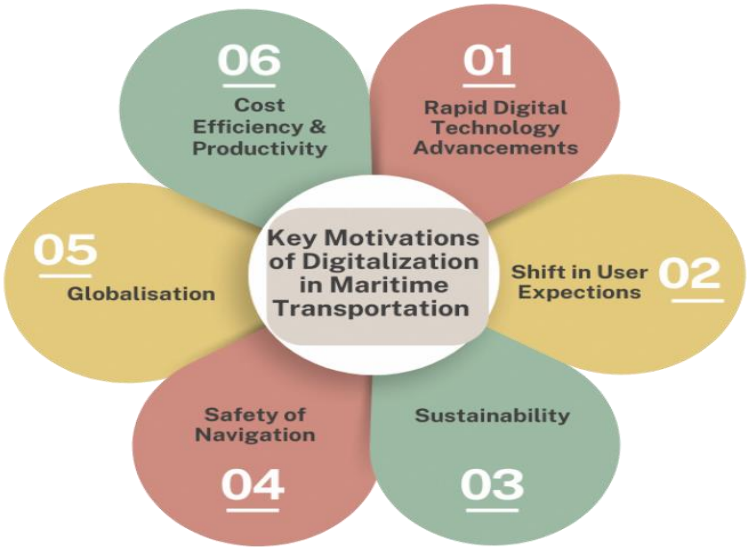


Figure 1 Key Motivations of Digitalization in Maritime Transportation

Rapid advancements in digital technology are driving innovation, streamlining processes, and enhancing decision-making capabilities in the maritime industry. Today, users expect seamless and convenient experiences to perform their work efficiently, pushing for more automation and interconnected systems and operations. Sustainability concerns are also prompting the maritime industry to adopt digital technologies that optimize fuel consumption, reduce emissions, and minimize environmental impact [1]. The International Maritime Organization's (IMO) sulphur cap and the Energy Efficiency Existing Ship Index (EEXI) pushes the industry forward to cleaner and more sustainable operations [5]. Today, there are rapid developments in alternative fuels such as liquefied natural gas, hydrogen, methanol, ammonia, and biofuels, as well as advancements in energy-efficient green technologies like wind-assisted propulsion, waste heat recovery systems, solar power technologies, hull air lubrication systems, and improved hull designs and materials. These green technologies are crucial for protecting the environment and ensuring a more sustainable future for the maritime industry. Maritime green technologies and digital technologies are increasingly interconnected as the maritime industry seeks to reduce its environmental impact.

Globalization is driving the need for efficient and interconnected maritime operations, making digitalization essential for seamless communication, coordination, and compliance across international waters. Thus, it is crucial to ensure common digital technology standards within the maritime eco-system to ensure interoperability and robust technologies are adopted to reduce operational risk for a safer and more efficient maritime operations.

Utilizing digital technologies to navigate the complexities of global trade allows maritime businesses to enhance their competitiveness, streamline processes, and adapt to the demands of a connected global economy [2]. The need for cost effective and high

productivity in maritime operations motivates the adoption of digital technologies to streamline processes, optimize resources, and reduce operational expenses [3].

It is inevitable that digital technologies will disrupt existing maritime operations. Embracing the adoption of these technologies with a consultative and systematic approach will be crucial for the success of digitalization in the maritime industry.

1.3 The Technology Radar: Identifying Key Developments

Adoption of Maritime Autonomous Surface Ships (MASS)

Maritime Autonomous Surface Ship (MASS) means a ship which, to a varying degree, can operate independently of human interaction. The three levels of autonomy defined are:

- Full Autonomy: The vessel can operate entirely on its own without human intervention, making decisions and navigating based on real-time data in assessing situations and make decisions autonomously.
- Partial Autonomy: The vessel can perform certain tasks independently, such as navigation and collision avoidance, with some human supervision.
- Remotely Operated: The vessel is operated by a human operator from a control station on shore or another ship.

These ships use advanced technology such as digital sensors, artificial intelligence, and communication systems to navigate and make decisions at sea. While the MASS developments are progressing steadily, several ports of the world have made significant progress in the developments.

Harnessing Big Data & Artificial Intelligence

Big data refers to the massive volume of structured and unstructured data that is generated by businesses and individuals. Combining with analytics tools (i.e. Artificial Intelligence (AI) technology), it helps to uncover patterns, trends, and insights that can be used to make informed decisions. Today, there is an increasing number of developments and research in data collection and analytic techniques for the maritime industry. According to Lloyd's Register research in 2023, it is envisaged that by 2040, AI applications will influence every facet of life. Today's empirical models process only 10% of vessel data, which is significantly inferior to AI models that can process 90% of vessel data, providing accurate performance insights [4]. AI-driven models can enhance decision-making and tackle safety concerns that may occur from insufficient situational awareness or data.

Digital Maritime Sensors & Internet of Things (IoT) Integration in Maritime Industry

Digital maritime sensors refer to sensors employed in maritime for the monitoring and enhancing of safety of navigation in the waters. Internet of Things (IoT) is a network of physical devices that are embedded with sensors, software, and connectivity to exchange data. Enabling devices to be controlled and monitored remotely, creating a smart and efficient environment. In recent years, there has been an upward trend in the adoption of digital sensors in maritime operations, along with a noticeable shift from conventional analogue sensors to digital ones. The advantage of utilizing IoT is in gathering and analysing the data collected from these digitalised sensors which can then be used to guide subsequent actions. Given the global efforts to explore alternative fuels such as ammonia, hydrogen, methanol, biofuels, and liquefied natural gas to reduce the sector's carbon footprint, there is a strong need to explore new digital sensors capable of detecting these fuels. This would enable early detection of leaks, ensuring safety in navigation. Digital sensors integrated with IoT will have the potential to significantly enhance maritime safety.

Adoption of VDES in Maritime Industry

VHF Data Exchange System (VDES), an advanced communication system designed to facilitate high-capacity data exchange platform for the maritime industry. It builds upon the existing Automatic Identification System (AIS) but offers greater bandwidth and improved data transmission capabilities. VDES enables real-time communication for a variety of applications, including navigation, weather updates, and vessel traffic management and is regarding as one of the key technologies. By integrating satellite and terrestrial components, VDES ensures reliable connectivity even in remote maritime regions. Today, there are two key VDES non-profitable groups in driving maritime VDES developments namely, The VDES Alliance and Satellite VDES Consortium in Japan. The VDES Alliance focuses on promoting VDES technology and ensuring interoperability [6], while the Satellite VDES Consortium aims to support the growing demand for reliable digital communication at sea using satellite-based VDES [7]. At IALA-DTEC, members have been actively demonstrating the VDES capabilities and developments through demonstrations and sharing of trial results.

Securing Maritime Transactions with Blockchain Technology

Blockchain technology is a decentralized, distributed ledger system that securely stores data. Blocks are spread throughout a network of various computers. Each block contains data, is marked with timestamp and includes digital signatures linking with the previous block. This technology provides transparency, security, and immutability of data. The essence of this technology is based on trust and transparency with other stakeholders in the shipping process [8].

Heighten Cybersecurity Focus

There has been increasing focus and demand of protecting systems, networks, and data from digital attacks in maritime systems. This includes securing computer systems, networks, and

mobile devices, as well as implementing processes and procedures to protect data from cyber threats. It is no surprise that cybersecurity is a vital component in the digitalization technology developments [1].

Maritime Digital Twin Developments

A digital twin is a virtual representation of a physical object or system. It is created using real-time data from sensors, devices, and other sources to model the physical characteristics and behaviour of an object or system. Digital twin enables monitoring, analysis, and prediction of performance of its physical counterpart by simulating different scenarios and conditions.

Availability of Robust Digital Communication Connectivity Options via IMT-2020 and Satellite

The maritime industry is experiencing a significant demand for robust digital communication connectivity. The high-speed and low-latency capabilities of 5G enhance communication efficiency, while satellite connectivity ensures reliable coverage even in remote areas of the ocean. With the availability of 5G and satellite connectivity options, there is potential to revolutionize how ships communicate with onshore operations, enabling real-time data transmission and remote monitoring.

Use of Robotics for Maritime Operations

Maritime robotics refers to Autonomous Underwater Vehicles (AUVs) used for underwater exploration, Remotely Operated Vehicles (ROVs) for underwater inspections and maintenance, Unmanned Surface Vessels (USVs) for oceanographic research and monitoring, and Unmanned Aerial Vehicles (UAVs) used in maritime operations. The Maritime and Port Authority of Singapore had demonstrated the benefit of using UAVs for managing oil spill incidents within port waters, deploying multiple drone flights to capture high-quality video footage for transmission back to the shore-based operations centre in Singapore. These live high quality video footages can be used to monitor and predict movement of oil spills affected by waves, tides and wind, validate oil spill models, and allow better deployment of response assets. Maritime incidents in the port waters are unavoidable, and speed is of the essence to resume normalcy for port and maritime operations. In Aug 2024, MPA conducted a ferry rescue exercise, simulating collision between two domestic ferries, one electric and one diesel-powered, within Singapore port waters where UAV was deployed from a vessel to inspect the hull of the distress ferry, and live high quality video footage was sent to the shore-based operations centre for hull damage assessment to aid in the recovery operations.

Harmonization of Maritime Digital Information (S-100)

Harmonization of maritime digital information is the process of standardizing and integrating data across various maritime systems and platforms to ensure seamless communication and interoperability. It allows for efficient exchange of information between different stakeholders in the maritime industry, such as ports, shipping companies, and coastal authorities. It aims to improve safety, efficiency, and decision-making in maritime operations and is fundamental building block for digitalization in maritime sector. Developing the S-200 series of product specifications continues to be a key focus of IALA's technical work, which is closely aligned with the IMO's Common Maritime Data Structure (CMDS) and IHO's S-100 framework. The S-200 series is a suite of IALA-developed Product Specifications built on the IHO S-100 Universal Hydrographic Data Model, which serves as the foundation for the next generation of digital navigation systems, including Electronic Navigational Charts (ENCs), maritime services, and other geospatial data [9].

Maritime Services in the context of e-Navigation

While the harmonization of maritime digital information through frameworks like S-100/S-200 provides a robust foundation for data modelling, the effective delivery of this information to ships requires a complementary layer of technical services. These services enable the operationalisation of maritime data into usable, real-time digital services that support navigational safety and efficiency.

IALA has taken a leading role in developing such services, with its committees actively contributing to the advancement of e-navigation. The VTS Committee, for instance, is working on digital traffic clearance and route exchange services, while the ARM Committee is progressing the development of AtoN information services. These efforts align with the broader international push (particularly at IMO and IHO) to define and implement Maritime Services as part of the e-Navigation strategy.

Secured Digital Infrastructure

To ensure secure and efficient communication of these services, additional digital infrastructure is required. Platforms such IALA's Maritime Connectivity Platform (MCP) are essential in this regard, providing a trusted framework for identity management, service discovery, and secure data exchange between stakeholders. MCP enables interoperability across systems and supports the seamless integration of digital services into shipboard and shore-based operations.

Together, these developments underscore the importance of not only standardising maritime data but also ensuring its reliable and secure delivery through well-defined technical services and supporting infrastructure.

2 IALA's DIGITALIZATION VISION AND STRATEGIES

2.1 Proposed IALA Digitalization Vision Statement

The maritime industry stands at a critical juncture as digitalization reshapes its landscape. Hence, there is a need to articulate a vision for digitalization where IALA can effectively communicate its long-term goals and aspirations to its members, partners and international stakeholders. The shared vision will help to foster collaboration, innovation, and knowledge-sharing within the maritime community, driving collective efforts towards achieving a safer, more efficient, and sustainable maritime transport chain [10].

IALA Digitalization Vision Statement

IALA envisions playing a role as an international platform that brings together national authorities, industry stakeholders, research institutions, and relevant international organizations to harness innovative digital technologies, transforming marine navigation and aids to navigation to enhance safety, efficiency, and sustainability through harmonized digitalization endeavours.

2.2 Proposed Digitalization Strategies

IALA will adopt the following strategies to achieve its vision:

S1 - Establish IALA as the premier source of maritime digitalization standards, knowledge, and expertise, empowering national authorities to provide marine Aids to Navigation in alignment with relevant international standards and recommendations.

S2 - Harmonize and coordinate maritime digitalization initiatives with other international organizations to drive the advancement of digital solutions.

S3 - Develop comprehensive standards, guidelines, and recommendations for the maritime community to facilitate the adoption of digital technologies that enhance safety and efficiency of vessel traffic and to protect the environment.

S4- Facilitate and coordinate the sharing of the latest digital technologies from companies, research institutions, and national authorities to broaden knowledge, expertise, and awareness of available digital solutions that have the potential to enhance navigation safety.

S5 - Support capacity-building initiatives for the adoption of digital solutions.

S6 - Support the provision of trusted digital infrastructure that enables the delivery of digital maritime services and secure data exchange.

3 DISCUSSIONS ON IALA PUBLICATIONS RELATED TO DIGITAL DEVELOPMENTS

3.1 Discussion

This section discusses potential opportunities and the timeline of relevant digital technology-related publications, while also proposing recommendations to enhance the effectiveness of IALA's efforts in shaping maritime navigation in the digital age. The discussion presents the views from the members for the IALA's consideration. Additionally, it presents a compilation of both existing IALA publications (i.e., recommendations, guidelines, and standards) and developing publications extracted from the IALA work plan for 2023 to 2027, related to IALA digitalization developments. The list of identified digital technologies are as follows:

- Digital information (S-100)
- VDES
- MASS
- Maritime Cybersecurity
- Maritime Digital Twin
- Maritime Robotics
- Maritime Digital Communications
- Maritime Artificial Intelligence
- Maritime Digital Sensors and Internet of Things

The respective IALA publications' development timelines are presented in the subsequent section.

Potential Opportunities

The first observation from the review was the opportunity to enhance the comprehensiveness of existing IALA publications regarding emerging digital technologies. While several publications effectively cover foundational aspects such as MASS, VDES, S-100 digital information, and maritime cybersecurity, there is potential to develop comprehensive publications that provide similar guidance on other emerging digital technologies such as artificial intelligence, digital sensors, Internet of Things, satellite communications, digital twins, and maritime robotics technologies. This will help to set the baseline literacy of all IALA members and maritime industry towards the various emerging digital technology which will aid in their assessments on how these technologies would disrupt their existing operations and develop their future respective operation concepts.

It was observed that recommendations and guidelines for some digital technologies are covered more extensively over the others. This could be attributed to the different pace of the digital technology, or it could be the interests of IALA members to be focused on certain

technology over the others. While this may risk certain developed technologies being overlooked and hinders the development and adoption of these technologies. This may also discourage investment in less-promoted technologies, stalling innovation in those areas within the maritime industry and resulting in missed opportunities to harness potential technologies that could enhance maritime safety and operational efficiency. Therefore, it is crucial for IALA to ensure that all digital technologies receive adequate attention to keep pace with the developments.

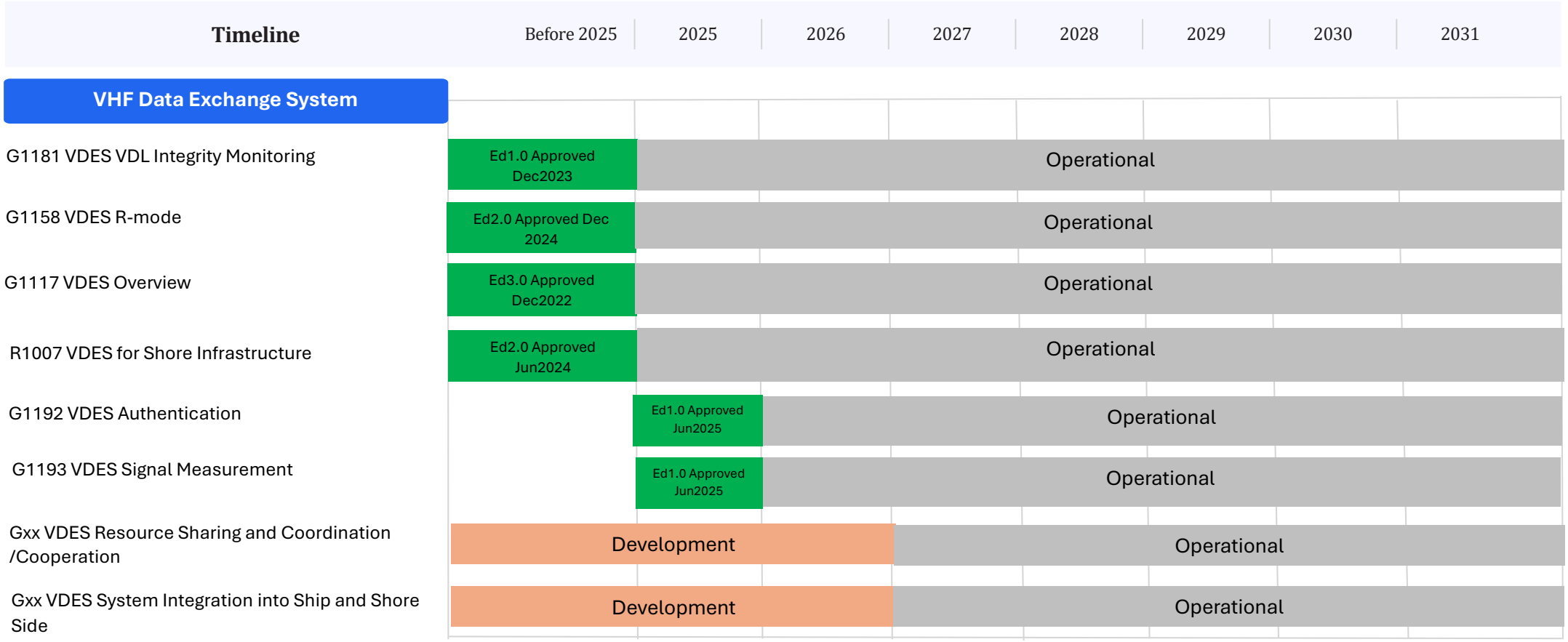
It was also observed that the publications on digital technologies span all four IALA committees. Some developments may require cross-committee collaboration, highlighting the need for closer and more effective communication mechanisms between committees. It is crucial for IALA to ensure coherent development in the digital publications in all committees. This can be achieved by establishing a clear IALA digitalization vision statement and digital strategies, as presented in the previous section, to foster better understanding and collaboration between committees. With unified goals and objectives, IALA can better focus its resources and work towards supporting digitalization developments for its members and the maritime industry.

To ensure that IALA continues to deliver quality digital technology publications, it must leverage its strengths by harness expertise from various national members, industry members and research institutions, while keeping a close watch on the relevant digital development at other international organisations. Providing a platform for discussion and the exchange of ideas among stakeholders will help ensure that diverse perspectives are considered when developing these publications. In navigating the uncertainties presented by advancements in digital technologies, it is vital for IALA to continue encouraging the sharing and demonstration of new digital technologies and experiences within its committees.

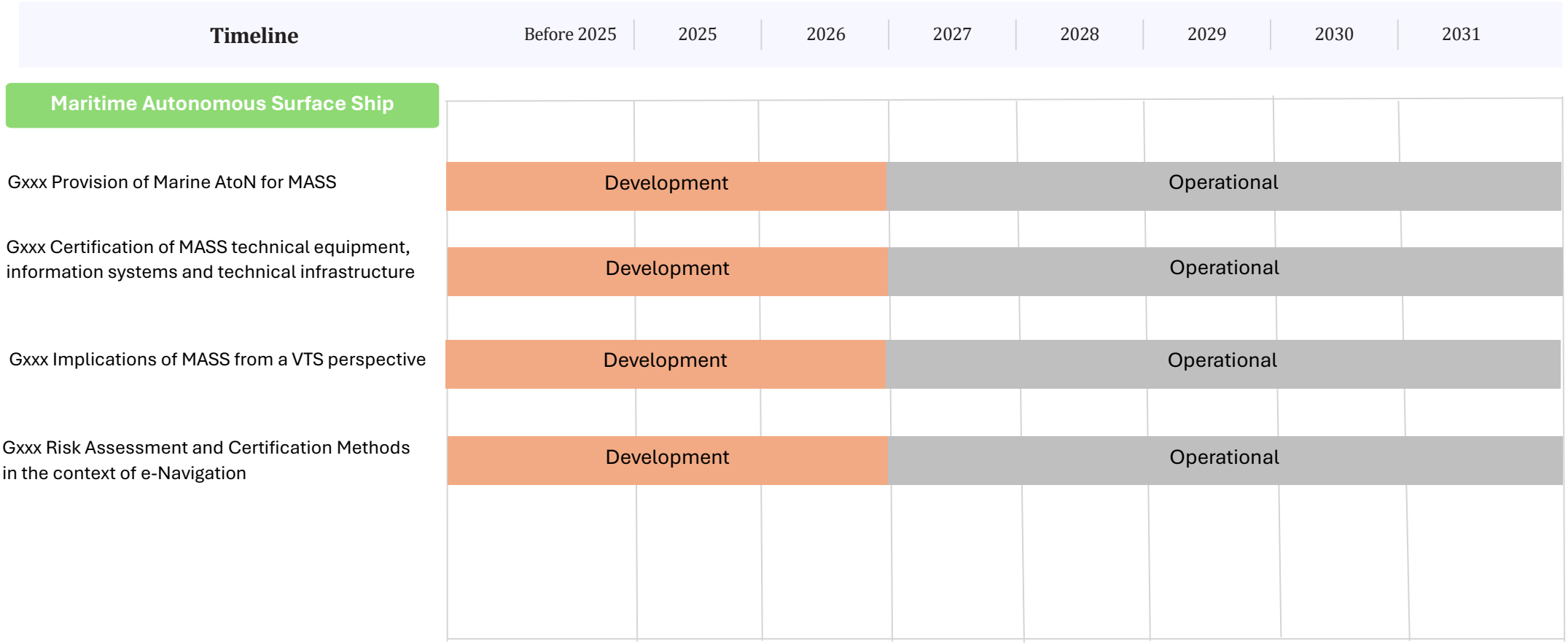
A critical aspect of IALA's digitalization strategy is the recognition of external dependencies and the need for close collaboration with other international organisations. The International Maritime Organization (IMO) is progressing several initiatives that intersect with IALA's domains, including the development of the MASS Code, a potential new output on maritime cybersecurity, the IMO Digitalization Strategy, and the Connectivity Framework for S-100. These initiatives (and others) may reference IALA standards, recommendations, and guidelines, and conversely, IALA must assess their implications for its own work, particularly in areas such as AtoNs, VTS, and the delivery of Maritime Services. Similarly, the International Hydrographic Organization's (IHO) ongoing development of the S-100 framework directly impacts IALA's S-200 product specifications and the associated technical services, including the Maritime Connectivity Platform (MCP). IALA must ensure alignment and interoperability across these frameworks. Furthermore, developments in the IMT and IoT space, including those led by the ITU and IEC, may influence communication technologies and infrastructure relevant to IALA's remit. To remain effective and future-ready, IALA's work programme must actively monitor, engage with, and contribute to these international efforts, ensuring that its outputs are both informed by and influential within the broader maritime digitalization ecosystem.

3.2 Development Timeline for Digital Information (S-100) Related Publications

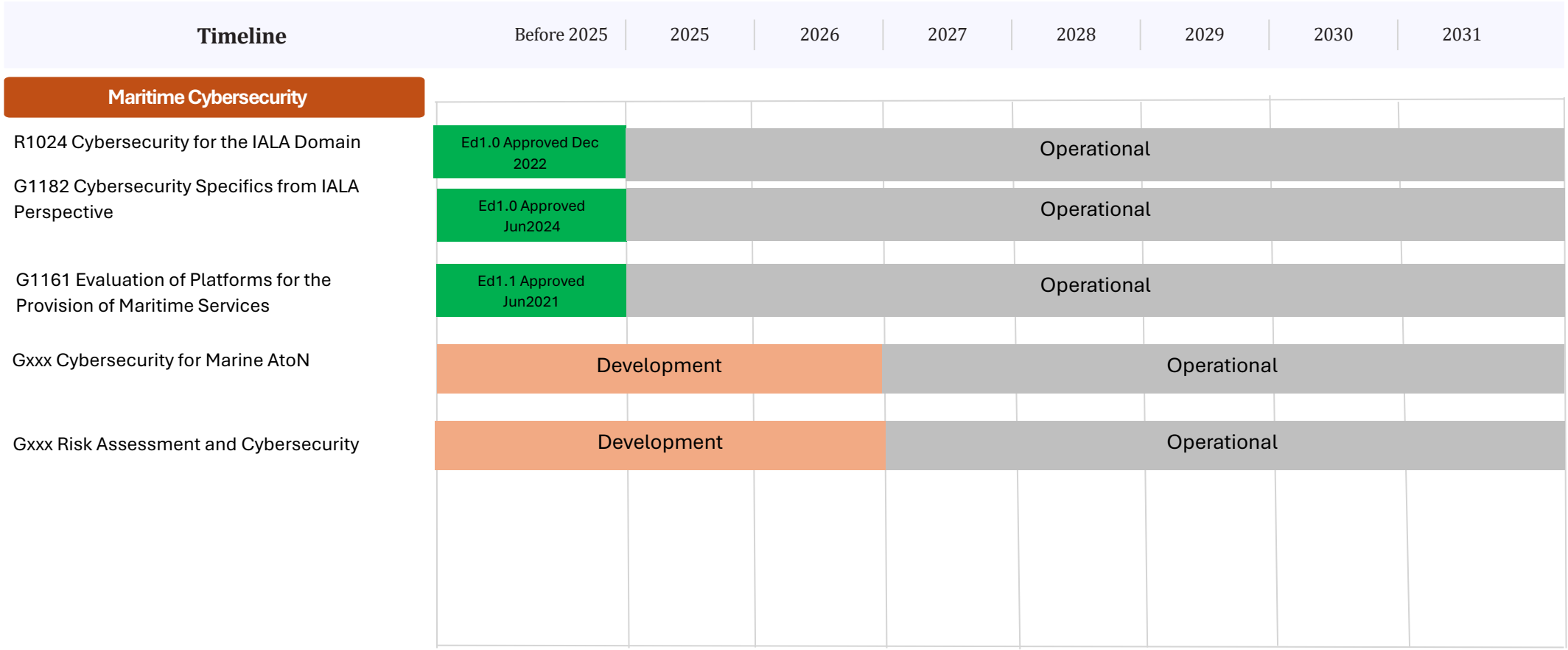
3.3 Development Timeline for VDES Related Publications



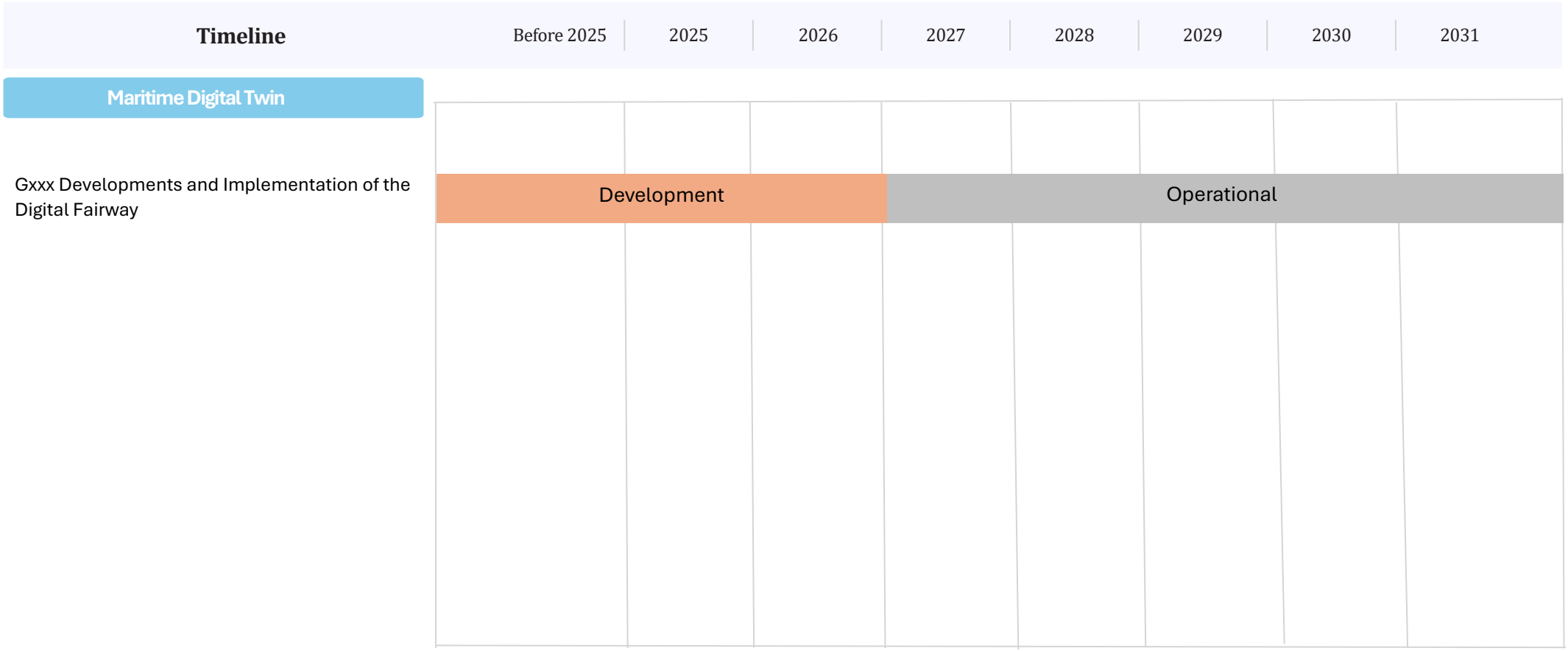
3.4 Development Timeline for MASS Related Publications



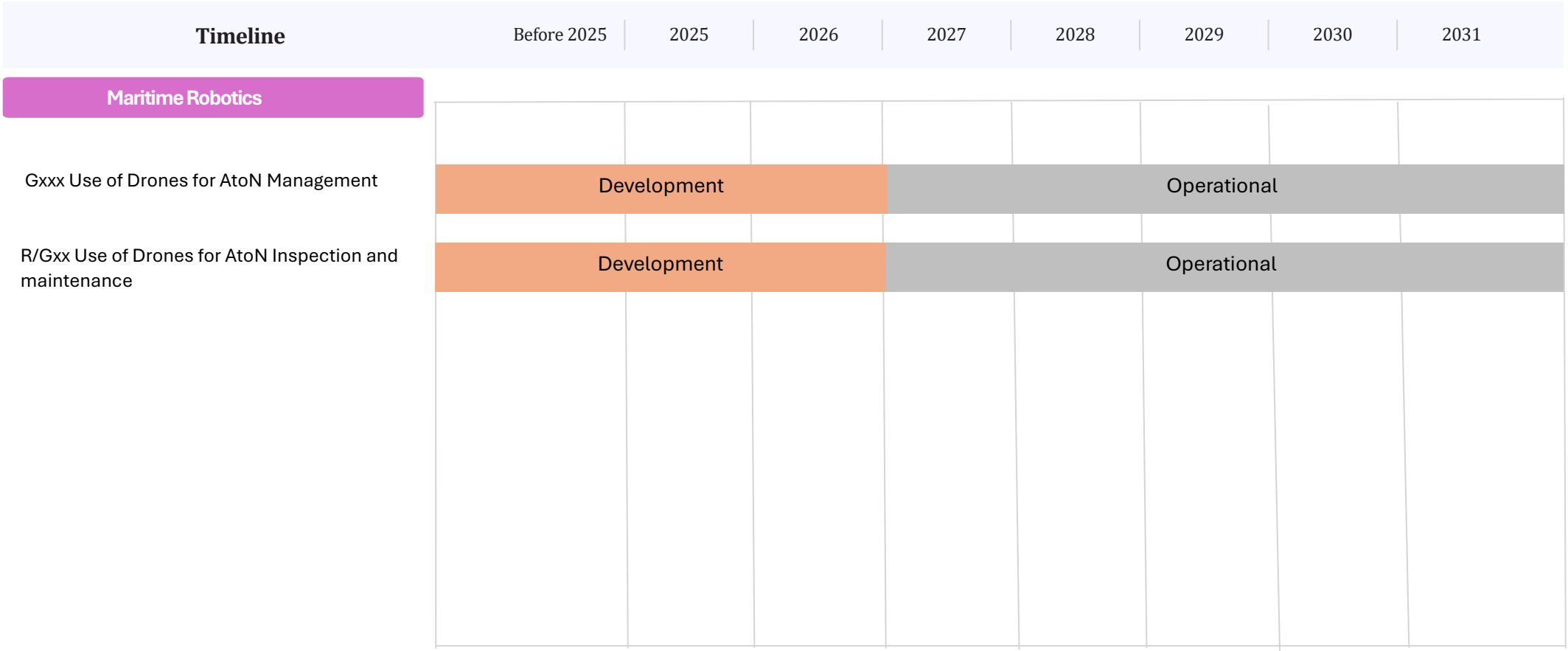
3.5 Development Timeline for Maritime Cybersecurity Related Publications



3.6 Development Timeline for Maritime Digital Twin Related Publications

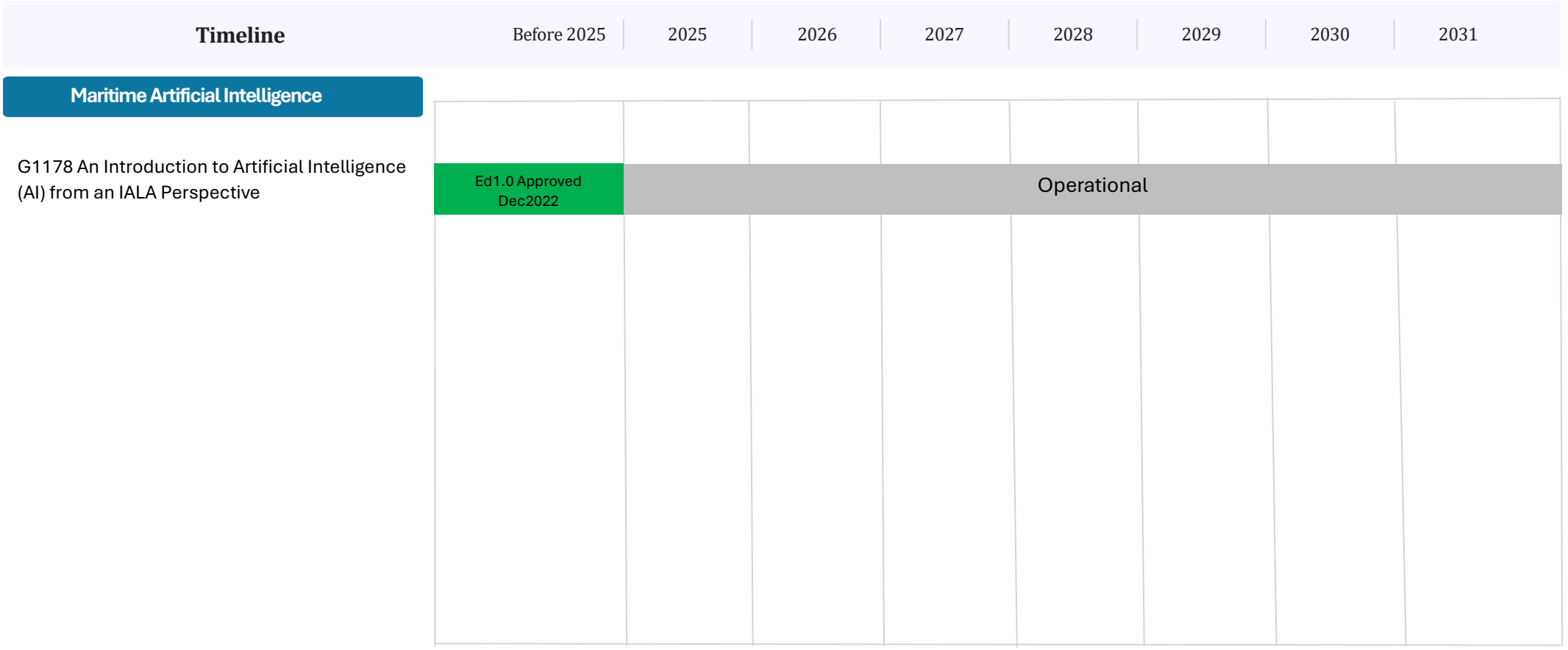


3.7 Development Timeline for Maritime Robotics Related Publications



3.8 Development Timeline for Digital Communications Related Publications

3.9 Development Timeline for Maritime Artificial Intelligence Related Publications



3.9 Development Timeline for Maritime Digital Sensors and IoT Related Publications

4 Conclusion

This discussion paper first presents the current key global trends driving maritime digitalization, which include the rapid advancement of digital technologies, shifts in end-user expectations, sustainability, a focus on safety of navigation, globalization, and cost efficiency and productivity. The paper identifies nine key digital developments relevant to both IALA and the maritime industry: digital information (S-100) technology, VDES, MASS, maritime cybersecurity, maritime digital twins, maritime robotics, maritime digital communications, maritime artificial intelligence, and maritime digital sensors and the Internet of Things. Each of these technologies is briefly described, along with its relevance and use cases in today's maritime world.

Recognizing the importance of establishing a common digitalization vision for IALA to communicate its ambitions to its members and other international organizations, this discussion paper also proposes a digitalization vision statement for IALA along with corresponding digitalization strategies to achieve that vision. The vision may serve as a guiding principle for future initiatives, ensuring that all efforts are aligned with the overarching goals of IALA. This will further instil confidence in stakeholders regarding IALA's commitment to advancing maritime digitalization efforts.

This paper presented information on the current state of publication developments within IALA towards the emerging digital technologies, timelines of such developments and discussed views from IALA members perspectives. The information in this discussion paper may be useful for IALA members in their planning of their digitalization journey and supports the IALA's future planning towards digital technology guidelines, recommendations and standards developments.

Lastly, it is recognized that IALA plays a pivotal role in shaping today's maritime digitalization and must continue to take on the responsibility of custodianship for maritime digital technology standards to help its members navigate through the disruptions and uncertainties associated with the adoption of digital technologies in their operations and strategies.

References

[1] Raza, Z., Woxenius, J., Vural, C.A. and Lind, M. (2023). Digital transformation of maritime logistics: Exploring trends in the liner shipping segment. *Computers in Industry*, [online] 145(145), p.103811. doi:https://doi.org/10.1016/j.compind.2022.103811.

[2] BCG Global. (2020). *The Digital Imperative in Container Shipping*. [online] Available at: https://www.bcg.com/publications/2018/digital-imperative-container-shipping.

[3] Nunes, R.A.O., Alvim-Ferraz, M.C.M., Martins, F.G. and Sousa, S.I.V. (2024). Towards a Sustainable Growth of the Shipping Sector—A Systematic Review of Future Shipping Emissions Scenarios. *Sustainable Development*, 33(3), pp.3554–3575. doi:https://doi.org/10.1002/sd.3291.

[4] Llody's Register (2023) Global Maritime Trends 2050. The Economist Group.

[5] International Maritime Organization (2023). *IMO's work to cut GHG emissions from ships*. [online] www.imo.org. Available at https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx.

[6] Vdes-alliance.org. (2025). *VDES Alliance – Making VDES Happen*. [online] Available at: https://www.vdes-alliance.org/ [Accessed 22 Jul. 2025].

[7] Satellite VDES Consortium. (2023). *Satellite VDES Consortium*. [online] Available at: https://vdes.jp/en/ [Accessed 22 Jul. 2025].

[8] Shonae (2022). *Blockchain Technology: The Future of Shipping*. [online] International Cargo Express. Available at: https://icecargo.com.au/blockchain-technology-the-future-of-shipping/.

[9] IALA AISM. (2025). *Advancing Maritime Digitalization: The Development of the IALA S-200 Product Specification Series - IALA AISM*. [online] Available at: https://www.iala.int/e-bulletin/advancing-maritime-digitalization-the-development-of-the-iala-s-200-product-specification-series/ [Accessed 22 Jul. 2025].

[10] Tajudeen, F.P., Nadarajah, D., Jaafar, N.I. and Sulaiman, A. (2021). The impact of digitalisation vision and information technology on organisations' innovation. *European Journal of Innovation Management*, ahead-of-print(ahead-of-print). doi:https://doi.org/10.1108/ejim-10-2020-0423.

[11] IALA AISM. (2024). *Homepage - IALA AISM*. [online] Available at: https://www.iala.int/.