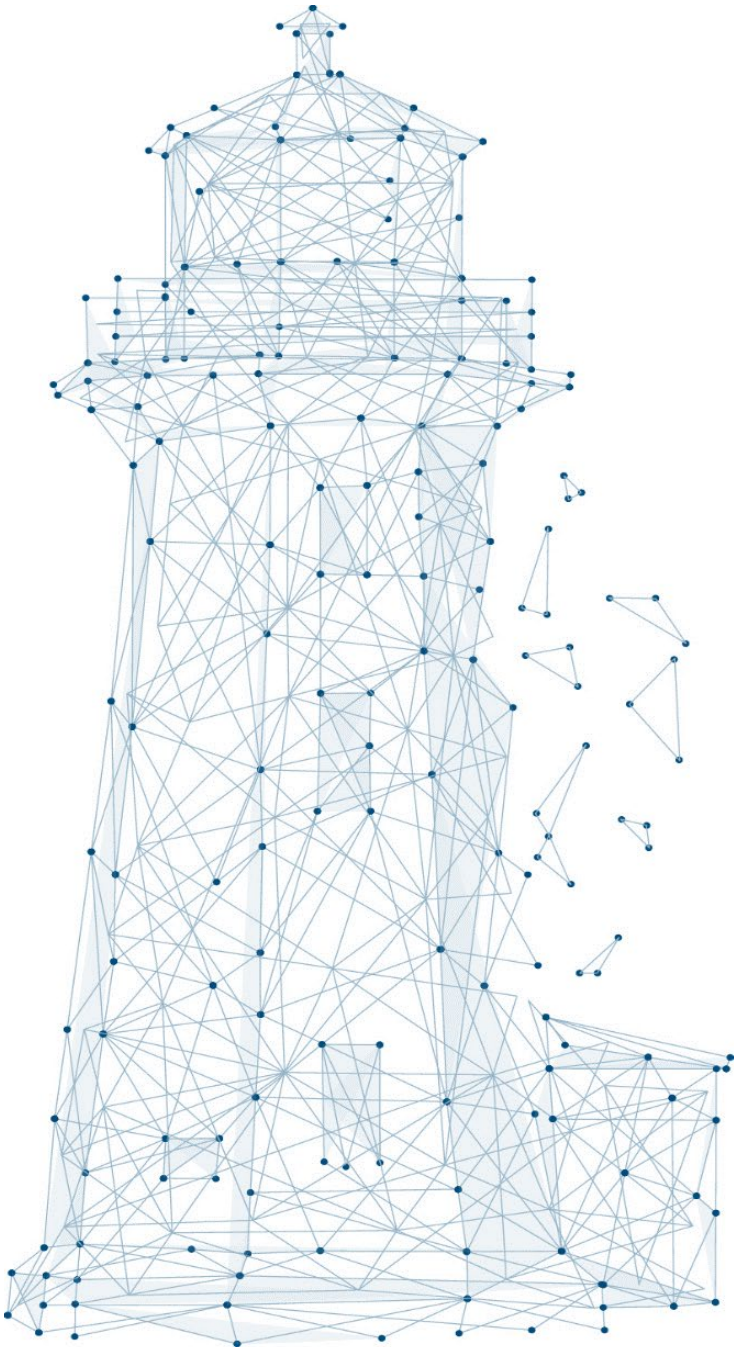
Australian Government

Australian Maritime Safety Authority

Navigation Services in Australian Waters

Outlook to 2035



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Foreword

I am pleased to present Navigation Services in Australian Waters – Outlook to 2035.

Five years from the initial release, this revised work maintains the forward-looking, perceptive viewpoint as it identifies emerging trends and drivers that will influence navigation services in our waters. It also describes the anticipated impact these will have on the maritime industry and lists the Australian Maritime Safety Authority's (AMSA) policy response to these changes.

Predictions have been made in this document, some of which could be described as being overly optimistic. But these are made for good reason, to promote thought and vision setting.

This work remains increasingly relevant, as changes in the way vessels receive, integrate, display and exchange information and use this information to navigate continue to gather pace.

Navigation Services in Australian Waters – Outlook to 2035 also contains a set of guiding principles for AMSA's provision of navigational services. It articulates the authority's aspirations and provides a basis for prioritising activities.

Leanne Loan
Executive Director, Policy and Regulation
September 2024

Executive Summary

Navigation Services in Australian Waters – Outlook to 2035 provides an insight into the provision of navigation services over the next decade (and beyond) for ships trading internationally and domestic commercial vessels (DCV).

It takes into account emerging trends and drivers in technology and communications for marine navigation and the impact on the maritime industry. It also details AMSA's policy response to these rapidly evolving changes in the navigation services landscape and projected response timeframes.

To set an authentic context of what lies ahead, *Navigation Services in Australian Waters – Outlook to 2035* takes the reader on a futuristic voyage on board the fictitious Blue Sky, a gas carrier en route from Hay Point, Queensland to Singapore. The scenario describes the types of technologies—new and legacy—that could be used by a typical Panamax-sized gas carrier in the year 2035.

The pace of change is great and AMSA, in keeping with our maritime safety and environmental protection responsibilities, will need to be agile and innovative in response.

For example, AMSA can contribute to a global approach to resilient Positioning, Navigation and Timing (PNT), and play a vital role in the adoption of Satellite Based Augmentation System (SBAS) by the maritime sector in our region. Additionally, AMSA's network of traditional physical aids to navigation (AtoN) will remain an essential component of navigation services available for the safe navigation of ships. However, by 2035 they may be secondary to the way in which many (but not all) vessels will navigate.

Automated navigation of ships represents a monumental shift in global surface transportation but, as the *Blue Sky* experience reveals, supporting systems such as physical AtoN and forms of operational control by humans will continue to remain relevant to the conduct of safe navigation.

AMSA's policy response in this regard will include enhancing the efficiency and effectiveness of its AtoN network, and putting measures in place to protect it (and future navigation networks) from cybercrime.

Key to *Navigation Services in Australian Waters – Outlook to 2035* is a set of principles to guide AMSA in the delivery of these new practices and technologies to enhance the ongoing appropriateness and reliability of navigation services. These principles also reaffirm AMSA's exemplar commitment to stakeholder and community engagement, and observance of the relevant conventions and International Maritime Organization (IMO) obligations.

Navigation Services in Australian Waters – Outlook to 2035 provides a prioritised framework for AMSA to continue fostering a safe, efficient, sustainable and secure maritime transport system for Australia.

1. Introduction

1.1 AMSA's role and responsibilities

AMSA is Australia's national maritime safety agency. AMSA's primary roles of maritime safety, protection of the marine environment from ship-sourced pollution, and maritime and aviation search and rescue (SAR) are established in *the Australian Maritime Safety Authority Act 1990*.

International trade is vital for the nation's prosperity. Australia is among the largest users of shipping services accounting for over 10 per cent of the world's seaborne trade. Australia also has some of the world's most environmentally sensitive sea areas, which vessels from across the globe must navigate to reach our ports.

The Navigation Act 2012 gives effect to international conventions on maritime safety issues including *the International Convention for the Safety of Life at Sea* (SOLAS). AMSA is responsible for many of Australia's obligations in Chapter V (Safety of navigation) of SOLAS to provide modern, fit-for-purpose navigation services that facilitate safe navigation.

A hallmark of AMSA's navigation services is a network of over 480 AtoNs at 360 sites around Australia. The number and type of AtoN at each site are optimised to support safe navigation by commercial shipping on coastal voyages. AMSA's AtoN network is consistent with the standards and guidance of the IMO, the International Telecommunication Union (ITU) and the International Association of Marine Aids to Navigation (IALA).

In addition to AtoN, AMSA's navigation services include ships' routeing and reporting systems, promulgation of maritime safety information (MSI), coastal pilotage, vessel traffic services (VTS), and an under keel clearance (UKC) management (UKCM) system in the Torres Strait.

1.2 About this work

Navigation Services in Australian Waters – Outlook to 2035 provides an insight to the provision of navigation services in the coming years. It takes into account emerging trends and drivers in technology and communications for marine navigation and outlines their impact on the maritime industry. It also informs the reader about AMSA's policy response to these changes.

This work encompasses the provision of navigation services for ships trading internationally and DCVs.

Navigation Services in Australian Waters – Outlook to 2035 will contribute to fostering a safe, efficient, sustainable, and secure maritime transport system for Australia.

2. Case study – navigating from Australia in the year 2035

The year is 2035. In December, Liberian-flagged Panamax-sized gas carrier *Blue Sky* (a fictious ship) is en route from Hay Point, Queensland to Singapore via the Great Barrier Reef, Torres Strait and Coral Sea particularly sensitive sea area (PSSA) (AMSA 2023a).

The vessel is 280 metres long, 30 metres in breadth and has a current draught of 12.2 metres. *Blue Sky* is carrying ammonia as cargo and using onboard ammonia as fuel, and has a deadweight capacity of about 65,000 metric tonnes.

Blue Sky's safe and efficient transit to Singapore is aided by an array of digital navigation and maritime services which were implemented alongside other measures to establish a Green and Digital Shipping Corridor between Australia and Singapore (DFAT 2024a).

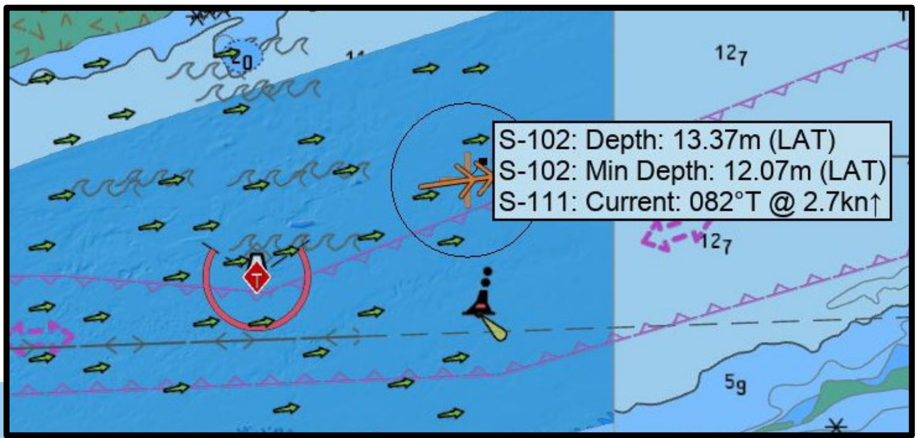
Route planning and sharing

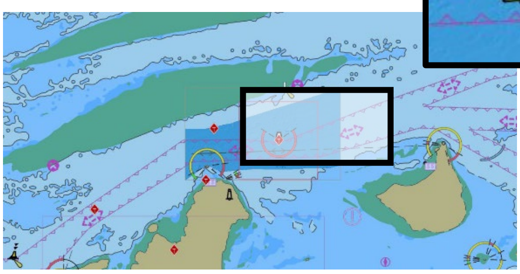
The intended voyage plan from Hay Point is prepared ashore by an authorised service provider and transmitted electronically to the ship, to be reviewed and executed.

Preparation ashore ensures inclusion of up-to-date, region-specific information that could impact the ship's voyage, such as forecast weather and sea state, UKC requirements, air draughts, no-go areas, MSI and compliance with any mandatory requirements.

To further refine the voyage, *S-100 Universal Hydrographic Data Model* (S-100) data products – including surface current data, high-resolution bathymetry, and real-time water level information – will be integrated into the voyage plan once it is uploaded onto the ship's Electronic Chart Display and Information System (ECDIS). Increasingly available in the past decade, *Blue Sky's* navigation team takes full advantage of the access to precise current forecasts, detailed undersea terrain maps, and tide information to enhance route safety and efficiency.

Blue Sky's navigation team takes full advantage of precise current forecasts, detailed undersea terrain maps, and tide information available in the ship's ECDIS





[Top] Inset showing S-102 Bathymetric Surface over ENC data for Nardana Patches in the Torres Strait

[Bottom] Image of Electronic Navigational Chart (ENC) for Prince of Wales Channel in the Torres Strait

Blue Sky's route from Hay Point to Singapore, once finalised, is shared electronically with relevant authorities such as the Great Barrier Reef and Torres Strait Vessel Traffic Service (ReefVTS), port and coastal pilots, as well as the company control centre ashore.

Services en route

Before its departure from Hay Point, *Blue Sky* will access a range of digital maritime services related to its voyage, based on its preferences. Examples of this are electronic navigational charts (ENC), weather, MSI and ReefVTS or other VTS centres. An example specific to Torres Strait is UKCM information from AMSA's system. This will enable *Blue Sky* to transit through Torres Strait safely and efficiently, with the maximum amount of cargo, commensurate with the permissible draught, supported by the services of a licensed coastal pilot.

When *Blue Sky* reaches Torres Strait, the route through Prince of Wales Channel—which is part of AMSA's UKCM service area—will be made available automatically. Using an internationally agreed standard for sharing UKCM information, the UKCM service provider will confirm the available tidal window to transit. The service provider will supply overlays, that display seamlessly on the ship's navigation system, to show non-navigable and almost non-navigable areas. The ship's crew and the coastal pilot will use the same information to ensure a shared mental model of the navigation plan.

Based on the ship's unique digital identity and associated permissions, it will be able to access services, such as en route ENC, weather and other updates, to optimise the passage. Further, *Blue Sky* will also be able to configure when and how it will receive such messages.

Regulated communication systems (I.e., Global Maritime Distress and Safety System (GMDSS)) will be supplemented by widely available commercial terrestrial and satellite services, in a competitive market, as more providers will offer services. The Officer of the Watch (OOW) will not need to choose a communications bearer—this switch will occur automatically and seamlessly, without any need for operator intervention.

Route monitoring

When the ship is navigating in open waters, automated, onboard systems will monitor the ship's progress, supporting bridge watch-keepers in carrying out manual routine tasks.

With its route either shared in advance or updated in real-time, VTS providers will be able to detect if Blue Sky deviates from its planned route. They will also be able to foresee any developing dangerous situations such as converging traffic and suggest route modifications, improving route efficiency and safety.

Route exchange will also allow for possible new route suggestions based on external factors such as weather, sea state and traffic density. These will be transmitted automatically from ashore and will be used on board, on demand.

Radionavigation - Positioning, Navigation and Timing information

Blue Sky will benefit from continuous PNT information from multiple Global Navigation Satellite System (GNSS) constellations. SBAS will provide improved accuracy and integrity and terrestrial back-up systems will also be used where available.

Ship positioning methods like radar image matching, conspicuity mapping, terrain matching, and simultaneous location and mapping will enhance the accuracy and reliability of navigation information. These methods use multi-source PNT data processing units to cross-check and strengthen positioning and navigation. Additionally, physical terrestrial services such as eRACON could be used for improved PNT resilience in coastal waters.

Onboard systems and watch-keepers will be aided by a modern and technology enabled, physical AtoN network that will be used to validate position and provide safety assurance, ensuring safe navigation.

Port arrival

To ensure that *Blue Sky* does not arrive before the port is ready, the ship, the operator ashore, and the receiving port's digital port window will harmonise routing plans through regular communication with the ship and will automatically allocate an optimum arrival time. This exchange will be conducted as early as possible, to let the ship adjust speed, save fuel, and reduce greenhouse gas (GHG) emissions.

Use of a national Maritime Single Window (MSW) for transmission of cargo manifests, digital ship reporting, and immigration information, will reduce workload of the crew and allow for the supply chain network to be optimised. Digital maritime services such as remote pilot and tug booking applications will be used for entry into port limits.

Studies have shown that speed optimisation using digital services such as just-in-time arrival (JITA) can save up to 14% on fuel costs (IMO 2022). Furthermore, it has been shown that exploring new routes can reduce fuel consumption by over 40% (KHOA, KRISO 2022). These routes, previously unsuitable for navigation due to low confidence in the accuracy of location of charted features, can now be used thanks to high-quality bathymetry data, and are aided by surface current data and real-time water level information.

Use of a common digital environment will improve the coordination of services such as tug services by providing up-to-date information on ship arrival times and services required.

3. Community expectation

There is broad expectation that ships transiting Australian waters are seaworthy, and are operated and navigated safely by competent seafarers. There is zero tolerance for shipping accidents and ship-sourced marine pollution, particularly in environmentally sensitive waters such as the Great Barrier Reef, Torres Strait, Coral Sea, the waters off the north-west coast of Australia, and the Great Australian Bight.

The increasingly diverse mix of industry sectors including offshore renewable energy, operating in Australia's blue economy present new challenges for traditional ocean users. Additionally, it is important to understand that the maritime industry tends to take a careful approach to change, prioritising safety and reliability. Rapid technological advances have brought about a mix of old and new—traditional methods like paper charts and manual controls are still in use, while digital services, automation, and autonomy are becoming more common. This requires us to be thoughtful in how we manage change, making sure we keep the best of what we've had while embracing the new technologies that can make things better.

The unique and diverse nature of Australia's maritime environment drives AMSA to do its utmost to ensure only vessels of the highest quality and standards call at our ports. In this regard, Australia's strict and fair port State control (PSC) regime is widely noted throughout the global maritime community. AMSA regularly engages with maritime safety agencies in the Asia-Pacific and Indian Ocean regions through forums, agency to agency collaboration and delivery of training for PSC staff (AMSA 2023b).

Whether we are developing our own standards for DCVs or working internationally to influence the development of global standards for shipping, our primary focus is about managing the risks to safety and the marine environment. In terms of navigation services, this includes the adoption of real-time information systems, improving the accessibility and integration of navigation tools, and maintaining cost-effective and secure navigation services.

It is imperative AMSA influences our regulated communities, port authorities, private entities, and researchers to embrace technological advancements through digitalisation of the maritime industry. This will ensure that navigational safety standards evolve with the industry, there is an increased environmental protection mechanism, further contribution to de-carbonisation through voyage optimisation, and a reduction in the physical burden on seafarers in Australian waters resulting in less fatigue.

AMSA AtoN Cape Byron lighthouse - Awarded IALA heritage lighthouse of the year, 2021

4. Trends, their implications for industry and our policy response

Over the coming years, the following trends are expected to affect AMSA's provision of navigation services. The tables below outline the implications for industry and our policy response to the coming changes.

4.1 Positioning, navigation and timing

Electronic PNT solutions are the norm for the modern mariner, with several GNSS available. PNT accuracy is improved by augmenting the GNSS signal. In the maritime sector ground-based augmentation systems (GBAS) are increasingly making way for satellite solutions to increase GNSS position accuracy.

GNSS signals are vulnerable to disruptions such as jamming and spoofing, where signals are deliberately blocked or falsified (Burgess 2024). The growing frequency of such incidents underscores the need for enhanced protective measures, the development of alternative navigation solutions and a global consensus on a coordinated approach to resilient PNT for the maritime sector (Critchley-Marrows et al. 2024).

PNT also underpins a variety of safety-related maritime services and is a key requirement for e-navigation (IMO 2018). Achieving resilient PNT requires effective solutions for the synthesis of data from disparate PNT technologies.

Examples of PNT technologies include:

- Multi constellation GNSS receivers
- SBAS for GNSS
- Radar absolute positioning (includes, e-RACON and enhanced radar positioning systems (ERPS), radar conspicuity mapping, terrain mapping, and Simultaneous localization and mapping (SLAM))
- eLoran (enhanced Loran, a modernised version of Loran-C)
- Light detection and ranging (LiDAR)
- Inertial navigation systems (INS)
- Fusion techniques for PNT information

The Australian and New Zealand governments operate the Southern Positioning Augmentation Network (SouthPAN) SBAS service for the Australian region (GA 2024a). Work is being conducted internationally to develop performance and acceptance standards for the maritime sector.

For more information on the SouthPAN SBAS, see **Appendix A**.

Trends that will affect positioning, navigation and timing services	Implications for industry	Our policy response & timeframes
• Multi-constellation GNSS has become the primary source of PNT information. • Augmented GNSS (either by ground-based or satellite means) will continue to play a vital role in the provision of high accuracy and integrity-proven PNT information.	• Ships will increasingly rely on electronic PNT information, primarily GNSS-based. This will result in safety and efficiency benefits, including improved accuracy and integrity monitoring. • SouthPAN early Open Services have been operating since September 2022, with safety-of-life certified SouthPAN services expected in 2028. • To enable marine GNSS receiver equipment to make use of SBAS, changes to onboard equipment may be necessary to meet IMO and International Electrotechnical Commission (IEC) standards.	• Work at IALA to develop guidance for its members to transition from GBAS to SBAS. *Mid term* • Work at IMO and IEC, liaise with the International association for marine electronics companies (CIRM) and other bodies to facilitate the introduction of SBAS-enabled marine GNSS receivers. *Mid term* • As SBAS continues to be implemented in the Australian region, work domestically to ensure maritime interests are part of the SBAS program. *Ongoing* • Promote the SBAS awareness campaign throughout the maritime industry to encourage the uptake of SBAS (AMSA 2023c). *Ongoing*
• The increasing availability of GNSS and other sources of electronic PNT information (e.g. e-racons) are contributing to resilient PNT on board ships. • Development of a variety of technologies to integrate satellite, terrestrial and ship-sensed PNT solutions on board ships. • Growing consensus that a national PNT resilience plan is required to mitigate degradation of satellite based PNT solutions due to intentional or unintentional interference.	• Over-reliance on GNSS can make ships vulnerable to signal interference, jamming, or spoofing, compromising navigation. • Benefits of integration of PNT information will accrue to: – coastal navigation – navigation in environmentally sensitive sea areas – port approaches – harbour manoeuvring	• Critically appraise emerging PNT technologies for their suitability to provide resilient PNT in Australia. *Ongoing* • PNT resilience planning may require the re-commissioning of some physical terrestrial PNT infrastructure. *Mid term*

4.2 Marine aids to navigation

AMSA maintains a network of over 480 marine AtoN, consistent with international standards, to ensure safe navigation in Australian waters. AtoN are established where the volume of traffic justifies, and degree of risk requires.

AMSA's AtoN network is primarily used by commercial shipping and includes traditional lighthouses, beacons and buoys as well as electronic aids (i.e., racon and Automatic Identification System (AIS) AtoN). The states, ports and territory collectively operate many more AtoNs.

The advent of virtual AIS AtoNs has allowed the rapid deployment of a digital navigation marker. Transmitted from a separately located AIS base station these digital markers offer several advantages: weather resilience, flexibility and cost-efficiency, coverage and adaptability. Notwithstanding these benefits, limitations to consider include requirement for suitably located base stations, risk of inaccurate position data, and susceptibility of AIS data to spoofing or jamming.

AIS AtoN technologies will need to be replaced with systems that are protected in line with modern cyber security best practices. The concept of a secure virtual AtoN via AIS-Application Specific Messages (ASM) and VDES has been proven (Wipmenny et al. 2018). At this stage further development is pending consensus on optimal technologies.

In light of these considerations and noting that not all vessels are equipped to receive and interpret virtual AtoN information, virtual AtoN are not intended to replace physical markers but rather complement them where traditional infrastructure is impractical.

Proper training and awareness among mariners is essential to effectively utilise these tools and ensure navigational safety.

Aid to Navigation	Number
Primary lights (includes floating aids)	346
Secondary lights	12
Unlit beacons	3
Racons	37
Tide Gauges	5
Radar facility	0
AIS facility	60
Met-ocean sensors	5
Virtual AIS AtoN	19
Total AtoN	**487**

Number and type of AtoN operated by AMSA, July 2024.

As the custodian of many iconic historic lighthouses, AMSA has long recognised the importance of preserving their cultural heritage and will continue to implement management strategies for their preservation

Trends that will affect Aids to Navigation	Implications for industry	Our policy response & timeframes
• Maritime communications will be an enabler for innovative AtoN solutions. • Growing use of electronic AtoN (e.g. AIS/VDES AtoN) to supplement the physical marking of hazards to navigation, particularly temporary hazards. • The relative ease of establishing virtual AtoNs (i.e., for marking hazards in an emergency). • Advances in the development of physical AtoN (Internet-of-Things).	• Ships will increasingly need modern navigation systems that are capable of effectively using electronic AtoN. • Virtual AtoN will remain effective to increase awareness of navigation hazards for crew on vessels equipped with compliant navigation systems. • Benefits are: – Enhanced safety through real-time and accurate information – Integration with existing onboard systems (e.g., complementing visual aids) – Faster response to temporary hazards	• Explore obtaining near real time satellite VDES information for use at AMSA. *Mid term* • Optimise and maintain AMSA's terrestrial AIS infrastructure, particularly in areas where it is important to transmit messages to ships via AIS (e.g. from ReefVTS). *Ongoing* • Provide existing data from tide gauges and metocean sensors in machine-readable formats. *Mid term*
• Physical AtoNs may become a secondary source of navigation information for some vessel types, however, will remain essential component of Australia's AtoN network. • With growth in the use of new technology radars, conventional racons are not as effective. • Harmonisation and improvements in AtoN networks remain important nationally and internationally.	• Improved AtoN network efficiency and cost savings, as providers regularly review their mix of visual and electronic AtoN.	• Conduct periodic reviews to critically assess the need for individual AtoNs, to ensure the safety of coastal navigation for domestic and international trading vessels. *Ongoing* • Work with AMSA's contracted maintenance service providers to adopt technologies and innovative practices that enhance the efficiency and effectiveness of AMSA's AtoN network. *Ongoing*
• Increasingly connected networks of navigation services and AtoNs may be vulnerable to cyber threats.	• There is potential for cybercrime to have an adverse effect on the provision of AtoNs and availability of navigation services.	• Consider the importance of cyber security and software quality assurance for the integrity of AMSA's AtoN network (including AMSA's UKCM system) *Ongoing*
• Heritage lighthouses will continue to be an important part of Australia's culture.	• Management of heritage lighthouses remains an important part of AMSA's obligations.	• Meet our obligations regarding our heritage-listed lighthouses. *Ongoing*

4.3 Digital Maritime Services and the S-100 data model

IMO's e-navigation Strategy Implementation Plan (SIP) foreshadows the exchange and presentation of navigation-related information, in electronic form, between shore and ship. Termed Maritime Services, they aim to reduce workload and human errors, improve efficiency and situational awareness, and enhance the safety of navigation.

According to IMO, the term Maritime Service "*refers to the provision and exchange of maritime-related information and data in a harmonised, unified format*" (IMO 2019). For each service, domain coordinating bodies (e.g., International Hydrographic Organization (IHO), IALA, World Maritime Organization (WMO), etc.) are assigned responsibility for guiding implementation activities and developing technical service specifications. The actual provision of a service is within the responsibility of the service providers (national authorities, hydrographic offices, SAR services, etc.).

Examples of Maritime Services:

- MSI including;
  - Navigation warnings promulgated by the Joint Rescue Coordination Centre (JRCC) and the Bureau of Meteorology (BoM),
  - Warnings issued by state or territory marine safety agencies and port authorities,
  - Notices to mariners (NTM) issued by the Australian Hydrographic Office (AHO) and state and local waterway authorities.
- Real-time and forecast tide and tidal stream information
- Interactive and integrated weather and wave overlays issued by BoM,
- Services available in the Great Barrier Reef and Torres Strait including shipping traffic information provided by ReefVTS.

The SIP identifies 15 maritime services. These are listed at **Appendix B.**

The maritime sector is currently experiencing a significant transformation, driven by key trends such as the introduction of Maritime Autonomous Surface Ships (MASS). While MASS represents an emerging trend in maritime technology it is only one element of the broader evolution in maritime operations and digitalisation. The integration of such technologies with VTS and pilotage systems requires further advancements in digitalisation, data exchange protocols and cybersecurity.

A common maritime data structure (CMDS) is crucial to represent relevant maritime information in a standardised way. This is essential for the interoperability between different information systems and facilitates the extension of existing systems or the development of new services.

S-100 has been adopted for the implementation of the CMDS.

The S-100 data standard supports various types of data sources. Building on this framework, specifications have been developed for representing the various types of maritime data that are required support the digitalisation of maritime services. These include ENCs (S-101), navigational warnings (S-124), AtoN information (S-125), traffic management information (S-127), UKCM data (S-129) and others (IHO, 2024).

Next-generation connectivity frameworks such as the Maritime Connectivity Platform (MCP) help to make these standardised services available to end-users and secure the underlying data exchange.

A conceptual overview of the MCP is given in **Appendix C.**

Trends that will affect digital maritime services	Implications for industry	Our policy response & timeframes
• The advent of digital maritime services will improve the way that navigation and safety-related information is exchanged between ship and shore. • Digital maritime services will become available for all types of commercial ships, as communication technologies become more readily available. • Integration of onboard systems will increase, and the exchange and display of navigation and safety-related information will become more harmonised. • (MASS) highlights the need for a renewed emphasis on data modelling that supports machine readability.	• S-100 compatible ECDIS to be available for installation from 1 January 2026. From 1 January 2029 all new ECDIS equipment installations (new build vessels and equipment replacement) must be S-100 compliant. • Digital maritime services will provide navigation and safety-related services more efficiently onboard. This will reduce workload and improve situational awareness, leading to improved safety outcomes. • Onboard navigation systems will become increasingly integrated, connected to shore and, to some extent, standardised. For example: – integration between GMDSS and navigation equipment – ECDIS / Integrated Navigation Systems (INS) linked directly with communications equipment, i.e., VDES or satellite – standardised user interface design for navigation equipment – harmonised display of navigation information • Overall benefits accrue to: – increased efficiency in several areas – improved situational-awareness and decision-making – reduction of emissions through route optimisation, JITA, continuous monitoring and data analysis – improved emergency response systems leading to less risks for seafarers	• Provide leadership nationally for the provision of digital maritime services. *Ongoing* • Support the development of the S-100 data model and utilise its potential in the implementation of new services. *Ongoing* • Work with relevant international organisations to ensure that digital maritime services received on ships are displayed on board in a harmonised and effective manner, conforming to approved protocols for information exchange. *Mid term* • Participate in testbed projects to demonstrate the provision of digital maritime services in the region using the MCP. *Near term* • Participate in the development of the international governance framework of the MCP. *Near term*

4.4 Communications bearer

New distribution methods are required to achieve real time transfer of the data associated with digital maritime services. The means of exchanging data must have the capacity to support the secure two-way transmission of potentially large datasets associated with S-100 data products.

The performance requirements for communication systems bearing digital maritime services depend on the specific service and associated factors such as: bandwidth requirements, cost, location, or legal requirements. Candidate technologies include cellular networks (4G, 5G, etc.), internet via Low Earth Orbit (LEO) satellite constellations, and VDES.

A feature of cellular networks and modern LEO constellations is Internet Protocol (IP)-based communications. The advantage of these technologies is their broad range of applications including significant benefits to cyber-secure digital maritime services. Continuous broadband internet connectivity will become a baseline requirement for the effective conduct of shipping operations. Coupled with societal expectations for crew connection, education and entertainment, it is expected that the number of vessels with broadband connectivity will continue to grow.

Cellular Networks.

Cellular networks have become increasingly relevant for maritime communication in coastal areas. When a vessel is in the range of a cell tower, the crew or onboard systems can access the internet, make voice calls, send text messages, or transmit data. There are also many initiatives focusing on the provision of maritime information via IP, either by public-facing web portals or by standardised web services. Additionally, new technologies like LTE-Maritime, specifically developed for maritime environments, extend the reach and speed of these connections, offering high data rates and coverage up to 100 km from shore.

Low Earth Orbit satellite constellations.

LEO satellites are an emerging technology that is increasingly utilised for providing worldwide internet access. Due to their low orbit, they can provide high-speed and low-latency internet connectivity. This is especially useful for real-time applications and Maritime Services that require large amounts of data to be transmitted to or from distant locations where most other terrestrial communication links are not feasible for ship-to-shore communication (e.g., GMDSS sea area A3).

VHF Data Exchange System.

VDES was developed by the ITU and IALA as the successor to AIS.

Through a combination of terrestrial and satellite components VDES' two-way communication capability and potential for worldwide coverage eliminates key limitations of traditional AIS. VDES also features a higher bandwidth allowing for integration of cyber security protocols and possible use in the communication of low to medium-intensity data applications. VDES supports a range of e-navigation use cases including SAR, VTS and ship reporting.

For more information on VDES, see **Appendix D.**

To address the cybersecurity challenges associated with increased connectivity and automation, the industry is moving towards implementing cyber-resilient mechanisms. These include comprehensive training for personnel on cyber threats and best practices, the adoption of secure cloud services for data storage and processing, development of business continuity plans to mitigate cyber incidents, and the validation of data from multiple sources (i.e., AIS, radar, cameras, and Long-range identification and tracking (LRIT)) to ensure accuracy and integrity.

Trends that will affect communications bearers	Implications for industry	Our policy response & timeframes
• Internet access on board ships at sea is increasing. • Ships are more connected with shore organisations and can share information more easily. • Shipping companies have more access to shipboard information. • Increased connectivity will encompass a wider variety of ships. • Satellite communications will become increasingly affordable, with an increase in the number of providers. • Advances in technology will improve the ability for ships to be connected.	• Improved connectivity will lead to: – more oversight of ship operations, support for safety-related decision-making and efficiency of operations – provision of digital maritime services, increasing safety and efficiency – 'maritime actors' such as port authorities and agents, will be able to exchange information in an automated and secure manner, to optimise global supply chains – enhanced crew well-being as crews can stay in contact with families and friends and consume educational or entertainment content – growing shore monitoring of shipboard systems (e.g. main engine and cargo) • Public-facing portals enabling easy access to business processes for mariners.	• To be involved in international and national efforts for consensus on the required communication frameworks, protocols and channels. *Near term* • Consider the most appropriate methods for the provision of digital maritime services in Australia (based on the outcomes of the MCP testbed). *Mid term* • Monitor the availability and cost of commercial internet/IP-based satellite communications, as they provide more capability and capacity than GMDSS or VDES. *Ongoing*
• Cyber threats and up-to-date software will continue to be a challenge for digital technologies and information exchange.	• The ability to protect against cyber threats and ensure robustness of software, will become increasingly important. • Need for new training programs to deal with cyber security and S-100 data services.	• Contribute to developments of guidance on cyber security, software quality assurance for navigation systems, and technology related to safety of navigation. *Mid term* • Take steps to ensure that future navigation services and AtoN networks are resilient to cyber-attacks. *Ongoing*

4.5 Maritime Resource Names

Currently, there is no single system for specifying maritime identifiers in a uniform and unambiguous way. Global harmonisation using unique identifiers for maritime resources is necessary to develop and maintain enhanced data exchange applications for ship-to-ship, ship-to-shore, shore-to-ship, and shore-to-shore communications. Harmonisation allows for efficient administration and delivery of maritime safety and SAR information, ensuring interoperability between existing and developing administrative and operational systems while maintaining backward compatibility.

Maritime Resource Names (MRNs) are a universal naming scheme for maritime resources on a global scale. MRNs can be used to identify maritime organisations, AtoNs, buoys, digital maritime services, chart features, AIS base stations, berth numbers, VTSs and many other resources. They harmonise referencing, are unique, decentralised, and flexible in their schema. IALA especially recommends utilising MRNs for the management of AtoNs, VTS-data and MSI (IALA 2024a). Due to their high relevance in several digital applications associated with Maritime Services, MRN databases are likely to become an essential part of Australia's digital transformation.

By facilitating integration across data layers on ECDIS, MRNs benefit supply chain management systems through a harmonised naming schema, and supporting the synthesis of Maritime Services across national networks.

All MRN will have the same structure consisting of: Prefix "urn:mrn", followed by an Organization ID (OID), resource type, and resource information. Organisations can apply for OIDs through IALA. The resource type and resource information component of the MRN is entirely managed by the organisation and typically contains the type of the resource and further resource information (such as an ID) (IALA 2021).

Figure 1 provides a fictional example of an AMSA-managed AtoN located in Queensland with the ID "2389-4".

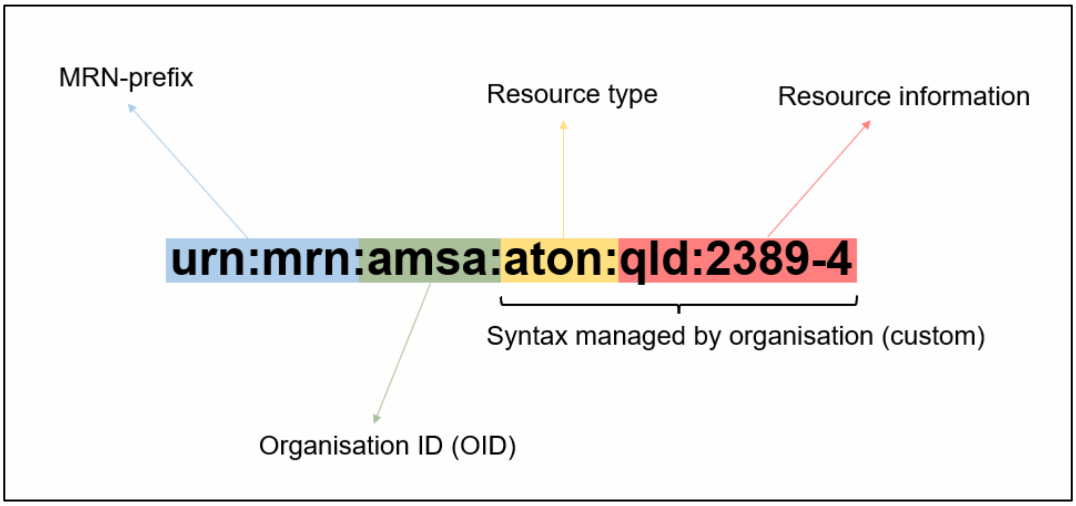


Figure 1. Example Maritime Resource Name

Trends that will affect Maritime Resource Names	Implications for industry	Our policy response & timeframes
• Australia's digital transformation and the increased utilisation of digital technologies requiring harmonised naming schemes for referencing. • The enhanced interconnectivity and integration of information systems onboard and ashore demanding higher levels of system interoperability. • Integration of supply chain enablers and onboard cargo management systems to increase efficiency. • The S-100 data scheme uses MRN as identifiers for datasets and as the means to 'link' features and objects across product 'layers' for a harmonised display of ENC information.	• Data management systems and databases will benefit from a harmonised naming schema. • New maritime services will rely on the existence of MRN databases and processes for MRN issuing in organisational MRN name spaces. Therefore, public authorities must consider setting up digital infrastructure to comply with these requirements. • The CMDS relying on MRNs for referencing. • MRNs will simplify the integration of different layers of data on an ECDIS by referencing (chart) features in route plans, navigational warnings, and other types of data.	• Raise awareness of MRN nationally, particularly in relation to the provision of digital maritime services and their role in S-100 dataset production. *Mid term* • Contribute to any whole-of-government effort to establish MRN issuing for the digital maritime transformation of Australia. *Ongoing* • Review AMSA's maritime service processes and resource management and make recommendations for compatibility with MRNs. *Long term*

4.6 Vessel Traffic Services

VTS are internationally recognised navigational safety measures designed to improve the safety and efficiency of vessel traffic, enhance the safety of life at sea, and to protect the environment. The aim of VTS is to mitigate the development of unsafe situations by monitoring ship traffic, responding to developing situations and providing information or advice, warnings and instructions, as deemed necessary to ensure the safety and efficiency of ship movements in the VTS area.

AMSA is the competent authority for VTS in Australia and is responsible for ensuring that VTS are established and operated in accordance with relevant international conventions and IMO instruments, IALA standards and national legislation. There are 28 VTSs in Australia (including ReefVTS) operated by eight authorised VTS providers (AMSA 2022).

To date VTS have relied on voice communication via VHF for necessary information exchange with vessels. With MASS operations on the horizon, VTS must begin to incorporate digital means of communication to fulfill their mission in the future.

Early digital VTS services will include automated traffic clearance services and providing mariners with information about the location and movements of other vessels. More advanced services will centre on route exchange, monitoring and navigational advice from VTS, JITA, slot management and decision support services. It is expected that these services will utilise the e-navigation architecture and will be implemented as Maritime Services.

Technologies like VDES that have the potential to reach beyond the limits of VHF voice coverage. Coupled with 4G/5G and satellite internet VTS centres will have access to reliable, high-speed communication with both autonomous and conventional vessels. With global connectivity, VTS centres of the future could deliver navigational safety information and operational advice to vessels beyond the VHF horizon and into remote areas.

Marine pilots are likely to be among the first to benefit from the adoption of S-100 based-data due to the relative ease of updating or replacing Portable Pilot Units (PPUs) compared to the permanently installed shipborne Electronic Chart Display and Information System (ECDIS). PPUs will be able to receive real-time information, such as digital navigational information from VTS or UKC (Under Keel Clearance) data, enhancing situational awareness and decision-making.

Increased digitalisation of the monitoring and management of ship traffic represents a secular trend advancing the seamless flow of information and improving the decision-making process for maritime operators. This trend extends to all facets of maritime operations, ensuring that both autonomous and traditional vessels benefit from improved navigational aids and decision-support tools. For instance, AI and Machine Learning algorithms can process massive volumes of data from various sources to provide real-time risk assessments, collision avoidance options, optimise routing based on weather and traffic conditions, and detect anomalies that may indicate potential safety hazards.

Trends that will affect Vessel Traffic Services	Implications for industry	Our policy response & timeframes
• The number of VTS in Australia is increasing. • VTS is increasingly becoming the conduit between ships and a variety of port organisations. • Connectivity between ships and VTS in Australia and internationally is increasing. • Broadening of the shipboard navigation team to include VTS to assist in on board decision-making. • Routine information will be exchanged electronically and automatically, but voice communications will remain important. • The advent next generation VTS with capabilities for route exchange, JITA and human-centred design of equipment. • VTS will have the capability to automatically provide information to individual ships, based on current and predicted weather.	• Industry can expect more bespoke information for their ships, more efficient traffic organisation, using route exchange and JITA mechanisms. • Ship movements will be monitored more closely and provided with assistance, if needed. • VTS will play a central role in assisting ports to improve supply chain efficiencies. • Benefits are: – increased situational-awareness on both ship- and shore-side. – higher efficiency in traffic management and reduction of VTS operator (VTSO) workload – automation of anomaly detection and issuing of early warnings. – capability to adapt to modern shipping trends and MASS.	• AMSA to maintain its national leadership in the coordination and development of international standards and guidance on VTS. *Ongoing* • Considering AMSA's role as the national competent authority, ensure that VTS providers in Australia continue to comply with domestic legislation and relevant IMO and IALA standards. *Ongoing* • Encourage the safety benefits and efficiencies that can be realised through implementing VTS and explore the benefits of large scale coastal VTS for some regions of Australia. *Ongoing* • Provide leadership nationally for the provision of digital VTS. *Ongoing* • Work together with regional partners to establish authorised VTS. *Ongoing*
• Integration of MASS and Remote Operation Centres (ROC) to VTS and pilotage systems and processes • Increased availability of data services and communications bearers in managed traffic areas. • Introduction of remote pilotage for uncrewed vessels • Cybersecurity enhancements: Increased focus on secure communication, data integrity, and protection against cyber threats in VTS and coastal pilotage operations.	• Increased navigation safety in environmentally sensitive areas • Increased traffic efficiency and reduction of transit times in mandatory pilotage areas through improved decision-support systems, availability of new real-time data sets • Increased availability of navigation services in areas previously without VHF coverage.	• Update and extend training and certification standards for VTS to include MASS. *Mid term* • Work with relevant international organisations to ensure that digital VTS information received on ships are displayed on board in a harmonised and effective manner, conforming to approved protocols for information exchange. *Ongoing* • Ensure the compliance of emerging technologies with existing VTS and pilotage standards. *Ongoing*

4.7 Maritime single window

A Maritime Single Window (MSW) is a digital portal facility that allows parties involved in maritime trade and transport to lodge standardised information and documents electronically via a single-entry point or 'window'. The information is required to fulfil all import, export, and transit-related customs and biosecurity regulatory requirements. Information is lodged electronically, with individual data elements being submitted once only.

Shipboard information such as its name, call sign, position, time, course and speed—held on board its AIS unit—can form a central element of the data set emanating from a ship.

International ships calling at Australian ports are currently required to communicate with different government agencies and industry bodies, through different means, to comply with individual agency requirements. Australian requirements for port entry result in ships providing the same information multiple times to different agencies.

The establishment of effective single window reporting in Australia would transform the Australian international maritime and trade environment, allowing for seamless and integrated interaction between government and business and significantly reduce red tape.

This will lead to increased efficiency of port approaches, discharge and loading processes, along with creating a central access point for real-time data analysis and understanding. Reducing the time frame in which a ship waits to enter or exit a port may also reduce fuel usage and in turn reduce costs associated with transportation and emissions.

Trends that will affect Maritime Single Window	Implications for industry	Our policy response & timeframes
• Public authorities to use MSW for electronic data exchange in ports for ship clearance from 1 January 2024. • Authorities to ensure information is submitted by ships only once and re-used to the maximum extent possible.	• A single window would create a secure digital interface between government and industry, and provide a single data point for Australian businesses to meet all international trade and regulatory requirements. • The MSW will ensure the electronic transmission of data by ships is streamlined to enable the reuse of information by the Government where possible. • The streamlined flow of data relating to a ships movements from international MSWs, prior to entering Australian waters, will contribute to a decrease in ship waiting times at Australian ports by reducing the time associated with obtaining regulatory clearances. • Implementation of a MSW will help reduce reporting and data duplication by capturing information from a single place and sharing it with the required regulatory agencies. • Reducing the timeframe in which a ship waits to enter or exit a port due to reporting may contribute to reductions in fuel usage and in turn reduce costs associated with transportation and emissions • Leveraging available capabilities and technologies could facilitate increased trade and reduced costs for industry and government. • MSW can be a central access point for data to contribute to real-time understanding of maritime environment and domain awareness for regulatory agencies.	• Contribute to whole-of-government effort led by the Department of Infrastructure, Transport, Regional Development, Communication and the Arts to establish single window reporting for the facilitation of seaborne trade in Australia. *Near term*

4.8 Trends and influences on navigation safety

Australia's 'blue economy' continues to grow and diversify (DCCEEW 2024). Trends such as new industries being introduced into Australian waters, and increasing demand for tourism into increasingly remote destinations drive the need for continued evaluation of the navigation services landscape.

In 2023 there were more than 28,700 ship arrivals by over 6200 foreign-flagged ships in Australia, an increase of 7.4 per cent over 2022. Bulk carriers accounted for 50.4 per cent of the ship arrivals. Passenger ship arrivals in 2023 numbered over 1000, signalling a return to pre COVID-19 levels (AMSA 2024).

Iron ore and coal remain Australia's largest bulk commodity exports, followed by gas (DFAT 2024b). The Australian cruise industry is one of the success stories of Australian tourism with the number of Australian cruise passengers having almost doubled in the five years prior to COVID-19. In 2023 overseas cruise passenger numbers were at a similar level to 2019, and the number of Australians cruising Australian waters were 75% greater than 2019 figures (CLIA 2024).

Areas of offshore activity around the Australian coastline are changing. After decades of oil and gas exploration, the development of offshore renewable energy infrastructure may change the composition and patterns vessel traffic in areas not previously associated with energy sector activities.

We are also witnessing the growing use of automation and advanced technologies on board ships. This includes the advent of MASS. Advances in technology on board ships and the systems and infrastructure that support ships, will lead to a commensurate reduction in human error and crew fatigue and improvements in safety.

On the international level, the IMO is aiming to implement a non-mandatory goal-based MASS Code for Maritime Autonomous Surface Ships by 2025, which will serve as the foundation for a mandatory goal-based MASS Code expected to enter into force on January 1, 2032.

Offshore renewable energy development will change the composition and pattern of vessel traffic in many areas of the Australian coast.

Trends that will affect navigation safety	Implications for industry	Our policy response & timeframes
• Increasing trends in: – The number and size of ships calling at Australian ports (albeit small percentage increases). – The size, speed and draughts of international ships, in particular container ships. – Cruise ship traffic, particularly the endeavour to visit areas where the hydrography is not yet fit-for- purpose. – Concentration of shipping traffic around floating liquefied natural gas (FLNG) hubs off the north-west coast of Australia. • New export opportunities and changes in products exported may affect shipping patterns and traffic density in some areas.	• Increasing commercial pressures on ships and ports. • Industry will have to respond to more stringent international rules regulating air emissions from ships. • Automation may lead to a reduction in human error and crew fatigue, potentially increasing safety, though this could be offset by the need for additional training and familiarisation.	• Conduct periodic AtoN and navigation safety reviews. *Ongoing* • Assess risks using IALA risk management tools and implement mitigation measures to reduce risk. *Ongoing* • Monitor shipping activity and proactively implement risk mitigation measures as required. *Ongoing*
• Offshore exploration techniques will continue to evolve and change, with changes technology including MASS and novel vessels, and location. • Growing use of automation and advanced technologies on board ships.		• Contribute to the development of IMO's MASS Code. *Ongoing* • Critically evaluate the human factor implications of the introduction of increased automation and advanced technologies on board ships. *Ongoing*
• The transition to alternative fuels to reduce sulphur oxide and GHG ship emissions, with necessary changes to propulsion and power systems to support these fuels (e.g. LNG, biofuels, hydrogen).		• Understanding and preparing for any regulatory and incident response changes that these alternative fuels may generate, including keeping abreast of developments in alternative fuels and propulsion systems. *Ongoing*
• Increase in Australian offshore renewable energy sector in non-traditional offshore regions.		• Keep abreast of developments in offshore oil and gas exploration, carbon capture and sequestration and renewable energy to manage any emerging risks and potentially implement water space management measures. *Near and mid-term*

5. Navigation systems and services – a summary

<table>
<tr><th>Navigation system or service</th><th>Future State</th><th>Estimated time frame</th></tr>
<tr><td>SBAS-enabled GNSS receivers on board ships</td><td>Subject to a number of milestones including:
IEC test standards and SBAS-enabled receivers available
Guidance on the use of SBAS for the maritime industry available.
Acceptance and integration of the Australian SBAS capability</td><td>2024-25</td></tr>
<tr><td>SBAS available in the Australian region (SouthPAN)</td><td>Early Open Services available since 2022
ICAO certified Safety-of-Life (SOL) services (primarily for aviation sector).</td><td>SOL - 2028</td></tr>
<tr><td>Terrestrial AIS</td><td>Terrestrial AIS networks may remain essential for safety related real time tracking and messaging in some areas and for redundancy in safety critical applications such as ReefVTS.</td><td>Retain for 10-15 years.</td></tr>
<tr><td>Satellite AIS</td><td>Improved performance and latency of information.
Data may be available through whole-of-government means.</td><td>Will be used for the foreseeable future (as available).</td></tr>
<tr><td>VHF Data Exchange System</td><td>Terrestrial VDES and Satellite channels are in operation across the world with limited regional coverage.
AMSA will continue to evaluate the suitability and availability of VDES for digital maritime services in Australia.</td><td>Implementation in Australia subject to future evaluation.</td></tr>
<tr><td>Visual aids to navigation</td><td>Will remain essential for the safe navigation of ships.</td><td>Will remain an enduring requirement.</td></tr>
<tr><td>Electronic aids to navigation</td><td>Physical and virtual AtoNs will complement existing infrastructure.</td><td>Increased utilisation of secure virtual AtoNs until 2028.</td></tr>
</table>

Navigation system or service	Future State	Estimated time frame
Digital maritime services	• Existing 'analogue' services will migrate to a digital format and additional services will be provided. • New digital maritime services and public-facing portals will be provided via internet connectivity.	• Development commenced.
Maritime Connectivity Platform	• The MCP framework will be adopted for Australia's maritime services, as appropriate.	• 2024-2030
Vessel Traffic Services	• Continued increase in number of VTS, with AMSA providing competent authority oversight and authorisation • Routine information will be exchanged electronically and automatically, but voice communications will remain important.	• Ongoing • Development has started.

6. The Guiding Principles

Over the coming years, these principles will guide us in the delivery of navigation services and AtoN.

6.1 Guiding Principle 1: New practices and technologies

Introduce new practices and technologies to enhance the ongoing appropriateness and reliability of navigation services.

One of AMSA's primary responsibilities is to provide contemporary, fit-for-purpose, navigation services for coastal and ocean navigation.

AMSA maintains its national network of AtoN using contracted maintenance service providers. In delivering the AtoN network, AMSA seeks to introduce innovations and efficiencies where possible to improve the delivery of services and the condition of its assets. AMSA and its contractors aim to maintain the network in accordance with international standards and guidance, and with minimal impact on Australia's unique marine environment.

We actively participate in international forums, particularly at IMO and IALA where we engage in the development of new practices and technologies in navigational services. We then assess these for their suitability in Australia.

Advances in technology and evolving rules and practices mean that the maritime world is now on the cusp of a paradigm change in the way navigation services will be delivered from ashore and received on board. Examples of this include digital navigational warnings, notices to mariners, and weather and wave information that will be integrated into the navigational information display on future electronic navigation systems.

The capability of meteorological and oceanographic organisations is continually advancing. For example, in the future BoM will play a role in providing digital services to the shipping industry. The availability of real-time localised and relevant digital information on weather, wave and ocean conditions and hazards can be overlaid on a navigational display will support risk-based decision making.

It is essential that any change introduced by AMSA is based on international rules, approved information exchange protocols, industry involvement and community expectation.

Image: Cellular networks have become increasingly relevant for maritime communication.

6.2 Guiding Principle 2: Stakeholder engagement

AMSA engages with a variety of domestic stakeholders to canvass a range of views and expertise on safety of navigation matters. This ensures that the AtoN and navigation services provided by AMSA are efficient, effective, and meet the needs of the levy-paying commercial shipping industry.

Our four key navigation stakeholder groups are:

6.2.1 Navigation Safety Advisory Group (NSAG)

NSAG is the peak consultative body to AMSA for matters relating to the safety of navigation in Australian waters. Chaired and organised by AMSA the group meets bi-annually to discuss and provide expert advice to AMSA on nautical, navigation safety and AtoN matters.

NSAG membership includes representatives from shipping companies, port authorities, marine pilots, state or territory marine safety agencies, the Royal Australian Navy and the AHO. Membership is reviewed periodically to ensure it adequately represents the interests of the levy-paying commercial shipping industry.

Agenda topics include ECDIS, e-navigation, nautical charts and publications, ship routeing and reporting systems, PNT, AtoN management and requirements, VTS and coastal pilotage. The focus includes both shipborne systems and the way they are used as well as the shore side infrastructure and systems that support safe navigation.

6.2.2 Aids to Navigation Working Group (AtoN WG)

The aim of the AtoN WG is, as far as practicable, the harmonisation in the delivery of AtoN services across Australia. Chaired by AMSA, membership is comprised of agencies responsible for the management of AtoN across Australia including port authorities and state or territory marine safety agencies. The WG meets bi-annually to provide a mechanism for collaboration and information sharing on issues of common interest and concern in relation to the delivery of AtoN services.

Strategic focus areas include management aspects of delivering an AtoN service. Operational focus areas extend to new lighting technologies and power sources, moorings and structures, heritage and work health and safety (WHS) matters. The WG also considers matters related to the development of international guidance on all aspects of AtoN provision.

6.2.3 National S-100 Working Group (S-100WG)

The national S-100WG is an initiative of the Intergovernmental Committee on Surveying and Mapping. The group was established to coordinate interests and activities of Australia's key stakeholders in shaping the S-100 data model and related standards.

AMSA is an active participant in the group whose membership includes, state and territory marine safety agencies, port authorities, other government agencies and other stakeholders.

The national S-100WG aims to: provide a forum for discussions to promote the harmonised implementation and maintenance of S-100 based services; facilitate and coordinate the creation, use, and quality of S-100 products ensuring that they are in line with the objectives of the WG members; collaborate to ensure product management activities are in line with the priorities of the WG members and affected organisations.

6.2.4 VTS Advisory Group (VTSAG)

The VTSAG is a peak consultative body to AMSA on matters relating to AMSA's responsibilities for Vessel Traffic Services (VTS) in Australia. Chaired by AMSA, the group provides a forum to share expertise, information and experiences on VTS matters in Australia and provide feedback to AMSA, as the Competent Authority for VTS in Australia, on policy, operational, technology, training and regulatory issues associated with the delivery of VTS.

Membership includes the AHO, VTS providers, state and territory marine safety agencies, port authorities, pilots and other stakeholders.

The aims of the VTSAG include: facilitating a common understanding of the delivery of VTS in Australia; promote a standardised approach to the delivery of VTS that reflects international obligations and best practices; and providing a forum for VTS providers to contribute to the preparation and review of IMO guidelines, IALA Standards and associated recommendations, guidelines and model courses.

Image: VTS are a key aid to navigation in areas with a high volume and/or complexity of vessel traffic movements.

6.3 Guiding Principle 3: Standards

AMSA provides navigation services in accordance with our International treaty obligations, IALA standards and guidance, and national legislation. We actively engage in the development of international regulations, standards and guidance that will affect the provision of navigation services in our waters.

6.3.1 International Maritime Organization

The SOLAS convention is arguably the most important of all international treaties concerning the safety of ships engaged on international voyages. In addition to stipulating minimum standards for the construction, equipment and operation of ships, the convention also places obligations on coastal States.

Chapter V of the convention deals with the safety of navigation. Regulation 13 (Establishment and operation of aids to navigation) states, inter alia, that *'Each Contracting Government undertakes to provide, as it deems practical and necessary…such aids to navigation as the volume of traffic justifies and the degree of risk requires.'*

Amendments to SOLAS Chapter V and associated regulations and guidelines concerned with the safety of navigation are developed by the IMO's Navigation, Safety, Communications and Search and Rescue (NCSR) technical sub-Committee and adopted or approved via the IMO's Maritime Safety Committee. AMSA represents Australia during discussions at the IMO on matters related to the safety of navigation ensuring Australia's interests are considered.

6.3.2 International Organisation for Marine Aids to Navigation

The goal of IALA is to *"foster the safe, economic and efficient movement of vessels, through improvement and harmonisation of aids to navigation worldwide and other appropriate means, for the benefit of the maritime community and the protection of the environment"* (IALA 2024b). IALA's 2024 change in status to an Intergovernmental Organization (IGO) provides a robust legal framework that will ensure transparency and facilitate close cooperation with other IGO's and governments worldwide, providing assurance for the marine AtoN industry.

IALA has four technical committees who develop guidance on all aspects of the provision of AtoN. IALA provides technical guidance on AtoN and navigation services by way of a suite of standards, recommendations, guidelines, manuals and model courses. IALA has demonstrated an ongoing commitment to considering emerging technologies, including autonomous systems, cybersecurity, among others when taking into account the needs of mariners and ships, and the requirements of AtoN authorities.

AMSA is committed to providing AtoN that align with international guidance and standards. To ensure that Australian interests are represented in their development AMSA actively participates in the work of many of the IALA committees and their working groups. This ensures that ships trading to Australia encounter the same type and quality of navigation services (in particular, AtoNs) as they do overseas, contributing to high level safety outcomes.

IALA also acknowledges the importance of heritage lighthouses to nations and shipping. This is achieved through guidance for their management and celebrating their contributions to history and culture through its annual heritage lighthouse award.

6.3.3 National obligations

Australia, as a signatory to the SOLAS convention, gives effect to this obligation under *the Navigation Act 2012*.

The Maritime Safety (Domestic Commercial Vessel) National Law Act 2012, allows AMSA to make regulations concerning the navigation equipment on DCVs, and separately, allows a state or territory to make laws for aids to navigation.

AMSA provides navigation services consistent with its international obligations in Chapter V of SOLAS. AMSA's AtoN network is consistent with the standards and guidance of the International Maritime Organization (IMO) and International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA).

7. Looking beyond 2035

This section looks ahead at the way ships may navigate beyond the year 2035. It also paints a picture of the delivery of navigation services beyond 2035 to support safe and efficient shipping.

The views that follow are inherently futuristic, yet not so far-fetched as to be beyond the realms of reality.

7.1 The automated navigation of ships on ocean passages

We are on the cusp of one of the most consequential disruptions of transportation in history. Automation is already well underway in the maritime industry. A digitised and well-connected ship (within itself and with the shore) can easily lend itself to autonomy.

Today, with conventional shipping, even with the most advanced equipment, the OOW still acts as the sole, true 'system integrator'. An autonomous ship controller, being supervised and supported by a staffed ROC will be the foundation for autonomous navigation onboard. And for this, real time, secure, high bandwidth connectivity will be the key.

This is not to suggest there will soon be ships navigating from berth to berth without an onboard crew or other human interaction. Rather, it is conceivable that such capability will be first rolled out in different parts of industry and at different levels. Ships on ocean passage may use high levels of automation while conducting ocean passage. However, during pilotage, berthing, navigating in a Traffic Separation Scheme (TSS) or a narrow channel, humans may take a higher level of operational control.

Australia, like many other countries, is already seeing autonomy used on smaller vessels for commercial work. It is anticipated that the next step will be higher levels of automation for short-sea voyages and on dedicated routes. It is therefore feasible that for many ships where high levels of automation exist, the need for visual AtoNs will remain when navigating in a near shore environment. It is also possible that ships with highly advanced systems and technologies may have little need to rely on visual AtoNs.

However, since technology that supports autonomous operations is developing rapidly, we will need to monitor this to determine whether physical AtoN such as lights and beacons will have a role for such ships.

We anticipate the most likely scenario is that a vessel may operate autonomously with a resident crew on board and have a level of direct support from a ROC located somewhere else in the world. For example, short-sea trades using highly automated systems and technology.

However, it remains likely that even beyond 2035 many vessels will still navigate with a crew onboard, and there will remain a dependence on physical AtoNs to supplement and support the provision of other sources of PNT information.

7.1.1 Benefits

Autonomy will lead to improved operations, with benefits for safety, reliability and efficiency (eg passage and cargo planning conducted from ashore). From a safety perspective, the benefits of autonomous navigation are:

- improved (and possibly error-free) collision avoidance
- avoidance, or optimised ship routeing, during severe weather or hazardous seas
- enhanced situational awareness
- reduced risk for crew in terms of safety and fatigue management
- potential reduction in crew costs, depending on the operating model (it is widely acknowledged that about 50-60 per cent of the daily operating cost of a ship trading internationally comprises crew costs).

7.2 Navigation services in the future

In the coming decades, if there are ships navigating the world's oceans without a bridge watch keeper, there can be serious, disruptive implications for navigation services.

The questions that we will need to address are:

- What type of AtoN will be required?
- What type of ship routeing systems will be established and what infrastructure will be necessary to support them?
- What type and level of oversight will be needed and by who?
- What will the role of shore control centres be in Australia and internationally?

We anticipate we will need to adjust many of our navigation services such as VTS, AtoN, hydrography and coastal pilotage.

7.2.1 Provision of aids to navigation

AMSA will remain responsible for the provision of AtoN necessary for the safety of ocean and coastal navigation in Australian waters. Consistent with the 1934 agreement between the Prime Minister and state premiers, the costs of providing and maintaining this network will continue to be met by the vessels that use them.

State or territory marine agencies and port authorities will continue to have responsibility for ensuring AtoN are provided for the safe entry and navigation of ports, and those required in waters frequented by fishing vessels and recreational craft.

With the shift towards digital maritime services, the way in which aids and services to navigation are provided in the future is likely to change and the relationships between AMSA, ports, and state and territory authorities, will become increasingly important. AMSA will need to explore future changes and challenges in the provision of AtoNs and implications for the division of responsibilities for the provision and management of aids and services to navigation in Australia.

7.2.2 Hydrography

The AHO is the Commonwealth Government agency (within the Department of Defence) responsible for the publication and distribution of nautical charts and publications and other information required for the safety of ships navigating in Australian waters. The AHO has a commitment to a digital first approach in production of charts and nautical publications, which is firmly keeping with its stated vision of "*excellence in the provision of digital maritime environmental products, services, and geospatial data*" (AHO, undated).

In 2020 the AHO introduced the HydroScheme Industry Partnership Program (HIPP). The scheme is a partnership with industry to conduct targeted hydrographic survey activities by commercial operators. Near-term HIPP goals include linking the Australia Chart Datum to the national ellipsoid

(AusHydroid) by 2030 while the long-term objectives include obtaining full bathymetric coverage of Australia's Exclusive Economic Zone by 2050 (AHO n.d.). Interested parties can declare areas of interest for survey by making a submission via the AusSeabed Survey Coordination Tool (AusSeabed, 2024) or view the HIPP survey plans and upcoming survey information on the AusSeabed Marine Data Portal (GA, 2024b).

AMSA is a member of the HIPP review panel which convenes annually to consider area of interest requests and priorities for allocation of survey resources. The focus of AMSA's recommendations to the panel is to improve the quality of survey in waters frequented by commercial shipping.

7.3 Case Study: Blue Sea and the digital ReefVTS

Year 2040:

Blue Sea, a fully autonomous container ship with a length of 220m and a capacity of 4,000 TEU is preparing to navigate the GBR and TS en route to Singapore. With only three engineers on board, its voyage is managed from a ROC located in Perth, WA.

Before departure a voyage plan is created by the ROC using advanced optimisation algorithms and real-time data, before being transmitted to the ReefVTS utilising the MCP. This ensures that the VTS is aware of the *Blue Sea's* intended route and can integrate it into the overall traffic picture. Using AIS, VDES, internet connectivity and S-100 data services, the *Blue Sea* shares comprehensive static and dynamic data with the ReefVTS, including the vessel's characteristics, cargo details, and real-time navigation data such as position, speed, and heading. ReefVTS, equipped with the latest VDES and IP-based technology, efficiently communicates with the *Blue Sea*. These high-bandwidth, low-latency communication channels allow for the rapid exchange of information, including traffic images, AtoN information, and real-time updates.

As the *Blue Sea* approaches the GBR the VTSO assesses the traffic situation and potential conflicts (supported by AI-based prediction and anomaly detection algorithms) using the received data from the *Blue Sea*. This data is seamlessly integrated to the VTS system's situational picture. Based on the assessment, the VTSO issues a S-100 based traffic clearance message to the *Blue Sea* via VDES, outlining the approved route and any necessary speed adjustments. Beyond the range of terrestrial VDES, the *Blue Sea* seamlessly switches to satellite-based internet connectivity to maintain communication with the ReefVTS, ensuring that higher volumes of data can be exchanged. This ensures continuous monitoring and support throughout the voyage.

Although the *Blue Sea* navigates autonomously, an AMSA-licenced marine pilot plays a crucial role in ensuring safe passage through the PSSA. Stationed at a remote pilotage centre, the pilot utilises a sophisticated shore-based system that mirrors the ship's navigation systems. This allows the pilot to: monitor the voyage in real-time; access all relevant data; and communicate directly with the autonomous navigation system. The pilot can provide guidance and recommend adjustments to the ship's course and heading as needed. Additionally, the pilot maintains constant communication with the ROC in Perth, collaborating with the shore-based team to ensure a safe and efficient transit.

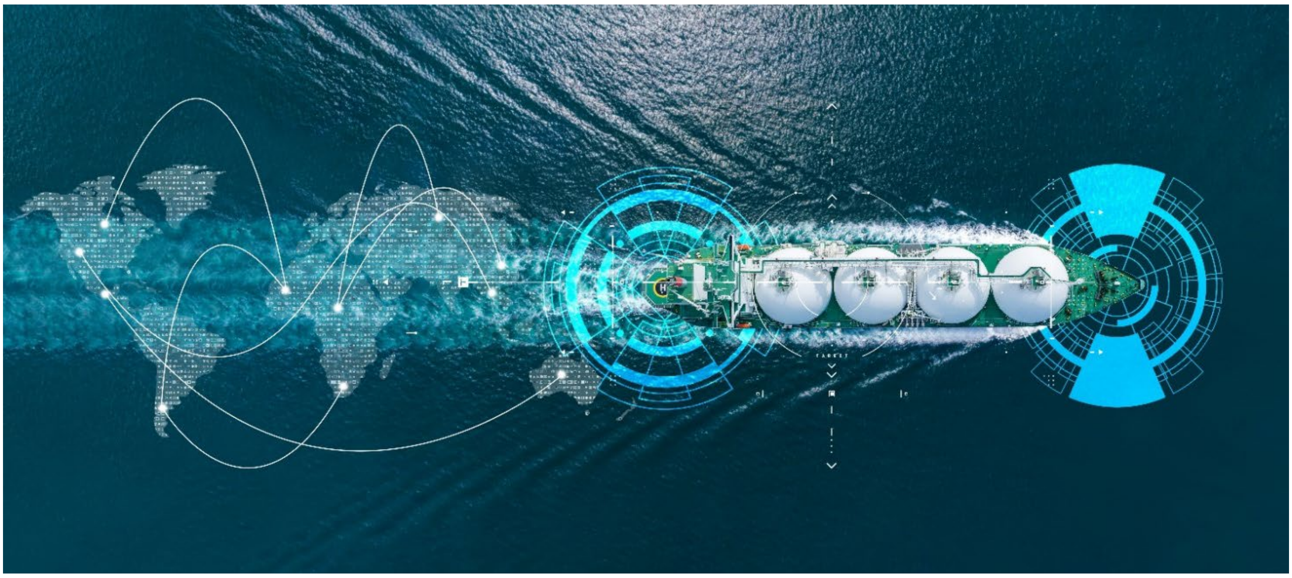


Image: The Blue Sea's voyage demonstrates the effectiveness of digital data exchange and the synergy between autonomous vessels, advanced VTS systems, and remote pilotage.

The VTSO continuously monitors the progress of the *Blue Sea* and other vessels in the area. Should any deviations from the planned route occur or unforeseen circumstances arise, the VTSO can intervene and provide updated instructions or navigational assistance via VDES or satellite-based internet. The vessel also receives other S-100 data from various marine service providers, including environmental information such as bathymetry, currents, and weather forecasts. This data is integrated into the *Blue Sea's* autonomous navigation system, enabling it to optimise its route for efficiency and safety while minimising environmental impact.

The *Blue Sea* successfully navigates the GBR, demonstrating the effectiveness of digital data exchange and the synergy between autonomous vessels, advanced VTS systems, and remote pilotage. As the *Blue Sea* continues its journey towards Singapore, the ROC maintains a close watch, ready to intervene, if necessary, while the ReefVTS continues its vital role as the guardian of the reef.

8. Conclusion

The Australian government, state and territory maritime agencies and port authorities, with a mandate for the safety of navigation and protection of the marine environment, are responsible for ensuring the provision of appropriate navigation services such as reliable AtoN, VTS and digital maritime services.

Navigation services in Australia play a key role in facilitating safe and efficient shipping, including mitigating the inherent risks associated with transporting cargoes through some of the world's most environmentally sensitive areas.

Furthermore, the push towards digitalisation in maritime operations holds significant potential for reducing GHG emissions. By optimising routes, enhancing vessel operations, and streamlining logistics through digital technologies, the maritime industry can achieve more efficient fuel usage and lower emissions. This shift not only supports environmental sustainability but also aligns with global efforts to combat climate change. The integration of digital services thus serves as a dual advantage, ensuring safer and greener maritime activities.

AMSA will continue to provide high quality navigation services, which facilitate the safety and efficiency of navigation. It will also introduce new practices, technologies and digital maritime services to enhance the reliability and efficiency of the AtoN network and reduce the associated environmental impact.

AMSA has been, and will continue to be, an innovative organisation that provides cost-effective navigation services.

Appendix A – SouthPAN Satellite-Based Augmentation System

In September 2022, the SBAS capability provided by GeoScience Australia called 'Southern Positioning Augmentation Network (SouthPAN),' early Open Services went 'live' allowing Australia's industry access to the benefits of accurate and reliable positioning services.

SouthPAN provides instant, reliable and accurate positioning services across all of Australia and New Zealand's land and maritime zones improving positioning accuracy better than <3m in the horizontal and 4m in the vertical (95% confidence level) when utilising the L1 SBAS Open Service. Australia's maritime industry can foster this technology to increase navigation safety, improve productivity and drive innovation. These positional corrections are achieved via computation of a high accuracy positioning solution in real-time when processed by an appropriate algorithm in the users SBAS enabled GNSS receiver.

While many GNSS receivers having the capability to track the L1 signal, a smaller range of receivers track the L5 signal as well. Receivers capable of tracking the L1 & L5 signals and which can process 'Precise Point Positioning (PPP) via SouthPAN' (PVS) messages, enable the user to utilise the PVS early Open Service. This capability enables position accuracy better than <0.40m in the horizontal and <0.55m in the vertical (95% confidence interval), after convergence. A convergence period of <80 minutes during PVS Open Services is required but allows dynamic manoeuvres (can be achieved while vessel is underway).

By 2028, the PVS Open Service will migrate from L5 to a new navigation signal and format. This will result in further improvements to PPP accuracy and reduced convergence times. SouthPAN Open Services will also be provided over the internet alongside the satellite broadcast.

To take advantage of the economical, navigation safety, and environmental benefits resulting from the SouthPAN Open Services, changes to the relevant IMO and IEC instruments is recommended to implement GNSS receiver performance standards that encourage the uptake of these advanced PNT technologies.

If an IEC test standard is agreed in the short term, we can expect manufacturers to bring certified SBAS-enabled receivers to the market by 2025-26. From 2026, we can expect to see such units on ships calling at Australian ports.

More information on SouthPAN can be found on the Geoscience Australia website.

www.ga.gov.au/scientific-topics/positioning-navigation/positioning-australia/about-the-program/southpan

Appendix B – List of initial digital maritime services

As part of the improved provision of services to ships, IMO's *Descriptions of Maritime Services in the context of e-navigation* (MSC.1/Circ.1610/Rev.1) identifies 15 maritime services. International efforts are now underway to refine the operational and technical services, develop data models and provide guidance to the global maritime community on establishing these services.

Service	Identified services	Domain coordinating body	Identified responsible service provider
1	MS 1 – VTS Information Service	IALA	VTS Authority *
2	MS 2 – Aids to navigation service	IALA	AtoN Authority *
3	*MS 3 – not in use*	*na*	*na*
4	MS 4 - Port Support Service (PSS)	IHMA	Local Port/Harbour Authority
5	MS 5 - Maritime Safety Information (MSI) Service	IHO	National Competent Authority *
6	MS 6 - Pilotage service	IMPA	Pilotage Authority/Pilot Organization
7	MS 7 - Tug service	IMO et al.	Tug Authority
8	MS 8 - Vessel Shore Reporting	IMO et al.	National Competent Authority and appointed service providers *
9	MS 9 - Telemedical Assistance Service (TMAS)	IMHA	National Health Organization/ dedicated health Organization
10	MS 10 - Maritime Assistance Service (MAS)	IMO et al.	Coastal/Port Authority/ Organization *
11	MS 11 - Nautical Chart Service	IHO	National Hydrographic Authority/ Organization
12	MS 12 - Nautical Publications Service	IHO	National Hydrographic Authority/ Organization
13	MS 13 - Ice Navigation Service	WMO	National Competent Authority/ Organization
14	MS 14 - Meteorological Information Service	WMO	National Meteorological Authority/Public Institutions
15	MS 15 - Real-time hydrographic and environmental information Service	IHO	National Hydrographic and Meteorological Authorities
16	MS 16 - Search and Rescue Service	IMO et al.	SAR Authorities*

* It is expected that AMSA will directly be involved in the implementation of this service.

Appendix C – Bringing it all together – the Maritime Connectivity Platform

The MCP is a communication framework for the efficient, secure and seamless electronic information exchange between authorised stakeholders.

For now a web-based testbed aims to demonstrate the services associated with the MCP. The testbed aims to allow maritime services to be 'discoverable' and usable.

The MCP consists of three components:

1. An identity registry that provides users, ships and devices with a structured identity (based on the MRN concept). It facilitates login to access services along with protocols for authentication, integrity and confidentiality.
2. A messaging service that contains a description of the variety of services available. For example, messages can be sent to a defined geographic area or to a group of ships.
3. A service registry, which provides access to a collection of maritime services that are available to the mariner or authorised stakeholder in a given area.

The MCP is generally organised in a decentralised way: There is not a single, central instance of the MCP that everyone uses. Different organisations can deploy their own instances of the MCP, which are interoperable due to standardisation processes for the MCP technical specifications.

The MCP testbed, being led by the Republic of Korea and the General Lighthouse Authority (UK), has the potential to contribute to IMO's plan for the implementation of its e-navigation strategy. The concept envisions the use of a variety of communication channels such as the internet, satellite links, cellular phone networks, marine radio channels and digital radio links. An operational instance of the platform (provided by the Navelink Industry Consortium) is also available and other instances are in the process of becoming operational service providers.

The MCP will enable the exchange of harmonised maritime information, developed using data models based on the IHO S-100 geospatial information standard.

More information on the MCP can be found at www.maritimeconnectivity.net

Appendix D – VHF Data Exchange System (VDES): A communications framework and a candidate technology

In today's age of near instant communications, it is unthinkable that a ship at sea should be isolated from 'always available communications', particularly when e-navigation means shore authorities will be able to provide ships with new digital maritime services.

The spectrum within which maritime radio communications takes place is limited and there are increasing demands being made on it by the introduction of new technologies and services.

Introducing VDES

VDES is a radio communication system that operates between ships, shore stations and satellites on AIS ASM and VHF Data Exchange (VDE) frequencies in the maritime mobile VHF band.

Why VDES?

VDES is seen as an effective and efficient use of radio spectrum, building on the capabilities of AIS and addressing the increasing requirements for data exchange. New techniques that provide higher data rates than those used for AIS, and the support for new cyber security technologies are core features of VDES.

What are the benefits of the satellite component of VDES?

The VDES satellite component provides cost effective coverage of a very large area. This is particularly important in the polar regions, outside geostationary satellite coverage.

The satellite component of VDES may increase uptake onboard ships, being a cost effective, global (but low capacity) capability.

VDES and R-Mode

Systems such as AIS and ECDIS use GNSS-derived PNT information.

The still-developing R (or Ranging) Mode is a potential terrestrial backup PNT system, independent of GNSS, which uses ranging signals transmitted from maritime infrastructure, for example, VDES base stations.

Adding additional R-Mode functionality to existing maritime infrastructure is appealing, as much of the hardware is already in place, removing the need to procure and install expensive transmitters and antenna systems. In addition, the VDES broadcast frequencies are protected and already established.

AIS base stations have also been installed in significant numbers around many coastlines and already serve the mariner. When upgraded to VDES, they are good candidates for R-Mode transmissions.

Where can I find more information on VDES?

More information on VDES can be found on the IALA website:

www.iala-aism.org/technical/connectivity/vdes-vhf-data-exchange-system

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Glossary

Acronym or abbreviation	Term
AHO	Australian Hydrographic Office
AIS	Automatic Identification System
AMSA	Australian Maritime Safety Authority
ASM	Application specific messages
AtoN	Aids to navigation
BoM	Bureau of Meteorology
CIRM	The international association for marine electronics companies
CLIA	Cruise Lines International Association
CMDS	Common Maritime Data Structure
DCV	Domestic Commercial Vessel
ECDIS	Electronic Chart Display and Information System
ENC	Electronic Navigational Chart
FLNG	Floating LNG (platform)
GBR	Great Barrier Reef
GHG	greenhouse gas
GMDSS	Global Maritime Distress and Safety System
GMSK	Gaussian Minimum Shift Keying
GNSS	Global Navigation Satellite System
IALA	International Association of Marine Aids to Navigation
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IGO	Intergovernmental Organisation
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IP	Internet Protocol
ITU	International Telecommunication Union
JITA	Just-in-time Arrival
JRCC	Joint Rescue Coordination Centre

Acronym or abbreviation	Term
LEO	Low Earth Orbit
LiDAR	Light detection and ranging
LNG	Liquefied Natural Gas
LRIT	Long-range identification and tracking
MASS	Maritime Autonomous Surface Ship
MCP	Maritime Connectivity Platform (formerly Maritime Cloud)
MRN	Maritime Resource Name
MSI	Maritime Safety Information
MSW	Maritime Single Window
NSAG	Navigation Safety Advisory Group
NTM	Notices to mariners
OID	Organisation ID
OOW	Officer of the watch
Panamax	Term for the limits and requirements of a ship that can travel through the Panama Canal.
PNT	Positioning, Navigation and Timing
PPP	Precise Point Positioning
PPU	Portable Pilot Units
PSC	Port State Control
PSSA	Particularly Sensitive Sea Area
PVS	Precise Point Positioning via SouthPAN
Racon	A transmitter-receiver associated with a fixed navigational mark which, when triggered by a radar, automatically returns a distinctive signal which can appear on the display of the triggering radar.
ReefVTS	Great Barrier Reef and Torres Strait Vessel Traffic Service
ROC	Remote operations centre
S-100	Universal Hydrographic Data Model
SAR	Search and rescue
SBAS	Satellite-Based Augmentation System
SOL	Safety of Life
SOLAS	The International Convention for the Safety of Life at Sea, 1974 (as amended)

Acronym or abbreviation	Term
SouthPAN	Southern Positioning Augmentation Network
TS	Torres Strait
UKC	Under Keel Clearance
UKCM	Under Keel Clearance Management
VDES	VHF Data Exchange System
VDES-SAT	VHF Data Exchange System - Satellite
VDES-TER	VHF Data Exchange System - Terrestrial
VHF	Very High Frequency
VTS	Vessel Traffic Service
VTSAG	VTS Advisory Group
VTSO	Vessel Traffic Service Operator
WG	Working Group
WMO	World Meteorological Organization

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