**This is a working paper at the conclusion of ENAV 20.**

**Draft Chapter 4 (E-Navigation) for the 2018 Edition of the IALA NAVGUIDE**

[1 Introduction 3](#_Toc477478638)

[2 Background 3](#_Toc477478639)

[2.1 Origins 3](#_Toc477478640)

[3 IMO’s strategy for the development and implementation of e-navigation 3](#_Toc477478641)

[3.1 The case for e-navigation 3](#_Toc477478642)

[3.2 Vision 3](#_Toc477478643)

[3.3 Definition 4](#_Toc477478644)

[3.4 What does the ‘e’ in e-navigation stand for? 4](#_Toc477478645)

[3.5 Key elements 4](#_Toc477478646)

[3.6 e-Navigation solutions 5](#_Toc477478647)

[4 IALA’s role 5](#_Toc477478648)

[4.1 IALA’s Strategic Vision 2014-2026 5](#_Toc477478649)

[4.2 The E-Navigation Committee 6](#_Toc477478650)

[4.3 Answers to Frequently Asked Questions on e-navigation 6](#_Toc477478651)

[5 Maritime Services Portfolios 6](#_Toc477478652)

[5.1 What are MSPs 6](#_Toc477478653)

[5.2 The sixteen initial MSPs 6](#_Toc477478654)

[6 Maritime Digital Infrastructure 8](#_Toc477478655)

[6.1 Architecture (Axel) 8](#_Toc477478656)

[6.1.1 Maritime Architecture Framework (MAF) 8](#_Toc477478657)

[6.1.2 IMO Architecture (Stephane) 8](#_Toc477478658)

[6.1.3 Common Shore Side Architecture 8](#_Toc477478659)

[6.2 Common Maritime Data Structure (Peter) 8](#_Toc477478660)

[6.2.1 Maritime Resource Name (MRN) 10](#_Toc477478661)

[6.2.2 S-100 Geospatial Information Registry 10](#_Toc477478662)

[6.3 Common Maritime Infrastructure 10](#_Toc477478663)

[6.3.1 Identity Management 10](#_Toc477478664)

[6.3.2 Service Management 10](#_Toc477478665)

[6.3.3 Maritime Cloud (Rasmus) including Maritime Messaging Service 10](#_Toc477478666)

[6.3.4 Global Maritime Distress Safety System (Jean Charles) 12](#_Toc477478667)

[6.3.5 Automatic Identification System / ASM 12](#_Toc477478668)

[6.4 Cyber Security 12](#_Toc477478669)

[7 Communications 13](#_Toc477478670)

[7.1 Introduction 13](#_Toc477478671)

[7.2 Communications systems and data exchange for the maritime domain 14](#_Toc477478672)

[7.3 IALA Maritime Radio Communications Plan 14](#_Toc477478673)

[7.4 Satellite communications systems 14](#_Toc477478674)

[7.5 VHF Data Exchange System 14](#_Toc477478675)

[7.5.1 Overview 14](#_Toc477478676)

[7.6 Digital Selective Calling (DSC) (VHF and HF) 16](#_Toc477478677)

[7.7 Digital VHF and HF 16](#_Toc477478678)

[7.8 Wi-Fi 16](#_Toc477478679)

[7.9 4G and 5G networks 16](#_Toc477478680)

[7.10 Satellite communication systems and services 17](#_Toc477478681)

[7.10.1 Geostationary satellites (GEO) 17](#_Toc477478682)

[7.10.2 Low Earth Orbiting satellites (LEO) 17](#_Toc477478683)

[7.10.3 Automatic Identification System 17](#_Toc477478684)

[8 Positioning, Navigation and Timing 24](#_Toc477478685)

[8.1 Introduction 24](#_Toc477478686)

[8.2 What is resilient PNT 24](#_Toc477478687)

[8.3 Electronic Position Fixing Systems 24](#_Toc477478688)

[8.3.1 Global Navigation Satellite Systems 24](#_Toc477478689)

[8.3.2 Regional systems 27](#_Toc477478690)

[8.3.3 Differential Global Navigational Satellite System 27](#_Toc477478691)

[8.3.4 Satellite Based Augmentation Systems 30](#_Toc477478692)

[8.3.5 Terrestrial systems 31](#_Toc477478693)

[8.4 Radar Aids to Navigation 36](#_Toc477478694)

[8.4.1 Radar Reflectors 37](#_Toc477478695)

[8.4.2 Radar Target Enhancers 37](#_Toc477478696)

[8.4.3 Radar Beacon 38](#_Toc477478697)

[8.4.4 Frequency-Agile Racon 38](#_Toc477478698)

[8.4.5 Racon Performance Criteria 39](#_Toc477478699)

[8.4.6 Racon Technical Considerations 39](#_Toc477478700)

[8.4.7 Use with New Technology Radars 40](#_Toc477478701)

[8.4.8 Radar Referenced Positioning 40](#_Toc477478702)

[8.5 Non-radio Positioning 40](#_Toc477478703)

[8.5.1 Inertial systems 40](#_Toc477478704)

[8.5.2 e-Pelorus 41](#_Toc477478705)

[9 Testbeds 41](#_Toc477478706)

[10 Implementation 42](#_Toc477478707)

[**Notes** 42](#_Toc477478708)

# Introduction

The IMO-led initiave termed e-navigation is a broad church.

Stated simply, the goal of e-navigation is to provide harmonised information, in electronic formats, in a seamless, customised and efficient manner, to better-designed navigational systems on board. Ashore, e-navigation aims to streamline the way maritime authorities, agencies and other stakeholders gather and exchange information.

This chapter aims to outline areas of e-navigation development that IALA has been involved in.

# Background

## Origins

In 2006, the International Maritime Organization (IMO) approved a proposal from seven of its Member States, who requested IMO develop an e-navigation strategy.

The stated aim of the proposal was to *“...develop a strategic vision for the utilization of existing and new navigational tools, in particular electronic tools, in a holistic and systematic manner.”* (MSC 81/23/10). The sponsors of the submission were concerned that if the introduction of new technology remained uncoordinated, it would result in a lack of standardization on board and an increased level of complexity. The proposed e-navigation vision was to create an overarching system that would provide a greater level of safety and incident prevention, resulting in reduced navigation-related accidents.

IMO led other international organisations, notably the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and the International Hydrographic Organization (IHO) and developed a stratgey for the implementation of e-navigation in 2008 (MSC85/26/Add.1 Annex 20) . A plan to implement the strategy, termed Strategy Implementation Plan (SIP) was completed in 2014 (NCSR1/28 Annex 7).

# IMO’s strategy for the development and implementation of e-navigation

## The case for e-navigation

The IMO strategy for e-navigation (MSC 85/26/Add.1 Annex 20) states that research indicates around 60% of collisions and groundings are caused by direct human error. Despite advances in bridge resource management training, it seems that the majority of watchkeeping officers make critical decisions for navigation and collision avoidance in isolation, due to a general reduction in manning.

The strategy also states that in human reliability analysis terms, the presence of someone checking the decision making process improves reliability by a factor of 10. If e-navigation can assist in improving this aspect, both by well-designed onboard systems and closer cooperation with vessel traffic management (VTM) systems ashore, the risk of collisions and grounding (and their inherent liabilities and costs to administrations) can be dramatically reduced.

## Vision

A vision for e-navigation is described in following general expectations for the onboard, ashore and communications elements:

**.1 On board**

Navigation systems that benefit from the integration of own ship sensors, supporting information, a standard user interface and a comprehensive system for managing guard zones and alerts. Core elements of such a system will include, actively engaging the mariner in the process of navigation to carry out his/her duties in a most efficient manner, while preventing distraction and overburdening;

**.2 Ashore**

The management of vessel traffic and related services from ashore enhanced through better provision, coordination and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency; and

**.3 Communications**

An infrastructure providing authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits.

## Definition

The IMO stratgey defines e-navigation as the *“harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment.”*

In other words, e-navigation means:

* The harmonised exchange and presentation of navigational information in electronic formats.
* Improved and harmonized data exchange and communications.
* Creation of a ‘wide area navigation team’, which allows the Officer of the Watch (OOW) and the Vessel Traffic Services (VTS) Operator to share tactical and planning information.
* Improved design of navigational and communication equipment.

## What does the ‘e’ in e-navigation stand for?

It is generally accepted that the IMO concept of e-navigation can be thought of as a brand, without the need for ’e’ to be specifically defined. The concept of e-navigation was first proposed by seven IMO Member States in 2006 as a process for the harmonisation, collection, integration, exchange and presentation of maritime information. As such, the ’e’ could have stood for ’enhanced’ or ’electronic’ (just like the ’e’ in e-commerce), but this would unnecessarily limit what can be done within e-navigation.

It must be noted that the generic term electronic marine navigation already exists in many forms. It should not be confused with this particular IMO initiative.

## Key elements

According to the strategy, the key elements for e-navigation based on user needs include:

* Architecture
* Human Element
* Conventions and standards
* Position fixing
* Communication technology and information systems
* Electonic Navigational Charts (ENC)
* Equipment standardization, and
* Scalability

According to the strategy, the implementation of e-navigation should be a phased, iterative process of continuous developmen, taking into account the evolution of user needs and the lessons learned from the previous phase/s.

As part of the basic requirements for the implementation and operation of e-navigation, it was agreed that implementation of e-navigation should be based on user needs, not technology-driven.

## e-Navigation solutions

The current SIP is based on the following five prioritized e-navigation solutions:

* S1: improved, harmonized and user-friendly bridge design;
* S2: means for standardized and automated reporting;
* S3: improved reliability, resilience and integrity of bridge equipment and navigation information;
* S4: integration and presentation of available information in graphical displays received via communication equipment; and
* S9: improved Communication of VTS Service Portfolio (not limited to VTS stations).

Solutions S2, S4 and S9 focus on efficient transfer of marine information and data between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore). Solutions S1 and S3 promote the workable and practical use of the information and data on board.

# IALA’s role

## IALA’s Strategic Vision 2014-2026

The aim of IALA is to foster the safe and efficient movement of vessels through the improvement and harmonisation of marine aids to navigation worldwide. This purpose is given effect by two key goals for 2026.

Goal 1 (G1)

Ensure that aids to navigation systems and related services, including e‐Navigation, Vessel Traffic Services, and emerging technologies, are harmonised through international cooperation and the provision of standards.

The strategy w.r.t e-navigation is to improve and harmonsie VTS, information structures, Martime Service Portfolios and communications, so as to achieve worldwide interoperability of shore and ship systems.

Goal 2 (G2)

All coastal states have contributed to an efficient global network of aids to navigation and services for the safety of navigation, through capacity building and the sharing of expertise.

Here, the strategy is to coordinate the further development of VTS, e‐Navigation and short range aids to navigation, taking into account new technologies and sustainability. And to continue to develop capacity building activities to improve the global operations and management of aids to navigation systems and related services

## The E-Navigation Committee

Since 2006, IALA’s e-Navigation Committee has led the development of IALA’s substantial contribution to the formulation of IMO’s strategy and the SIP.

There remains a vast amount work to be done to translate the e-navigation concept to operational reality. The working groups of the ENAV Committee are engaged in the following technical domains:

* Technical Domain 1: Data modelling and message systems (AtoN data information structure, exchange, presentation, S-100 Registry and Product Specifications)
* Technical Domain 2: e-navigation communications (VDES, satellite, WRCP, AIS technology)
* Teechnical Domain 3: Shore technical infrastructure (resilient PNT shore services – DGPS, eLoran, virtual AtoN technology)
* Technical Domain 4: e-Navigation test beds (gathering testbed results and analysis of results)
* Technical Domain 5: Maritime Services Portfolios(design, content and implementation)

Several multi-million dollar projects (completed and underway) have made noteworthy inroads in developing aspects of e-navigation. The IALA e-navigation portal (http://www.iala-aism.org/products-projects/e-navigation) provides detail on known testbeds and their results.

## Answers to Frequently Asked Questions on e-navigation

IALA has developed answers to some Frequently Asked Questions (FAQs) on e-navigation. These can be found on the IALA website at:

# Maritime Services Portfolios

## What are MSPs

A Maritime Service Portfolio (MSP) defines and describes the set of operational and technical services (and the level of service) provided by a stakeholder in a given sea area, waterway, or port, as appropriate. (NCSR 1/ 28 Annex 7 refers)

As identified by IMO, there is a need for a harmonised framework for the electronic provision of information related to maritime services between shore and ships. The list of maritime services available at a port, in a region or sea area is structured into services based on a responsible body. Such a service is termed a Maritime Service Portfolio or MSP. For instance, “Maritime Safety Information” is such an MSP with the “National Competent Authority” responsible within the area in question.

Services in a portfolio will vary, depending on the port’s or region’s facilities. For example, a small port may offer only a few services, whereas a large port may offer a greater number of services.

The objective of the MSP concept is to align global maritime services with the need for information and communication services in a defined operational area. To achieve this, the first step should be to identify the need for information services and communication infrastructure in the different areas. Also, a set of services will require a certain communication infrastructure capacity, varying from area to area.

## The sixteen initial MSPs

MSPs are being developed to achieve harmonization, integration and simplification on board and ashore, taking into account the use of the IHO’s S-100 Geospatial Information (GI) Registry.

IALA is developing guidance on the initial services identified by IMO in the table below. It aims to harmonise the format, structure and communication networks that will be used to exchange MSP information. Although IMO identified the preliminary list of 16 MSPs below (MSC 94/21 Annex 17), these may evolve with time.

|  |  |  |
| --- | --- | --- |
| **MSP Number** | **Services** | **Responsible Service Provider** |
| **1** | VTS Information Service (IS) | VTS Authority |
| **2** | Navigational Assistance Service (NAS) | National Competent VTS Authority/Coastal or Port Authority |
| **3** | Traffic Organization Service (TOS) | National Competent VTS Authority/Coastal or Port Authority |
| **4** | Local port Service (LPS) | Local Port/Harbour Operator |
| **5** | Maritime Safety Information Service (MSI) | National Competent Authority |
| **6** | Pilotage Service | Pilot Authority/ Pilot Organization |
| **7** | Tug Service | Tug Authority |
| **8** | Vessel Shore Reporting | National Competent Authority, Shipowner/ |
| Operator/Master |
| **9** | Telemedical Assistance Service (TMAS) | National health organization/dedicated health organization |
| **10** | Maritime Assistance Service (MAS) | Coastal/Port Authority/Organization |
| **11** | Nautical Chart Service | National Hydrographic Authority/ Organization |
| **12** | Nautical Publications Service | National Hydrographic Authority/ Organization |
| **13** | Ice Navigation Service | National Competent Authority Organization |
| **14** | Meteorological information service | National Meteorological Authority/WMO/ Public Institutions |
| **15** | Real time hydrographic and environmental information Service | National Hydrographic and Meteorological Authorities |
| **16** | Search and Rescue (SAR) Service | SAR Authorities |

# Maritime Digital Infrastructure

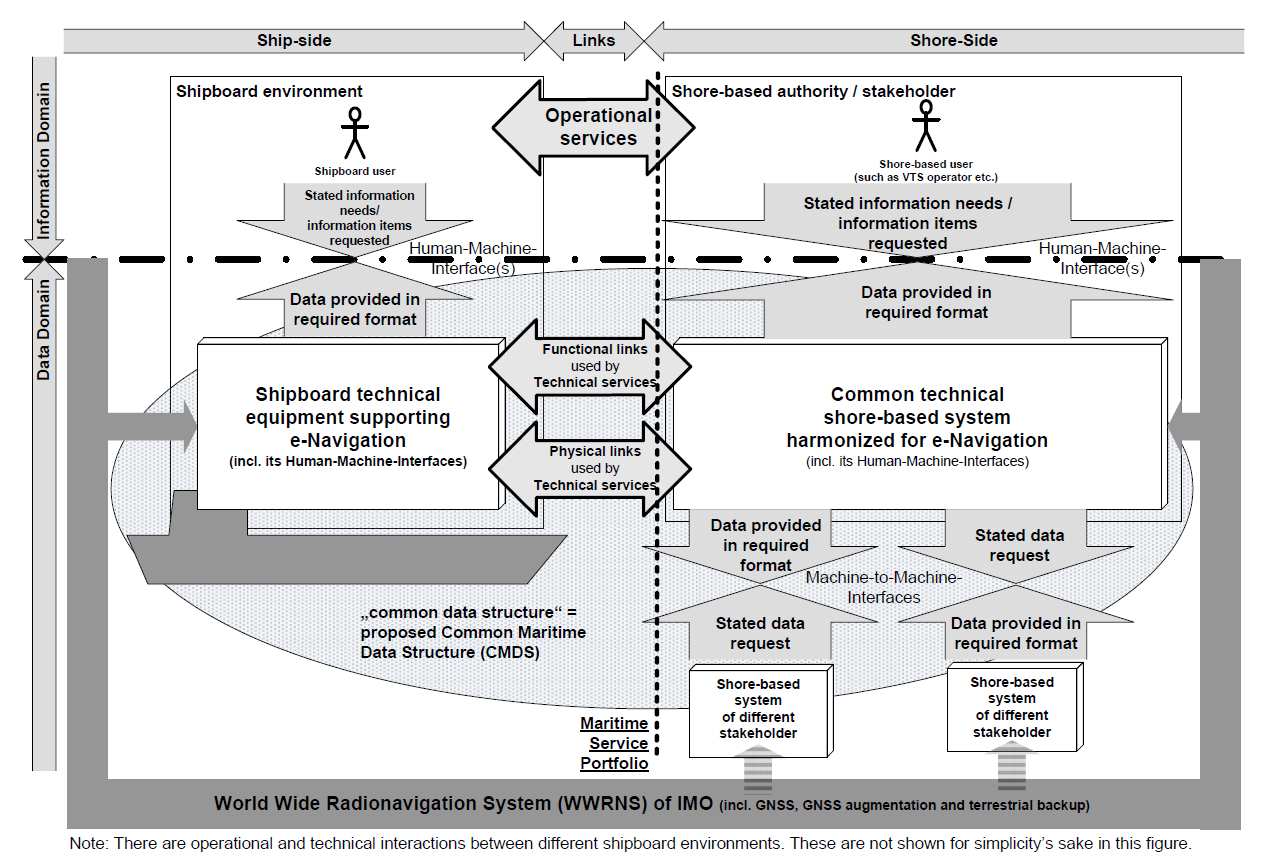
## Architecture (Axel)

XXXXXX

### Maritime Architecture Framework (MAF)

XXXXX

### IMO Architecture (Stephane)



### Common Shore Side Architecture

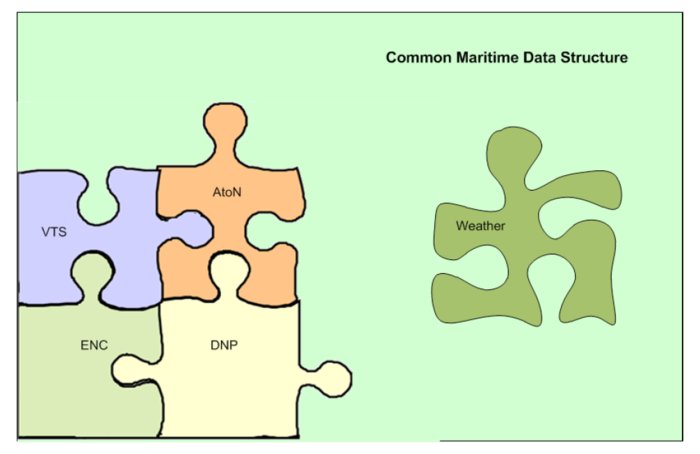
XXXX

## Common Maritime Data Structure (Peter)

The purpose of the IMO defined Common Maritime Data Structure (CMDS, see Figure 21) is to harmonise data exchange in the maritime domain by providing a common, authoritative reference. The CMDS is an abstract representation of entities within the maritime domain. It should be accessible by any stakeholder or implementer and should be the reference for the development of maritime services, applications and databases.

Considering the extent of the maritime domain, with all of its stakeholders, the responsibility for the CMDS is subdivided into smaller units, each of which is governed by a recognised authority. However, these authorities cooperate to harmonise the CMDS as a whole (e.g., to avoid duplication of entries). This is one of the main tasks of the IMO established IMO/IHO Harmonisation Group on Data Modelling (HGDM).

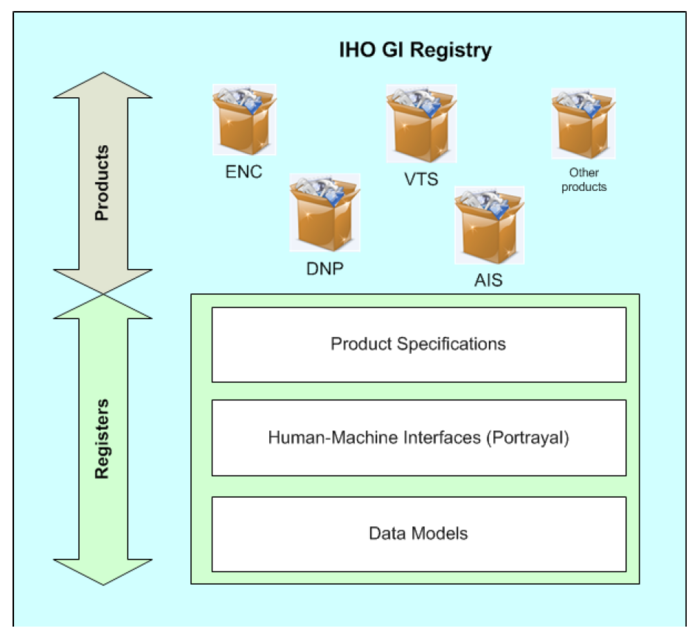
IHO developed the IHO GI Registry[[1]](http://www.iala-aism.org/wiki/ialawiki/index.php/Navguide:_Chapter_4_-_e-Navigation#cite_note-1), based on its S-100 standard, as a tool for data modelling for the specification and production of Electronic Navigational Charts (ENC) and Digital Nautical Publications (DNP). The GI Registry is generic in setup and has been adopted by IMO as the tool to develop the CMDS.

[](http://www.iala-aism.org/wiki/ialawiki/index.php/File:Navguide_4-5-4_Figure21_The_Harmonised_Common_Maritime_Data_Structure.png)

The Harmonised Common Maritime Data Structure

The above describes the simplified generic structure of the GI Registry. The major features of the registry include registers for:

* Product Specifications – includes everything needed to fully describe and specify a product such as data exchange protocols and references to HMI and CMDS entities from the GI Registry.
* Human-Machine Interface (HMI) – HMI definitions/ specifications can also include references to CMDS entities from the GI Registry. (This register is named Portrayal by IHO.

[](http://www.iala-aism.org/wiki/ialawiki/index.php/File:Navguide_4-5-4_Figure22_Simplified_View_of_the_IHO_GI_Registry.png)

Simplified View of the IHO GI Registry

### Maritime Resource Name (MRN)

XX

### S-100 Geospatial Information Registry

XXXXXXX

## Common Maritime Infrastructure

Ekrugfv

### Identity Management

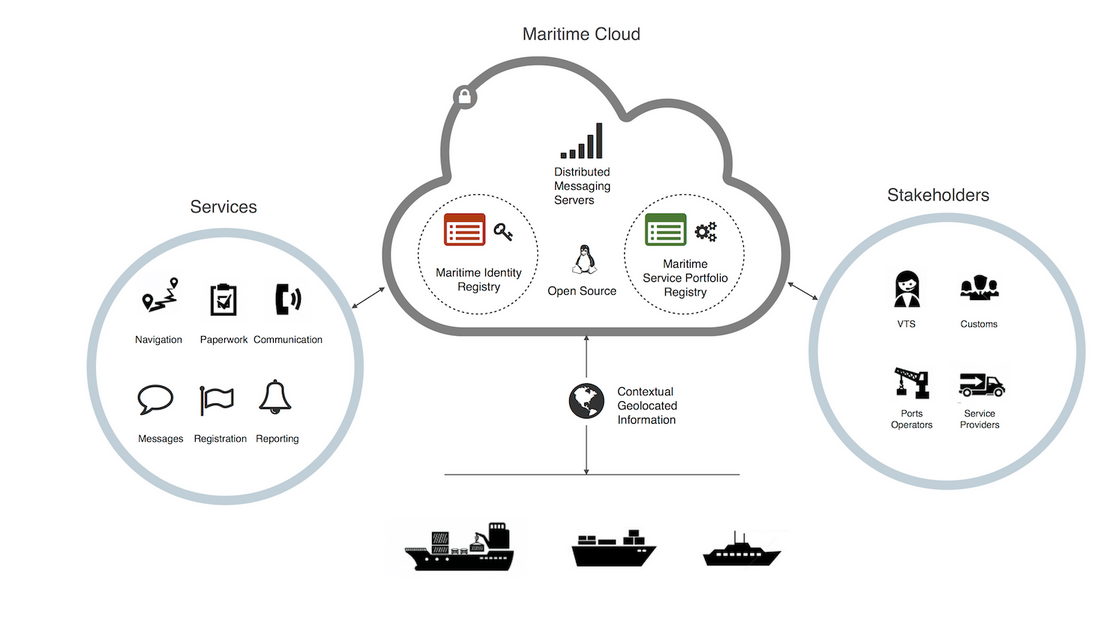
Jyqrgf

### Service Management

Areiua

### Maritime Cloud (Rasmus) including Maritime Messaging Service

The Maritime Cloud is an emerging concept for a proposed communication framework for efficient, secure and reliable electronic information exchange between authorised stakeholders. Basically, it defines the standards, protocols, infrastructure and governance for information exchange. It is not a storage cloud – nor is it cloud computing. The development of the Maritime Cloud was influenced by the System Wide Information Management (SWIM) concept (United States’ Federal Aviation Administration initiative for better sharing of Air Traffic Management system information).



***The Maritime Cloud concept***

*(Image courtesy: EfficienSea Project)*

The Maritime Cloud is structured such that:

* Services can be easily registered, discovered and used;
* Identities can be verified and used to digitally sign communication;
* Messages can be exchanged between components connected to the cloud. These can be either clients operated by humans or services.

Geographic and organisational contexts (e.g., a vessel’s location) are used as key parameters for service discovery, identity verification and message exchange.

The Maritime Cloud offers a so-called Service Registry. Components connected to the cloud ask the service registry how to access and use a service. Additionally, the Maritime Cloud provides a Maritime Messaging Service (MMS). This component can be imagined as an automated switchboard. It uses the communication channel available for communication to a service while the access point (the "telephone") stays the same



*Telephone exchange analogy*

Depending on the request (Name, Type, Location …) the end user is provided with possible service provider and can then choose which service to use.

Nowadays, daily processes include a lot of paper work. Documents need to be signed to prove authenticity. The Maritime Cloud offers the means to digitally assure the identity of the communicating partners.

The maritime cloud does not include data storage or application hosting. This remains the responsibility of service providers and organisations.

The Maritime Cloud is focused on improving communication and digital interactions based on open standards, while reusing existing components and infrastructure within the current organisations to enable a smooth transition to adoption

### Global Maritime Distress Safety System (Jean Charles)

XX

### Automatic Identification System / ASM

XXX

## Cyber Security

YY

# Communications

## Introduction

From J C Corneleau – at ENAV 20 – in yellow highlight

It should be recall the first safety requirement on board ships after the TITANIC disaster was to install radio (wireless as we used to say in 1912) equipment on board ships. Jack Philips & Harold Bride, the two Marconi radio operators on board TITANIC saved 1813 persons (almost half number of persons on board) by sending the very first SOS of history. Member States should not forget this basic: Radio-communications at sea are connected with the safety of life and the efficiency of maritime Search and Rescue.

The 9 GMDSS functional requirements cover not only distress alerts and SAR communications but also Maritime Safety Communication (MSI), general radio communications as well as bridge to bridge communications. Public Correspondence and FAL forms transmitting are for instance covered under general radio-communications. The 4 levels of priority in radio-communications are described in the ITU Radio-communication Regulation: Distress, Urgency, Safety and other communications.

The general principles of GMDSS should be kept easy to use for seafarers as it is basically:

Sea Area A1: VHF coastal radio station (CRS) coverage;

Sea Area A2: MF coastal radio station (CRS) coverage;

Sea Area A3: coverage of a recognized satellite system (Inmarsat at the present time) and

Sea Area A4: not Sea area A1, A2 nor A3, but HF CRS coverage.

ITU is preparing HF new technology, in particular digital HF on the marine band. The technology is already available. It seems there is no more HF coastal radio station, meanwhile there are still 84 HF CRS declared in the GMDSS master plan. In addition, there are still 36 HF stations broadcasting facsimile. Facsimile system is still recommended by WMO pending new systems may provide the same graphical information. In this context, in resolution A.801(19), annex 2, appendix 1, there are basic principles for establishing HF coast stations such as 2 stations should be selected on opposite sides of an ocean region. The main issue for the future of a good functioning global HF network was how to keep up the minimum number of HF stations and who would bear the costs.

There are few requirements concerning the shore side in the present GMDSS, despite the basic concept is that search and rescue authorities ashore will be rapidly first alerted to a distress incident so that they can assist in a co-ordinated SAR operation with the minimum delay. The modernization of GMDSS considered so far the following provisions of radio-communication services:

1) CRS and CES global distribution: Considering that Sea Area A3 is in the modernization of GMDSS dependent on Sea Area A4, HF would be the only option on a ship, and noting that in the case that solar flares damage satellites, HF communications would be the only backup for satellite communications, Member States should consider the global HF distribution. GMDSS infrastructure should be considered and the way the GMDSS master plan could be efficiently secured.

2) Shore-to-shore communication: Considering the increase of satellite systems with other long-distance communications systems in general, such as MF/HF, Member States should consider a global network to deliver distress alerts to the appropriate search and rescue services. Res.A.1001(25) 4.4 relative to the routeing of maritime distress alerts focused on the only associated MRCCs of the satellite systems participating in the GMDSS. There is a need to secure the shore-to-shore communication up to the SAR Point of Contact (SPOC) of any Member State in order to fulfil UNCLOS article 98, paragraph 2 and SOLAS V.

In order to achieve the review and modernisation of GMDSS, IMO Member States involved in the correspondence group (CG) on the review and modernization of GMDSS were requested to take into account:

* e-navigation gap analysis;
* the need to integrate navigation systems and communication systems;
* the need to read MSI in graphical display;
* functionalities for shore-to-shore communications;
* common shore-based system architecture (CSSA) for communications;
* usability of equipment;
* software quality assurance of equipment;
* man-machine interface and

the scalability to all types of vessels.

## Communications systems and data exchange for the maritime domain

XX

## IALA Maritime Radio Communications Plan

IALA has prepared a Maritime Radio Communications Plan (MRCP) for the communications required to support e-Navigation. The MRCP is intended to meet the key strategy element of identifying communications technology and information systems to meet user needs. This may involve the enhancement of existing systems or the development of new systems. The IALA work starts by identifying existing and future systems, then drawing on the user requirements already identified to assess the information flows and the data channels needed.

## Satellite communications systems

XX

## VHF Data Exchange System

### Overview

At the World Radio Conference 2015 the International Telecommunications Union identified 6 frequencies in the VHF maritime mobile band for the use of digital data transfer. The frequencies form part of the developing VHF Data Exchange System (VDES). With the ability to group the these frequencies together to provide a larger band for data transfer, the VDES will enhance digital data functionality in the future.

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 through the system. VDES will include AIS as it currently exists. New techniques that provide higher throughput using multiple [] channels which can:

* be merged to provide higher data rates
* provide simultaneous message diversity from multiple sources.

Furthermore, VDES network protocol is optimized for data communication. The objective is that each VDES message is transmitted with a high confidence of reception.

Implementation of VDES has commenced, building on the allocation of spectrum at WRC-15 where the ITU approved a standard for VDES, Recommendation ITU-R M.2092-0. A remaining outstanding issue is the approval of the satellite component for the VDE channels which is targeted for approval at WRC-19.

The system concept, including VDES functions and frequency usage are illustrated pictorially in Figure YY (full system, including Satellite allocations)

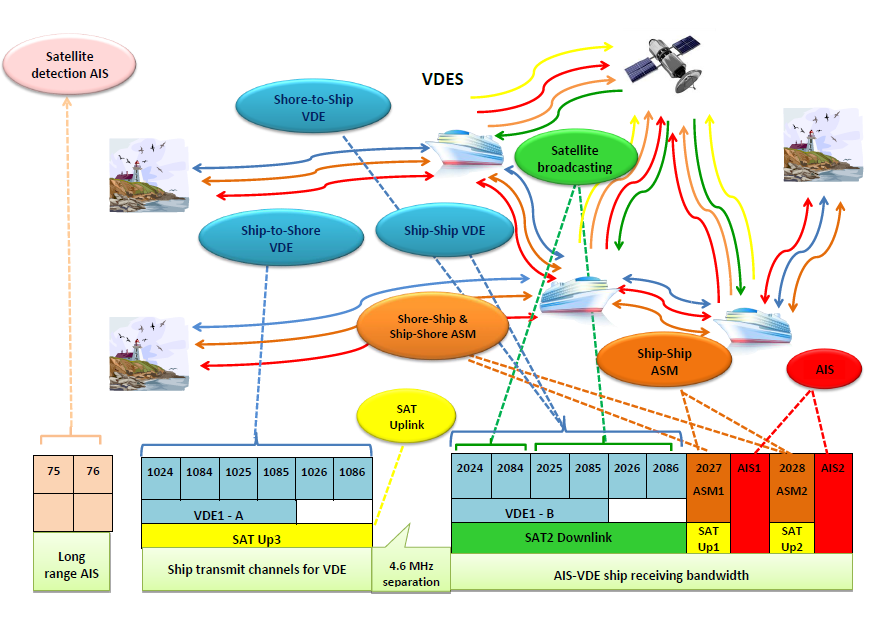


Figure YY - VDES functions and frequency use – full system

Table XX presents the channel allocation of VDES.

| Channel number in RR Appendix 18 | Transmitting frequencies (MHz) for ship and coast stations | |
| --- | --- | --- |
| Ship stations (ship-to-shore)  (long range AIS)  Ship stations (ship-to-satellite) | Coast stations  Ship stations (ship-to-ship)  Satellite-to-ship |
| AIS 1 (87B) | 161.975 | 161.975 |
| AIS 2 (88B) | 162.025 | 162.025 |
| 75 (long range AIS) | 156.775 (ships are Tx only) | N/A |
| 76 (long range AIS) | 156.825 (ships are Tx only) | N/A |
| 2027 (ASM 1) | 161.950 (2027) (SAT Up1) | 161.950 (2027) (SAT Up1) |
| 2028 (ASM 2) | 162.000 (2028) (SAT Up2) | 162.000 (2028) (SAT Up2) |
| 24/84/25/85 (VDE 1)  24  84  25  85 | 100 kHz channel  (24/84/25/85, lower legs, merged)  Ship-to-shore  Ship-to-satellite (SAT Up 3) | 100 kHz channel  (24/84/25/85, upper legs, merged)  Ship-to-ship, Shore-to-ship  Satellite-to-ship under certain conditions (SAT2 possible extension) |
| 157.200 (1024) | 161.800 (2024) |
| 157.225 (1084) | 161.825 (2084) |
| 157.250 (1025) | 161.850 (2025) |
| 157.275 (1085) | 161.875 (2085) |
| 26/86  26  86 | 50 kHz channel  (26/86, lower legs, merged) VDE 2  Ship-to-satellite (SAT Up3) | 50 kHz channel  (26/86, upper legs, merged)  Satellite-to-ship (SAT 1) |
| 157.300 (1026) VDE 2, SAT Up3 | 161.900 (2026) (SAT 1) |
| 157.325 (1086) VDE 2, SAT Up3 | 161.925 (2086) (SAT 1) |

Table XX Channel allocation for VDES

IALA has published a Guideline that provides an overview of VDES, including the road map to develop and implement this system. [*make link to IALA Guideline 1117VDES Overview*]

## Digital Selective Calling (DSC) (VHF and HF)

[text]

## Digital VHF and HF

[text]

## Wi-Fi

[text]

## 4G and 5G networks

[text]

## Satellite communication systems and services

[text]

### Geostationary satellites (GEO)

[text]

### Low Earth Orbiting satellites (LEO)

[text]

### Automatic Identification System

Since its advent in the late 1990s, AIS has been a stand-out success. Originally meant for use in a ship-to-ship mode for collision avoidance and as a means for littoral States to obtain information about a ship and its cargo (i.e. as a VTS tool), its use has grown immensely. Maritime authorities such as AMSA now use AIS to support their aims and charters. Uses include:

* + search and rescue
  + ship operations
  + vessel tracking
  + investigations and prosecutions
  + environment protection
  + port State control
  + salvage and intervention
  + compliance with pilotage requirements
  + vessel traffic services
  + planning of navigational services (e.g. ships’ routeing measures)
  + monitoring of (and use as) aids to navigation
  + strategic planning

The success of AIS is paradoxically its problem as well, in some ways. There is now a proliferation of its use (e.g. Class B AIS stations, AIS man overboard devices and AIS SARTs). This has created significant loading on the VHF Data Link in busy areas (e.g. 64% in the Gulf of Mexico and 40% each in Japan and Korea (2015 data)).

Therefore, it is clear that the existing AIS frequencies will not cope with future requirements and that e-navigation will need more capacity for data exchange.

IALA played a leading role in seeking ITU approval to establish the VHF Data Exchange System (VDES). The VDES concept addresses the need for additional capacity for digital data exchange in an e-navigation world. Many Members, along with commercial interests, conducted sea trials to prove the VDES concept.

Some countries are modernising its AIS shore station network to use software-defined radios. Australia’s AIS service manager (ASM) is also VDES-ready, and complies with the VDES standard, as it exists today. Australia continues to prepare for and support the introduction of VDES, through the introduction of new hardware and software in its shore station network

Automatic Identification System (AIS) is a ship and shore-based data broadcast and interrogation technology, operating in the VHF maritime band, that makes it possible to monitor and track ships from suitably equipped ships, and shore stations.

AIS’ characteristics and capability make it a powerful tool for enhancing situational awareness, thereby contributing to the safety of navigation and efficiency of shipping traffic management. Shipboard AIS enables the provision of fast, automatic and accurate information regarding risk of collision allowing the Closest Point of Approach (CPA) & Time to Closest Point of Approach (TCPA) to be calculated from the positional information transmitted by target vessels. AIS increases the possibility of detecting other ships, even if they are behind a bend in a channel or river or behind an island in an archipelago. AIS also solves the problem inherent with radars, by detecting smaller craft, fitted with AIS, in sea and rain clutter.

An AIS unit is a VHF radio transceiver capable of exchanging information such as station identity, position, course over ground, speed, length, ship type and cargo information etc., with other ships and suitable receivers ashore within VHF range. Figure 27 gives an overview of the system.

Once set up correctly, information from an operational shipboard AIS unit is transmitted continuously and automatically, without any intervention by the ship’s staff. AIS transmissions consist of bursts of digital data ‘packets’ from individual stations, according to a pre-determined time sequence. Therefore, AIS is an important supplement to existing systems, including radar. In general, data received via AIS will enhance the information available to the Officer of the Watch and the Vessel Traffic Service Operator (VTSO).

The International Maritime Organization (IMO) has established carriage requirements for merchant ships. The International Telecommunication Union (ITU) has defined the technical characteristics and ratified the global frequencies. In addition, the International Electrotechnical Commission (IEC) has developed methods for testing AIS for global interoperability.

|  |
| --- |
| This section aims to provide a broad overview of AIS. The reference list at the end of this section assists the reader seeking amplifying information on various aspects of AIS. |

#### Purpose & Function

The purpose of AIS is to positively identify vessels, provide additional information in order to assist in collision avoidance and assist in vessel tracking. It also aims to simplify and promote the exchange of information automatically, thereby reducing the need for doing so verbally (e.g.mandatory ship reporting by radiotelephony).

AIS satisfies the following functional requirements, as laid down by IMO:

* in a ship-to-ship mode for collision avoidance;
* as a means for littoral States to obtain information about a ship and its cargo;
* as a VTS tool, i.e. ship-to-shore (traffic management).

AIS automatically exchanges shipboard information (provided by shipboard sensors), between vessels and between a vessel and a shore station(s).

#### System Characteristics

Frequencies and Capacity

AIS operates on two dedicated VHF FM radio frequencies AIS1 (channel 87B – 161.975 MHz) and AIS2 (channel 88B– 162.025 MHz) in the maritime mobile band. Transmissions consist of bursts of ‘data packets’ from individual stations, according to an automatically determined time-ordered sequence. Stations organize themselves on the common frequencies (AIS 1 and AIS 2) based on the knowledge of their own transmissions and that of other stations. This method of operation is known as Self Organizing Time Division Multiple Access (SOTDMA). The time slots for AIS transmissions are all precisely aligned to Coordinated Universal Time (UTC), provided for by a Global Navigation Satellite System (GNSS) receiver. This avoids the possibility of two stations transmitting at the same time, in the same slot. There are 2250 time slots available on each frequency per minute, making the total number of slots equal to 4500.

In this architecture, the Administration determines whether its ships will report to a national, regional/cooperative, or the international LRIT data centre. Each of these types of centres may use multiple communications service providers. The architecture is also designed to accommodate multiple application service providers. Building on the basic concept noted above, a ship carries radio communications equipment that reports identification, position and time to the national, regional/cooperative, or international LRIT data centre tracking that ship. The Administration of the ship can access the LRIT information directly from the data centre.

Other Contracting Governments that are entitled to that information (i.e., port and coastal states) can request the information through their data centre and thence through the international LRIT Data Exchange. The LRIT information is routed to the requesting data centre through the data exchange.

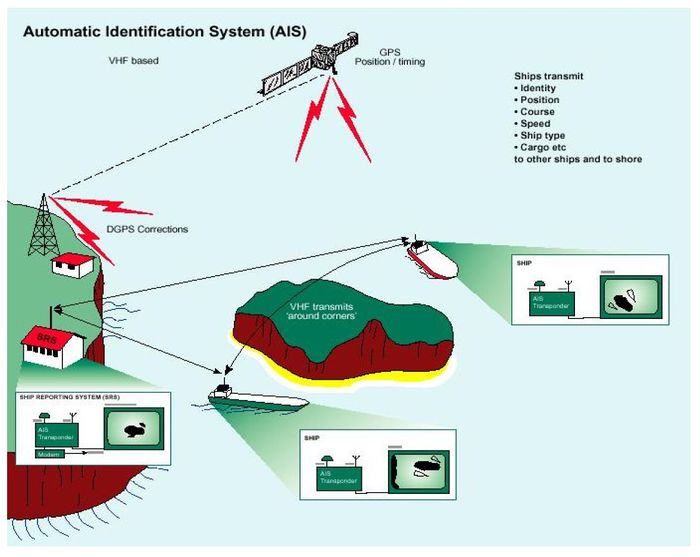
[](http://www.iala-aism.org/wiki/ialawiki/index.php/File:Navguide_2014_Figure_27.jpg)

Figure 27 - Overview of the AIS System

#### Shipboard AIS

A shipboard AIS unit transmits its own data to other vessels and to AIS equipped stations continuously and autonomously. It also receives AIS data of other stations (ship and shore) and can display this data textually and graphically, as required.

Each AIS station consists of a VHF transmitter, two VHF SOTDMA receivers, a VHF DSC receiver, a GNSS receiver (to provide timing for slot synchronisation), and a marine electronic communications link to shipboard display and sensor systems.

Positional information can be derived form the internal GNSS or an external electronic position fixing system. The display panel with the unit is often the only means of showing received AIS datA. Together with a keypad, this basic configuration is known as a Minimum Keyboard and Display (MKD).

The display part of a MKD, as a minimum, consists of three lines of data, each showing bearing, range and identity of the target. In practice, most MKDs display more lines of data and may also have a simple graphical display, showing the relative location of targets, rather like the Plan Position Indicator of a radar.

Ideally, AIS information should to be displayed graphically on a radar, ECDIS or on its own dedicated display.

#### Available Information

The AIS information transmitted by a ship station includes four different data sets:

Fixed or static information is entered into the AIS unit on installation and need only be changed if the ship changes its name, call sign etc. This information is broadcast every six minutes or on request by a shore authority;

Voyage related information (destination, ETA etc) is manually entered and updated during the voyage. This information is also broadcast every six minutes. In order that correct AIS information is broadcast to other vessels and shore authorities, mariners are reminded to enter current voyage related data such as draught, type of hazardous cargo, destination and ETA properly at the beginning of each voyage and whenever changes occur;

Dynamic information is automatically updated from the ship sensors connected to the AIS. This includes COG, SOG, position (with accuracy and integrity flag), time and navigation status (e.g., underway);

Broadcast or addressed short safety related messages, as required.

|  |
| --- |
| Refer to IALA publications:  Guideline 1028 on the Universal Automatic Identification (AIS) – Volume 1, Part 1 – Operational Issues;  Guideline 1029 on the Universal Automatic Identification System (AIS) – Volume 1, Part 2 – Technical Issues;  Guideline 1082 on an Overview of AIS. |

#### Shore-based AIS

SOLAS Chapter V, Regulation 19, 2.4 refers to the carriage requirements for AIS. The regulation states that AIS shall provide and receive information from appropriately equipped shore stations. The provision of shore based AIS will be necessary to attain the full benefit of the 1974 SOLAS Convention (as amended).

As AIS can be seen as a tool related to Vessel Traffic Services (VTS), Competent Authorities should consider implementing AIS into existing VTS Centres. Information on the use of AIS in VTS operations is contained in Sections 1015-1027 of the IALA VTS Manual.

|  |
| --- |
| Refer to IALA publications:   * Recommendation A-123 on the Provision of Shore Based Automatic Identification Systems; * Recommendation A-124 on the Automatic Identification System (AIS) Shore Station and Networking Aspects relating to the AIS Service. |

#### Meteorological & Hydrological Information

IMO is responsible for the AIS Binary Broadcast Messages (AIS Message 8) and a message structure has been defined for meteorological and hydrological information. A number of countries operate tide gauges and current meters to assist the prediction of tidal heights and streams or for the broadcast of real-time information to shipping. The latter is generally used to overcome the sometimes considerable differences between actual tide heights and predicted values due to meteorological and mean sea level fluctuations. Providing real-time information of this type, for example dynamic under-keel clearance, wave heights or sea state can be seen as applications of e-Navigation, requiring integration between shore-side and ship-borne systems.

#### AIS Aids to Navigation

A special type of AIS station fitted to an aid to navigation provides positive identification of the aid without the need for a special ship-borne display. In addition, AIS as an AtoN can provide information and data that will:

* complement or replace an existing aid to navigation, providing identity, state of ‘health’ and other information such as real time tidal height and local weather to surrounding ships or back to a shore authority;
* provide the position of floating aids (mainly buoys) by transmitting an accurate position (corrected by DGNSS) to monitor if they are on station;
* provide real-time information for performance monitoring, with the connecting data link serving to remotely control changes in AtoN parameters or switching on back-up equipment;
* provide local hydrological (hydrographical) and meteorological information;
* possibly replace radar beacons (racons) in the future, providing longer range detection and identification in all weather conditions;
* gather shipping traffic data on AIS fitted ships for future aid to navigation planning purposes.

For practical or economic reasons it may not be appropriate to fit an AIS to an AtoN.

|  |
| --- |
| Refer to IALA publications:   * Recommendation A-126 on the Use of the Automatic Identification System (AIS) in Marine Aids to Navigation; * Recommendation O-143 on Virtual Aids to Navigation; * Guideline 1050 on the Management and Monitoring of AIS Information; * Guideline 1081 on Virtual Aids to Navigation. |

#### Carriage Requirements

There are two ‘types’ of AIS units for ship stations. These are termed Class A and Class B units.

**Class A** ship-borne mobile units must comply with ITU-R M.1371, and are required to be carried on board those vessels to which Regulation 19 of SOLAS Chapter V applies and meet the IMO performance standard. All these ships were to have AIS fitted by 31 December 2004.

**Class B** ship-borne mobile equipment, while also complying with ITU-R M.1371, is designed for vessels such as pleasure craft and fishing vessels. These units provide less functionality than Class A units, and do not necessarily meet all the IMO performance requirements. They are designed to operate co-operatively with Class A units.

Administrations can require the carriage of Class B units as part of their domestic requirements.

#### Cautions When Using AIS

The Officer of the Watch (OOW) should always be aware that other ships, in particular pleasure craft, fishing vessels, warships and some shore stations including VTS centres, may not be fitted with AIS.

The OOW should always be aware that AIS fitted on other ships as a mandatory carriage requirement, might, under certain circumstances, be switched off, particularly where international agreements, rules or standards provide for the protection of navigational information. AIS can also provide incorrect information if the input data is wrong.

Navigators should be aware of the limitations of AIS. In particular, government agencies and owners should ensure that watch-keeping officers are trained in the use of AIS[[9]](http://www.iala-aism.org/wiki/ialawiki/index.php/Navguide:_Chapter_4_-_e-Navigation" \l "cite_note-9). Because of these limitations navigators are advised that AIS should not be used as the primary means of collision avoidance.

#### AIS via satellite

#### Use of AIS in Court cases

#### Strategic Applications

From a number of maritime perspectives (such as VTS and regulatory compliance), the availability of comprehensive ship information, offers a mechanism for:

* better monitoring of compliance with national and international regulations for mandatory routeing and reporting systems, Particularly Sensitive Sea Areas, discharging of oil, garbage disposal etc;
* maritime logistics applications such as fleet management, cargo tracking and port facilities (movement of pilot boats, tugs etc);
* better control, co-ordination and response in the event of marine incidents, such as SAR and pollution;
* shore -based navigational assistance;
* shipping information gathered from AIS can be channelled into a central repository of a local, national or regional network serving maritime administrations, port authorities, shipping agents, freight handlers, customs, immigration, etc..

#### Application Specific messages

#### More information

More information on AIS can be found within IMO, IALA, ITU and IEC documentation.

|  |
| --- |
| Refer to IALA publications:   * Guideline 1026 on AIS as a VTS Tool; * Guideline 1028 - Volume 1, Part I – Operational Issues; * Guideline 1029 - Volume 1 Part II – Technical Issues, Edition 1.1; and * Technical Clarifications on ITU Recommendation ITU-R M.1371-1 Edition 1.5. |

|  |
| --- |
| Refer to IMO publications:   * Recommendation on Performance Standards for an Universal Shipborne Automatic Identification System (AIS) (MSC 74(69) Annex 3); * Guidelines for the onboard operational use of shipborne Automatic Identification Systems (AIS) (Resolution A.917 (22), as amended by Resolution A.956 (23)); * Performance Standards for the presentation of navigation-related information on shipborne navigational displays (Resolution MSC.191(79); * SN/Circ.227 Guidelines for the installation of a shipborne Automatic Identification System (amended by SN/Circ 245); * SN/Circ.236 Guidance on the application of AIS Binary Messages; * SN/Circ.243 Guidelines for the presentation of navigation-related symbols, terms and abbreviations * SN/Circ.244 Guidance on the use of UN/LOCODE in the destination field of AIS messages. |

|  |
| --- |
| Refer to ITU Publications:   * ITU-R M.1371-1 Recommendation on the Technical Characteristics for a Ship-borne Universal Automatic Identification System (AIS) Using Time Division Multiple Access in the Maritime Mobile Band; * Radio Regulations, Appendix S18, Table of Transmitting Frequencies in the VHF Maritime Mobile Band; * ITU-R M.823-2 Recommendation on the technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in region 1 and 285-325 kHz in regions 2 and 3. |

|  |
| --- |
| Refer to IEC Standards:   * 61993 Part 2: Class A Ship-borne equipment of the Automatic Identification System (AIS) - Operational and Performance requirements, methods of testing and required test results; * 61108-1 (2nd edition): navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS); * 61162-1 (2nd edition) Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 1: Single talker and multiple listeners; * 62320-1: Maritime Navigation and Radiocommunication equipment and systems – Automatic Identification System. AIS base stations - Minimum operational and performance requirements - methods of test and required test results; * 62320-2 Maritime Navigation and Radiocommunication equipment and systems – Automatic Identification System. AIS aids to navigation - Minimum operational and performance requirements - methods of test and required test result; * 62287-2 (Part A and B) Class B AIS (Part A – CSTDMA; Part B – SOTDMA); * 61097-14 (pending) Global Maritime Distress and Safety System (GMDSS). AIS search and rescue transmitter (AIS-SART) – Operational and performance requirements: methods of testing and required test results. |

# Positioning, Navigation and Timing

## Introduction

IALA has developed a World Wide Radio Navigation Plan (WWRNP) aimed at providing the WWRNS to support e-Navigation. One key concept in this plan is the separation of the generation of correction data from the means of transmission, to facilitate broadcasting by a variety of methods. This could lead to the integration of terrestrial systems (DGNSS beacons, e-Loran, AIS) to provide shared data channels and common correction sources, as well as additional ranging signals, contributing to a redundant position-fixing solution, complementary to, but independent of GNSS.

Future standards for position-fixing systems should be considered in the context of position-fixing requirements for e-Navigation. This WWRNP could be the basis for a submission to IMO as a contribution to the WWRNS. The plan provides guidance to IALA members regarding potential future developments, which will enable members to identify areas requiring resource allocation and research activity.

## What is resilient PNT

## Electronic Position Fixing Systems

### Global Navigation Satellite Systems

Global Navigation Satellite System (GNSS) is a generic term for a satellite system that provides a world-wide position determination, time and velocity capability, for multi-modal use.

GNSS is based on a constellation of active satellites, which continuously transmit coded signals in one or more frequency bands. These signals can be received by users anywhere on the earth’s surface to determine their position and velocity in real time, based on ranging measurements.

If a GNSS is recognised by the IMO as a component of the World Wide Radio Navigation System (WWRNS) as set out in IMO Resolution A.1046(27), the receivers of that GNSS will satisfy the IMO carriage requirements for position fixing equipment referred to in Chapter V of the SOLAS Convention.

GNSS receivers, in combination with other equipment, are able to provide PNT information such as:

* absolute positioning;
* relative positioning (this can be further processed to derive speed over ground (SOG), course over ground (COG), etc.);
* timing.

This information may refer to a stationary observer (static positioning) or to a moving observer (kinematic positioning).

Several Global Navigation Satellite Systems (GNSS) have been deployed, fully or partially, or are under development.

GPS, GLONASS, and Beidou have been recognised as components of the WWRNS. It is expected that Galileo will be recognised in the near future. Regional GNSS components like QZSS and IRNSS are planned to become operational in the next few years and may be submitted for WWRNS recognition in due course.

GPS, Galileo, Beidou, QZSS and IRNSS operate interoperable services under the framework of the International Telecommunication Union (ITU).

#### Global Positioning System

The Global Positioning System (GPS) is a three-dimensional positioning, three-dimensional velocity and time system that became fully operational in 1995. The system is operated by the United States Air Force on behalf of the United States Government.

The U.S.Government provides two levels of GPS service. The Precise Positioning Service (PPS) provides full system accuracy to designated users. The Standard Positioning Service (SPS) provides accurate positioning to all users.

The GPS has three major segments: space, control, and user. The GPS Space Segment consists of a nominal constellation of 24 satellites in six orbital planes. The satellites operate in circular 20,200 km (10,900 nm) orbits at an inclination angle of 55 degrees and with a 12-hour period.

The GPS SPS is available on a non-discriminatory basis and free of direct user fees to all users with an appropriate receiver. The service satisfies the requirements for general navigation and harbour approach with a horizontal position accuracy of 9 metres (95% probability)[[3]](http://www.iala-aism.org/wiki/ialawiki/index.php/Navguide:_Chapter_4_-_e-Navigation" \l "cite_note-3)

A modernization program aims to improve the accuracy and availability for all users and involves new ground stations, new satellites, and four additional navigation signals: three new civilian signals known as L2C, L5 and L1C and a new military code called M-Code.

Further information on GPS can be found on the USCG NAVCEN website (www.navcen.uscg.gov) The website also has a link to the latest United States Federal Radionavigation Plan that provides a comprehensive account of current and future developments for GPS.

#### Global Orbiting Navigation Satellite System

The Global Orbiting Navigation Satellite System (GLONASS) is a three-dimensional positioning, velocity and time system managed by the Russian Space Agency for the Russian Federation.

It is available on a non-discriminatory basis and free of direct user fees to all users with an appropriate receiver. With a full complement of 24 satellites, the service satisfies the requirements for general navigation and gives a horizontal position accuracy in the region of 12.4m (95%) over any 24-hour interval, given a position dilution of precision (PDOP) of 2.[[4]](http://www.iala-aism.org/wiki/ialawiki/index.php/Navguide:_Chapter_4_-_e-Navigation#cite_note-4)

Recent launches have included the improved GLONASS M satellites with a second civil signal. Since 2011, the constellation is being replenished with GLONASS-K satellites that provide a third civil signal on L3.

GLONASS satellites use Frequency Division Multiple Access (FDMA), however new satellites will provide additional signals using code division multiple access (CDMA) to become interoperable with other GNSS.

Further information on GLONASS and future developments can be found on the Russian Space Agency, Information Analytical Centre website (www.glonass-ianc.rsa.ru).

#### Galileo

Galileo is Galileo is the European GNSS designed to be interoperable with other GNSS, managed and operated under civil control. The Galileo programme is currently in its deployment phase, which is due for completion in 2020. Planned satellite launches will enable early services to be offered as more satellites become available.

The deployment and the exploitation are entirely financed through the budget of the European Union, while two non-EU members, Norway and Switzerland, contribute through international agreements. Galileo will offer the following services:

1. An Open Service (OS): With positioning accurate to around 1 meter using up to three different frequencies (E5a, E5b and L1), free of charge to the user and providing positioning and synchronization information intended mainly for high-volume satellite navigation applications;
2. A Public Regulated Service (PRS): Restricted to European government-authorized users, for sensitive applications which require a high level of service continuity. It will use strong encrypted signals. It may be accessed by non-EU states and international organizations subject to bilateral agreements.
3. A contribution to the Search and Rescue Service (SAR) of the COSPAS-SARSAT system: Galileo’s worldwide search-and-rescue service will forward distress signals to a rescue coordination centre by detecting emergency signals from beacons and relaying messages to them in near real time.
4. A Commercial Service (CS): Encrypted for authentication purposes and offering very high accuracy to the sub-decimeter level, it will target applications for professional or commercial use owing to improved performance and data with greater added value than that obtained through the open service.

Galileo will use a constellation of 24 satellites to achieve its positioning performance targets, but aims to have a constellation of 30 satellites when fully operational, to include in-orbit spares.

Further information on Galileo can be found at the following website: http://ec.europa.eu/growth/sectors/space/galileo/

#### BeiDou

Beidou Navigation Satellite System (BDS) is China’s independently constructed and operated system. It can be compatible with other GNSS in the world. It can provide all-time, all- weather PNT services with high accuracy and high reliability for all kinds of users. As a joint office established by related governmental departments, China Satellite Navigation Office (CSNO） is in charge of management on the construction, application promotion and industrialisation of BDS.

BDS consists of three major components: the space constellation, the ground control segment and the user segment. The space constellation consists of 5 GEO satellites and 30 non-GEO satellites. U pon the full system completion, BDS can provide positioning, velocity measurement and timing services to users worldwide. It can also provide wide area differential services with the accuracy of better than 1m.

By the end of 2012, BDS consists of 14 operational satellites in orbit, including 5 GEO satellites, 5 IGSO satellites, and 4 MEO satellites, and possesses Full Operational Capability (FOC) for the Asia-Pacific region. It can provide positioning accuracies of better than 10m and velocity measurement with better than 0.2 m/s. Meanwhile, it also has the capability of providing one-way and two-way timing with 50ns and short message communications with 120 Chinese characters per message.

It is expected that when fully operational, the BeiDou constellation will consist of approximately 40 satellites and will be capable of providing global coverage.

For further details on BDS, including the number of satellites currently in orbit, please refer to the CSNO website [5].

Further information on BDS can be found on the CSNO website (http://en.beidou.gov.cn/index.html)

### Regional systems

#### Quasi-Zenith Satellite System

Japan is developing a Quasi-Zenith Satellite System (QZSS). QZSS is based on 3 satellites in highly elliptical, inclined orbits and one geo-stationary satellite. The final constellation is expected to consist of 7 satellites, with each transmitting 6 signals in the L-band: 3 in L1, one in E6, one in L2 and one in L5.

Full implementation will also provide augmentation services to GPS and QZSS.

The signal in E6 (L6) aims to support a commercial service with high data rate (2 kbps).

Further information is available at http://.QZSS.go.jps.

#### Indian Regional Navigational Satellite System

The Indian Regional Navigational Satellite System (IRNSS) will be an independent navigation system covering the Indian region through a space segment of 3 GEO satellites and 4 IGSO satellites. The inclination of the orbital plane of the IGSO satellites is low, so that all the satellites can be seen simultaneously over India.

Three IRNSS services are anticipated:

* Open Service using signals in the L5 and S bands;
* Precise Positioning Service using signals in the L5 and S bands;
* Restricted Access Service using signals in the L5 band only.

The Open and Precise services target dual frequency users but it is also intended to compute and broadcast ionosphere-corrections to support single frequency users. Owing to the limited coverage of the IRNSS network of reference stations the satellites will, apart from the navigation payload, also include a dedicated C-band uplink/down-link ranging payload to support precise satellite orbit determination.

### Differential Global Navigational Satellite System

The aim of GNSS augmentation services such as Differential Global Navigational Satellite System (DGNSS) is the improvement of GNSS based positioning within a given area. In this context various methods can be applied to increase the accuracy of GNSS based positioning and to verify the integrity of applied components (systems, services) and provided data. An essential basis for DGNSS service provision are own GNSS measurements gathered in real time at single reference stations or a network of them.

DGNSS service provides correction terms of ranging errors per satellite in view. This principle is applied by IALA Beacon DGNSS providing range and range rate corrections derived at reference station site from differences between surveyed and known distances to satellites in view. Satellite Based Augmentation Systems (SBAS) provides area correction parameter, whose application enables the determination of range and range correction for users in large-scale regions such as Europe. In this case a network of ranging and integrity monitoring stations (RIMS) is used to measure and model the spatial varying error behaviour.

Accuracies in the centimetre level can be achieved by DGNSS services employing the application of real time kinematic techniques (RTK) for positioning. The gain of accuracy is achieved by the common processing of range and phase measurements collected at reference station and user site to apply single and double difference methods during position determination.

In safety-critical application DGNSS services should be enriched with integrity functions realising the monitoring of data and system integrity in real time. The monitoring can be realised by plausibility and consistency tests as well as methods estimating error behaviour and budgets. Integrity data as results of the integrity monitoring informs the user about the current usability of applied components and provided output data.

The DGNSS service provision is realized by radio signals carrying augmentation, correction, and integrity data. Users operating in service areas and equipped with appropriate receivers can use these augmentation data to:

* enhance accuracy of GNSS based positioning;
* notify faulty satellites or GNSS failure;
* detect satellite signals with increased propagation errors;
* exclude disturbed signals from positioning;
* be informed about the usability of services or other information.

Currently, DGNSS services are provided for operational satellite navigation systems such as GPS and GLONASS. In principle, similar DGNSS services are planned or can be provided for developing GNSS such as GALILEO, BeiDou and QZSS.

Each DGNSS service can be separated into a part generating and a part distributing the augmentation data. The generation of DGNSS augmentation data requires own GNSS measurements gathered at a single reference station or a network of them. Different DGNSS messages and services may use different generation methods and means of dissemination. At present certain communication channels used for the provision of DGNSS augmentation data are assigned to specific DGNSS services. For example, the provision of DGNSS augmentation data is realized by terrestrial radio transmitters (IALA Beacon Transmitter, AIS) or via satellite transponders (SBAS).

#### IALA Beacon DGNSS

The aim of IALA Beacon DGNSS is the provision of non-encrypted differential corrections as well as integrity information to maritime users to improve accuracy and integrity of GNSS based determination of position, velocity and time data (PVT). The method of differential positioning was developed in the nineties, is internationally accepted and supported in most coastal waters, especially in areas of high traffic density. The differential corrections are determined at known positions of reference stations or a network of them. For this purpose the difference between expected and measured ranges is used to derive actual range and range rate corrections.

Additionally, integrity monitoring functionalities are implemented to assess the usability of GNSS signals and provided DGNSS service.

The radio link used for the provision of DGNSS correction and integrity data is internationally defined at ITU (Recommendation ITU-R M.823-3). At present the DGNSS signal transmission is realized in the maritime radionavigation band (283.5 to 325 kHz)[6]. At user site type-approved DGNSS radio beacon receivers meeting IEC 61108-4 test and performance standards are necessary to enable the ship-side use of DGNSS services for an improved PVT data determination.

The recapitalisation of DGNSS infrastructure is an ongoing process. Of the options available, some service providers have opted to replace existing hardware with similar dedicated Reference Stations and Integrity Monitors (RSIM); some have invested in software RSIM; while others have adopted a network of reference stations to create virtual RSIMs. Other solutions, such as integration with SBAS may evolve within the enhancement of the maritime PNT system.

The full list of about 400 maritime radiobeacon based DGNSS stations (as notified to IALA by authorities) can be accessed via the IALA website (www.iala-aism.org).

Refer to IALA publications:

* Recommendation R-121
* Guideline 1112

#### AIS for DGNSS Transmissions

Automatic Identification System (AIS) is a ship to ship and ship to shore data broadcast system, operating in the VHF maritime band, and is described in more detail in section XX.

AIS has the capability of providing DGNSS corrections to onboard equipment using standardized transmissions (Message No 17) as described in IALA Recommendation A-124.

#### Maritime Phase-Based GBAS (MGBAS)

In the last decades the development of phase-based techniques was driven by surveying to achieve position accuracies with GNSS in the centimetre level. In IALA R-135 the RTK technique was mentioned as an approach to meet maritime requirements on high-precision positioning in port areas and for automatic docking. Several manufacturers of maritime GNSS/DGNSS equipment provide solutions supporting RTK based positioning.

It is noted that RTK is a short-range system and that there is a need to introduce monitoring and assessment of the integrity of RTK services and RTK based positioning in the context of safety-critical applications.

#### RTK Over AIS

In survey applications the RTK correction information is usually distributed to users via VHF/UHF radio modems or via commercial broadband internet. However when used in hydrographical measurements further away from the shoreline these communication options might not be available all the time. The communication options in these areas would be via satellite or via AIS (the latter is also available only inside coastal VHF coverage usually less than 70km from shoreline).

RTK over AIS is in operational use for selected user groups in some countries and it has been reported to function without major problems and deliver the required positioning accuracy.

When using RTK over AIS, it should be noted that it puts a high demand on the channel loading. Other limitations of this technique are that only one mobile user can be served by one AIS base-station at a time, reduced understanding of accuracy due to rapid atmospheric fluctuations and that it may not be applicable in areas of high channel loading. The channel loading problem may be addressed in the future by using the additional channels allocated for VDES.

### Satellite Based Augmentation Systems

Satellite Based Augmentation Systems (SBAS) support wide-area or regional augmentation through the use of additional satellite-broadcast messages. The basic scheme is to use a set of monitoring stations (at very well-known position) to receive GNSS signals that will be processed in order to obtain some estimations of these errors that are also applicable to the users (i.e. ionospheric errors, satellite position/clock errors, etc.). Once these estimations have been computed, they are transmitted to the users by means of a GEO satellite.

#### Wide Area Augmentation System

The Wide Area Augmentation System (WAAS) has been implemented by the US FAA to support the use of GPS for general and commercial aviation over continental United States. It was recently extended to cover parts of Mexico and CanadA. At present, the WAAS architecture includes 38 reference stations, 3 master stations, 4 up-link stations, 2 geostationary satellite links and 2 operational control centres. Further information on WAAS can be found on the USCG Navigation Centre website (www.navcen.uscg.gov).

#### European Geo-stationary Navigation Overlay Service

The European Geostationary Navigation Overlay Service (EGNOS) is the European satellite-based augmentation system that provides safety critical navigation services to aviation, maritime and land-based users over most of Europe. EGNOS augments the GPS L1 Coarse/ Acquisition (C/A) civilian signal by providing corrections and integrity information.

EGNOS provides three services:

* + - * Open Service (OS), freely available to any user. The main objective of the EGNOS OS is achievable positioning accuracy by correcting several error sources affecting the GPS signals. (<https://egnos-user-support.essp-> s[as.eu/new\_egnos\_ops/sites/default/files/library/official\_docs/egnos\_os\_sdd\_v2\_2.pdf](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_os_sdd_v2_2.pdf)

);

* + - * Safety of Life (SoL) Service, provides the most stringent level of signal-in-space performance developed primarily to support aviation. Its use in the maritime sector is being explored with a view to supporting maritime SoL users in the future.

([https://egnos-user-support.essp-](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_sol_sdd_in_force.pdf)  [sas.eu/new\_egnos\_ops/sites/default/files/library/official\_docs/egnos\_sol\_sd](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_sol_sdd_in_force.pdf) [d\_in\_force.pdf](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_sol_sdd_in_force.pdf));

* + - * EGNOS Data Access Service (EDAS) is the EGNOS terrestrial data service which offers ground-based access to EGNOS data in real time and also in a historical FTP archive to authorised users (e.g. added-value application providers) ([https://egnos-](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_edas_sdd_v2_1.pdf)

[user-support.essp-](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_edas_sdd_v2_1.pdf)  [sas.eu/new\_egnos\_ops/sites/default/files/library/official\_docs/egnos\_edas\_sdd\_v2\_1.](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_edas_sdd_v2_1.pdf)  [pdf](https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_edas_sdd_v2_1.pdf)).

The EGNOS Space Segment comprises 3 geostationary (GEO) satellites. The EGNOS Ground Segment comprises a network of Ranging Integrity Monitoring Stations (RIMS), two Mission Control Centres (MCC), six Navigation Land Earth Stations (NLES), and the EGNOS Wide Area Network (EWAN) which provides the communication network for all the components of the ground segment.

Further information on EGNOS can be found via website <http://www.egnos-portal.eu/>and <https://egnos-user-support.essp-sas.eu/>).

#### Multi-Satellite Augmentation System

In Japan, the Multi-Satellite Augmentation System (MSAS) is an SBAS similar to EGNOS and WAAS. MSAS has been commissioned for aviation use, with two GEO-links using the L1 band via dedicated satellites shared with communications and meteorological missions. The system has been operational since 2007 and there are plans to add additional services on L5 in the future[8]. Further information on MSAS can be found via the website: (www.kasc.go.jp/\_english/msas\_01.htm).

#### GPS-Aided Geo Augmented Navigation System

India is developing a GPS-Aided Geo Augmented Navigation system (GAGAN), which is an SBAS similar to WAAS and EGNOS. GAGAN includes 8 reference stations, 1 mission control centre, 1 up-link station and 1 Geo link through the L1/L5 transponder on the INMARSAT 4-F1 satellite. At the time of writing, further information on GAGAN may be found via the website (www.isro.org).

#### System for Differential Corrections and Monitoring

Russia is developing an augmentation to provide corrections for GLONASS and GPS called the System for Differential Corrections and Monitoring (SDCM). This system will consist of 3 geostationary satellites, assigned PRN codes 125,140 and 141. Two satellites have been launched and are in operation with the third due to be launched in 2014.

### Terrestrial systems

#### Loran-C

Loran–C was a hyperbolic radionavigation system developed during the 1960’s to meet U.S. Department of Defense requirements. The Russian Federation operates a similar radionavigation system called CHAYKA. There are currently about 19 Loran–C and CHAYKA chains operating around the world. The principal coverage areas include Saudi Arabia, China Sea, Korea, North West Pacific, Russian Federation and North West Europe.

Loran–C chains comprise between three to five stations that have a spacing of 600 to 1000 nautical miles. The signal format is a structured sequence of specially designed radio pulses on a carrier wave frequency centred on 100kHz. One of the stations is designated as the ‘master’ and transmits groups of 9 pulses. The other stations are called ‘secondaries’ and these transmit groups of 8 pulses.

The spacing between groups of ‘master’ pulses from a single chain is a characteristic unique to that chain and is referred to as the Group Repetition Interval (GRI).

The 100kHz carrier wave frequency favours the propagation of a stable ground wave over long distances. Careful signal design allows Loran receivers to determine positions using the ground wave and reject the delayed sky wave that would potentially distort the received signal.

The transmissions from each chain are monitored and controlled continuously. System abnormality indicators are built into the signal format and can be identified by the receiver providing inherent integrity warnings.

#### eLoran

Enhanced Loran (eLoran) is a terrestrial navigation system developed from Loran-C. It is a Positioning, Velocity, and Timing (PVT) service for use by land, sea and air navigation as well as other applications reliant on timing datA.

eLoran is independent to and has dissimilar failure modes to GNSS and therefore complements GNSS use. Although offering reduced accuracy, it will allow GNSS users to retain the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted. eLoran provides positional accuracy in the region of 8 - 20 metres and time and frequency performance (to stratum-1 level) similar to current GNSS.

eLoran differs from Loran-C as it uses an all-in-view method of operation, calculating the distance to all eLoran stations in view. eLoran stations are also synchronised with, but independently of, GNSS time. Synchronising to a common time source allows receivers to employ a mixture of eLoran and GNSS signals. eLoran receivers calculate the distance from each station by firstly assuming that the entire earth’s surface is covered in sea-water. By knowing the speed of the signal over sea-water along with the times of transmission and reception a pseudorange can be calculated. This pseudorange is then adjusted to take into account the propagation delays due to the signal passing over land, these delays are called Additional Secondary Factor delays (ASFs). ASFs are measured by the service provider and are supplied to users as a database built into their receivers. ASFs may change slightly due to weather or seasonal effects, reducing the efficiency of the correction and affecting accuracy. However, this is resolved by installing a differential-Loran reference station nearby, which is able to measure the difference and calculate a correction. The correction information is then passed back to the eLoran station for dissemination to the user over the eLoran data channel.

The inclusion of a data channel as part of the main transmission is one of the inherent features of eLoran and can be used to provide other data services in addition to differential corrections.

For more information the reader is encouraged to seek the advise of Radio technical Commission for Maritime Services Special Committee 127 (SC-127) on eLoran Systems.

#### Compatibility Between eLoran and Loran-C

Legacy receivers are able to use both eLoran and Loran-C signals as eLoran stations form part of the presently organised chains. However, legacy Loran-C receivers will likely not provide the user with the best accuracy performance.

Users should ensure their receivers are able to decode the Loran Data Channel to receive integrity alerts, UTC time and differential-Loran correction datA. They should also ensure their receiver is capable of storing and applying up to date ASF datA.

#### Differential Global Navigational Satellite System

The aim of GNSS augmentation services such as Differential Global Navigational Satellite System (DGNSS) is the improvement of GNSS based positioning within a given areA. In this context various methods can be applied to increase the accuracy of GNSS based positioning and to verify the integrity of applied components (systems, services, sensors) and provided datA. An essential basis for DGNSS service provision are own GNSS measurements gathered in real time at single reference stations or a network of them.

In the simplest case the DGNSS service provides 3-dimensional positional correction parameters derived from differences between surveyed and known position at the reference station. This correction method is applied to satellite signals received at the user site which are common to those used at the reference station.

An increase on position accuracy can be expected, if the DGNSS service provides correction terms of ranging errors per satellite in view. This principle is applied by IALA Beacon DGNSS providing range and range rate corrections derived at reference station site from differences between surveyed and known distances to satellites in view. Satellite Based Augmentation Systems (SBAS) provides area correction parameter, whose application enables the determination of range and range correction for users in large-scale regions such as Europe. In this case a network of ranging and integrity monitoring stations (RIMS) is used to measure and model the spatial varying error behaviour.

Accuracies in the centimetre level can be achieved by DGNSS services employing the application of real time kinematic techniques (RTK) for positioning. The gain of accuracy is achieved by the common processing of range and phase measurements collected at reference station and user site to apply single and double difference methods during position determination.

In safety-critical application DGNSS services should be enriched with integrity functions realising the monitoring of data and system integrity in real time. The monitoring can be realised by plausibility and consistency tests as well as methods estimating error behaviour and budgets. Integrity data as results of the integrity monitoring informs the user about the current usability of applied components and provided output data.

The DGNSS service provision is realized by radio signals carrying augmentation, correction, and integrity datA. Users operating in service areas and equipped with appropriate receivers can use these augmentation data to:

* enhance accuracy of GNSS based positioning;
* notify faulty satellites or GNSS failure;
* detect satellite signals with increased propagation errors;
* exclude disturbed signals from positioning;
* be informed about the usability of services or other information.

Currently, DGNSS services are provided for operational satellite navigation systems such as GPS and GLONASS. In principle, similar DGNSS services can be provided for future GNSS such as GALILEO, BeiDou and QZSS.

Each DGNSS service can be separated into a part generating and a part distributing the augmentation datA. The generation of DGNSS augmentation data requires own GNSS measurements gathered at a single reference station or a network of them. Different DGNSS messages and services may use different generation methods and means of dissemination. At present certain communication channels used for the provision of DGNSS augmentation data are assigned to specific DGNSS services. For example, the provision of DGNSS augmentation data is realized by terrestrial radio transmitters (IALA Beacon Transmitter, AIS) or via satellite transponders (SBAS).

#### IALA Beacon DGNSS

The aim of IALA Beacon DGNSS is the provision of non-encrypted differential corrections as well as integrity information to maritime users to improve accuracy and integrity of GNSS based determination of position, velocity and time data (PVT). The method of differential positioning was developed in the nineties, is internationally accepted and supported in most coastal waters, especially in areas of high traffic density. The differential corrections are determined at known positions of reference stations or a network of them. For this purpose the difference between expected and measured ranges is used to derive actual range and range rate corrections.

Additionally, integrity monitoring functionalities are implemented to assess the usability of GNSS signals and provided DGNSS service.

The radio link used for the provision of DGNSS correction and integrity data is internationally defined at ITU (Recommendation ITU-R M.823-3). At present the DGNSS signal transmission is realized in the maritime radionavigation band (283.5 to 325 kHz)[[7]](http://www.iala-aism.org/wiki/ialawiki/index.php/Navguide:_Chapter_4_-_e-Navigation" \l "cite_note-7). At user site type-approved DGNSS radio beacon receivers meeting IEC 61108-4 test and performance standards are necessary to enable the ship-side use of DGNSS services for an improved PVT data determination.

The recapitalisation of DGNSS infrastructure is an ongoing process. Of the options available, some service providers have opted to replace existing hardware with similar dedicated Reference Stations and Integrity Monitors (RSIM); some have invested in software RSIM; while others have adopted a network of reference stations to create virtual RSIMs. Other solutions, such as integration with SBAS may evolve within the enhancement of the maritime PNT system.

The full list of about 400 maritime radiobeacon based DGNSS stations (as notified to IALA by authorities) can be accessed via the IALA website (www.iala-aism.org).

#### AIS for DGNSS Transmissions

Automatic Identification System (AIS) is a ship to ship and ship to shore data broadcast system, operating in the VHF maritime band, and is described in more detail in section 4.19.

AIS has the capability of providing DGNSS corrections to onboard equipment using standardized transmissions (Message No 17) as described in IALA Recommendation A-124. The use of AIS Message No 17 increases the number of vessels which benefit from DGNSS transmissions, with respect to better accuracy and integrity.

#### Maritime Phase-Based GBAS (MGBAS)

In the last decades the development of phase-based techniques was driven by surveying to achieve position accuracies with GNSS in the centimetre level. In IALA R-135 the RTK technique was mentioned as an approach to meet maritime requirements on high-precision positioning in port areas and for automatic docking. Several manufacturers of maritime GNSS/DGNSS equipment provide solutions supporting RTK based positioning.

It is noted that RTK is a short-range system and that there is a need to introduce monitoring and assessment of the integrity of RTK services and RTK based positioning in the context of safety-critical applications.

#### RTK over AIS

In survey applications the RTK correction information is usually distributed to users via VHF/UHF radio modems or via commercial broadband internet. However when used in hydrographical measurements further away from the shoreline these communication options might not be available all the time. The communication options in these areas would be via satellite or via AIS (the latter is also available only inside coastal VHF coverage usually less than 70km from shoreline).

RTK over AIS is in operational use for selected user groups in some countries and it has been reported to function without major problems and deliver the required positioning accuracy level. The correction data are broadcast to the mobile unit which initiates the transmissions.

When the mobile user requests RTK corrections, the AIS base station will start to reserve time slots (by FATDMA) for transmissions. For example, two 5 slot sequences every second can be reserved for both AIS channels. This will result in approximately 20% loading of the VDL. Using a lower message transmission frequency would not guarantee the expected RTK accuracy, especially on a moving platform. However, a higher transmission rate would cause too much loading on the VDL. The correction delay of about 1-1.5 seconds caused by the transmission over the AIS data link has been reported to be acceptable. When not required, the mobile user stops the request for RTK corrections and the base station stops reserving the time slots and releases them for other use.

The limitations of this technique are that only one mobile user can be served by one AIS base-station at a time, reduced understanding of accuracy due to rapid atmospheric fluctuations and that it may not be applicable in areas of high VDL loading. The channel loading problem may be addressed in the future by using the additional channels allocated for VDES.

#### Receiver Autonomous Integrity Monitoring

Receiver Autonomous Integrity Monitoring (RAIM) is a technology developed to assess the integrity of GNSS signals and therefore the integrity of GNSS based positioning. This kind of integrity monitoring is autonomously realized within the user’s receiver with special importance for safetycritical applications, such as aviation and maritime.

Range measurements are required from at least 4 GNSS satellites to enable the determination of position, velocity and time datA. However the application of RAIM in a navigation receiver requires redundancy in the range measurements.

Safety-critical RAIM algorithm might use only “Fault Detection” (FD) or “Fault Detection and Exclusion” (FDE), which enables the continuation of operation in the presence of a single GNSS satellite and signal failures. To detect a faulty satellite, at least five range measurements are required, whereas to isolate and exclude a faulty satellite, at least six range measurements are required. While RAIM can detect many failure modes, it cannot detect some failures affecting multiple satellites.

The upcoming availability of various GNSS will increase the usable number of navigation signals for RAIM based positioning. New and modernized GNSS supports the provision of GNSS signals in 2 or more frequency bands and improves therefore the capability of GNSS based ranging.

Future advancement in RAIM algorithms should improve the availability and continuity of RAIM based positioning. Such enhanced RAIM techniques – so called Advanced RAIM (ARAIM) – may become available to maritime users (www.navipediA.net/index.php/araim).

#### Ranging-mode

Investigations are being conducted on the benefit of expanding the functionality of existing systems; by providing a timing signal from which the user may then calculate their position independently from GNSS and this is known as Ranging-mode (R-mode).

At present the IALA MF beacon system and AIS Services are being considered as candidates for modification to add R-mode functionality. By providing timing information over their normal MF or VHF transmissions, a shipboard receiver may then calculate a distance (range) to the transmitter. By calculating the range to several stations, the user is able to calculate the ship’s position. Coverage, geometry and interference questions would need to be investigated.

The provision of R-Mode services would require the availability of an accurate non-GNSS timing source at the transmitter. High stability clocks could be an expensive option and it is more likely that time would be sourced from a low frequency radio time clock or eLoran.

## Radar Aids to Navigation

Radar aids to navigation are devices that provide returns to a ship’s radar that help to locate and/or identify a navigation mark.

The IMO carriage requirements contained in (Chapter V, Regulation 19) of the SOLAS Convention 1974 (as amended), states all ships of:

300 gross tonnage and upwards to carry a 9 GHz radar;

3,000 gross tonnage and upwards to be fitted with a 3 GHz radar or, where considered appropriate by the Administration, a second 9 GHz radar.

Some administrations may impose other carriage requirements.

IMO Resolution MSC.192(79) Adoption of the Revised Performance Standards for Radar Equipment 06 December 2004 states that 9 GHz radars should be capable of detecting radar beacons and should be capable of detecting SARTs and radar target enhancers. By omission, 3GHz radars are not required to detect radar beacons and SARTS. With the removal of the 3GHz radar racon detection requirement, ship-owners are free to use higher performing radars, often referred to as New Technology (NT) radars.

9 GHz radars are also extensively carried by vessels not covered by SOLAS or local regulation. Because of this high rate of carriage, radar aids to navigation in the 9 GHz band are especially useful.

### Radar Reflectors

A radar reflector is a passive device designed to return the incident radar pulses of electromagnetic energy back towards the source and thereby enhance the response on the radar display. By design, a radar reflector attempts to minimise the absorption and random scattering effects.

A radar reflector is generally installed as a supplementary device at sites that would also be marked with a light. The main objectives of its use are to enhance:

target detection at long ranges (for example, for landfall navigation);

target detection in areas of sea or rain clutter; and

radar conspicuity of aids to navigation to reduce the risk of collision damage.

The performance of a radar reflector can be defined in terms of its effective radar cross section (RCS). This is a value determined by comparing the strength of radar signals returned by the radar reflector with the equivalent return from a radar reflective sphere of 1m2 reflecting area.

The range at which a radar reflector target can be detected is dependent on the heights of the radar antenna and the reflector and the output power of the radar. There are analogies to the geographical range of visual marks. The radar performance of corner cluster reflectors may vary considerably from one make to another.

Use of small radar reflectors can also be subject to multipath fading effects. Please see IALA Guideline No.1010 on Racon Range Performance for a discussion on multipath fading.

Most radar reflectors are designed for use by 9 GHz radars. The reflectors are also usable with 3 GHz radars; however, the effective radar cross section is about an order of magnitude less.

### Radar Target Enhancers

A Radar Target Enhancer (RTE) is a device that amplifies and returns the pulse from a ship’s radar to give an enhanced image on the radar screen. The returned signal from an RTE is not coded. The RTE was designed primarily for buoys and small vessels that might normally carry a passive radar reflector. RTE testing has shown RTEs to have provided an effective radar cross section (RCS) of about 100 m2, compared with an RCS of 20 to 30 m2 for passive radar reflectors typically fitted to buoys.

To date, commercially available RTEs only operate in the 9 GHz band.

RTE use is subject to multipath fading effects. Please refer to IALA Guideline No.1010 on Racon Range Performance for a discussion on multipath fading.

### Radar Beacon

Radar beacons (racons) are receiver/transmitter devices operating in the maritime radar frequency bands (9 and 3 GHz) that enhance the detection and identification of certain radar targets. Please note that IMO MSC.192(79) removed the requirement for 3GHz radar to detect racons.

A racon responds to the presence of a ship’s radar by sending a characteristic pulse train. The response appears as a coded mark (or “paint”) on the ship’s radar display (refer Figure 24) that highlights the range and bearing of the racon. The display paint can be fixed to a specified length or can be dependent on the radar range setting and uses a Morse character for identification.

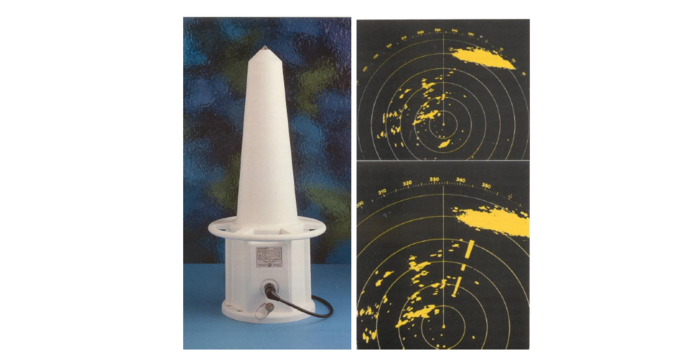
[](http://www.iala-aism.org/wiki/ialawiki/index.php/File:Navguide_4-9-3_Figure24_A_Racon_and_Radar_Display_with_and_without_Racon_Character.png)

Figure 24 - A Racon (left) and a Radar Display (right) with and without the Racon character  
**Applications**

A racon is generally considered to be a supplementary aid to navigation installed at sites that would also be marked with a light. The number of vessels capable of making use of a racon is effectively unlimited.

A racon can be used for:

* ranging and identification of positions in ice conditions or on inconspicuous coastlines;
* identification of aids to navigation, both seaborne and land based;
* landfall identification;
* indicating centre and turning point in precautionary areas or Traffic Separation Scheme (TSS)
* marking hazards;
* indicating navigable spans under bridges;
* identifying leading lines.

### Frequency-Agile Racon

A frequency-agile racon responds on the frequency on which it is interrogated and the response can be re-painted on each radar sweep. The purpose of frequency agility is to provide a signal to the radar that is within the receiver bandwidth of the radar. However, to avoid masking other features on the radar screen, the racon response is usually switched on and off on a preset cycle.

**Signal Characteristics**

Racons operate in the 9 GHz band with horizontal polarisation, and/or in the 3 GHz band with horizontal and optionally vertical polarisation.

|  |  |  |  |
| --- | --- | --- | --- |
| **Preferred Terminology** | **Alternatives** | | |
| 9 GHZ | 9300 9500 MHZ | X-BAND | 3 CM |
| 3 GHZ | 2900 3100 MHZ | S-BAND | 10 CM |

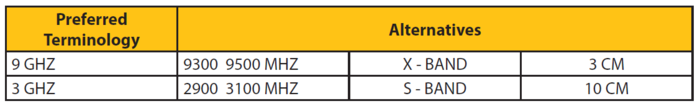
[](http://www.iala-aism.org/wiki/ialawiki/index.php/File:Navguide_2014_table18.PNG)

Table 18 - Preferred Terminology for the Description of Racon Operating Frequencies

### Racon Performance Criteria

The availability of a racon is the principal measure of performance determined by IALA. In the absence of any specific considerations, IALA recommends that the availability of a racon should be at least 99.8%.

|  |
| --- |
| Refer to IALA publications:   * Guideline 1010 on Racon Range Performance; * Recommendation R-101 on Maritime Radar Beacons (Racons); * Recommendation O-113 for the Marking of Fixed Bridges Over Navigable Waters. |

### Racon Technical Considerations

There are a number of technical considerations in the use of racons to assist the navigation of a ship:

* The angular accuracy of the bearing between the ship and racon depends entirely on the interrogating radar, while the accuracy of the range measurement depends on both the radar and racon;
* When racons are used in leading line applications, an alignment accuracy of about 0.3 degrees can be expected;
* When the ship is very close to the racon, side-lobes from the radar antenna can trigger the racon. The resulting multiple responses on the radar display may be a distraction and can mask other targets. Side-lobe suppression techniques are standard features of frequency agile racons.

### Use with New Technology Radars

All currently available and installed racons are designed for use with high power pulse radars. In comparison, NT radars use low power transmissions with long pulses. Due to the low received peak signal strength and long pulse at the racon, current racons may not detect NT radars and may not transmit a response usable by NT radars. Studies have shown that pulsed NT radars are able to reliably trigger racons at shorter ranges than would have been achieved with a conventional magnetron pulsed radar. Note that FMCW radars (also grouped into the family of New Technology radars) are a special case which require individual analysis and measurement. The IMO regulations regarding X band radars and racons remain unchanged and although detection and triggering range might be reduced, it is the responsibility of manufacturers of X band NT radars to retain racon functionality.

Despite changes to the IMO regulations relating to S band racons, existing racons with 3 GHz capability will continue to be useful to 3GHz pulse radars of both Magnetron and pulsed New Technology variants although advanced clutter reduction techniques optimised in the knowledge that display of Racon signals is no longer a functional requirement in this frequency band, may attenuate or even remove the Racon pulse train from the radar video and display. There may be a need to replace all high power pulse radars, thereby impacting all racons with 3 GHz pulse capability.

### Radar Referenced Positioning

Algorithms may be developed to allow the radar display to be overlaid upon the electronic chart using detectable recognised navigational features (racons, passive radar beacons or land edge patterns etc.). This technique, although unlikely to challenge the accuracy of a GNSS based position fix, might be adopted as part of a PNT integrity assessment and/or as a back-up in the event of GNSS service or equipment failure or corruption.

## Non-radio Positioning

### Inertial systems

Many studies have been carried out on the integration of GNSS with Inertial Measurement Units (IMU) for marine navigation. There exist various grades of IMU, from the very expensive navigation grade through tactical grade to low cost units based on the Micro Electro Mechanics System (MEMS). The IMU grade characterizes the achievable performance of data provision covering velocities and orientations. A small IMU grade is associated with higher drift rates. Depending on the different drift rates an IMU can provide contingency functionality for various lengths of GNSS outages.

Additionally, a GNSS – IMU sensor fusion scheme enables an improved integrity monitoring for various output data like position, speed and rate of turn. In combination with a GNSS compass an IMU can provide accurate and stable heading data even for longer GNSS outages. None of the currently available inertial systems is capable of maintaining all levels of navigation accuracy during a lengthy outage of GNSS. For ocean areas, both navigation and tactical-grade IMUs will give protection for appreciable outages over 15 minutes and navigation grade IMUs up to over 1 hour. For the coastal areas the required accuracy of 10 meter could be obtained for 3.5 minutes with a navigation-grade IMU and 1.5 minutes with a tactical grade IMU.

### e-Pelorus

An electronic pelorus is a device for taking bearings of visual marks and converting them to an electronic format for input to an electronic chart system. Such a device would enable the integration of visual AtoNs with e-Navigation. The concept was promoted in a paper by the Nautical Institute in about 2008, as a backup system for navigation.

Only a costly military version appears to exist at present. However, the feasibility of constructing a low-cost ePelorus from off-the-shelf components is being investigated, to demonstrate its effectiveness as a backup and to evaluate the potential for integrating visual AtoNs with e-Navigation.

Although Electronic Chart Display and Information System (ECDIS), as ship borne equipment, is not an “aid to navigation” as defined by IALA, it deserves to be mentioned because it brings major changes to the manner in which vessels are navigated. ECDIS uses digital vector data in a way that replaces the traditional paper charts with a more versatile electronic product that can draw on a variety of positioning and data inputs, such as GNSS, DGNSS, AIS, radar, echo sounder, compass, an electronic chart, navigational publications, the chart amendments and tidal and meteorological information.

# Testbeds

Testbeds are necessary for the demonstration, validation and implementation of e-navigation solutions.

However not all testbeds may lead to commercial implementation of solutions

(Discussion yet to be concluded in WG 2 – 14/3 AM)

The term testbed is used across many disciplines to describe a platform that is used for research, development or testing. Testbeds generally involve rigorous, transparent and replicable testing of scientific theories, innovative solutions, computational tools and new technologies. Testbeds should not be limited or restricted by current architecture, data structures or procedures.

IALA Guideline 1107 (on the planning and reporting of testbed results) statesb that e-navigation testbeds can allow for early identification and assessment of new system functionality, operational usability, areas of enhancements, identification of weaknesses and socio-technical impact.

In order for e-navigation solutions to have global application, IALA facilitates the collation and sharing of the outcomes of testbeds. A list of testbeds that are known to IALA can be found at:

<http://www.iala-aism.org/products-projects/e-navigation/test-bedsprojects/>

It is important that outcomes or lessons learnt from test-bed projects be considered in the context of the main elements of the IMO Strategy Implementation Plan (i.e. user needs, architecture, gap analysis and solutions that are the subject of cost-benefit and risk analyses).

# Implementation

Do we need this section ???

**Notes**

 A registry is simply a bookkeeping device where definitions/ specifications are kept in organised locations known as registers. the registry eases the tasks of development of new things, by providing a centralised source for finding definitions/ specifications

  Refer to in particular MSC85/26, Annex 20, paragraphs 9.9.1., 9.1.5, and 9.9.3.

  GPS Performance Stanards, 2008.

  United Nations Office for Outer Space Affairs, “Current and Planned Global and Regional Navigation Satellite Systems and Satellitebased Augmentations Systems”, 201

  At the time of writing, further information on Galileo may be found on the internet <http://ec.europA.eu/enterprise/policies/satnav/> galileo/index\_en.htm

  At the time of writing, further information on BeiDou may be found on the internet hhttp://www.en.beidou.gov.cn/csnclist.html

  A 1kW transmitter will generally allow position fixing to better than 10 metres over a radius of about 200 nautical miles.

  United Nation Office of Outer Space Affairs