IALA GUIDELINE

G1081
PROVISION OF VIRTUAL MARINE AIDS TO NAVIGATION

Edition 2.1

June 2021

urn:mrn:iala:pub:g1081:ed2.1

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DOCUMENT REVISION

Revisions to this document are to be noted in the table prior to the issue of a revised document.

Date	Details	Approval
Dec 2012	Edition 1.0	Council 49
May 2013	Edition 1.1 Minor amendments throughout the document to reflect developments at IMO NAV discussion on AIS AtoN.	
June 2021	Edition 2.0 Major amendments throughout the document with new sections and figures to reflect better knowledge of the technology, based on AIS AtoN testing in different countries.	Council 73
July 2022	Edition 2.1 Editorial corrections	

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1. INTRODUCTION

IALA recognizes that there are various tools available for use by Marine Aids to Navigation (AtoN) competent authorities to improve and enhance services to mariners. Among these are visual, radio and AIS AtoN, including the Virtual AtoN.

This document offers guidance on the provision of Virtual AtoN.

2. SCOPE

This document provides guidance on the limitations and benefits of Virtual AtoN, criteria for use, notification process, display, application and delivery methods, applicable standards and guidelines, availability and integrity and legal and liability issues.

This document is a general guide only and is not intended to specify in detail when or how to deploy a Virtual AtoN. Appropriate sources (see References) should be consulted for additional relevant information.

The concept of Virtual AtoN has its roots in AIS, but in the future other means of transmission and presentation may evolve. References to AIS in this document should not be construed as limiting Virtual AtoN to that system. Reference documents are the latest from the date of issue of this Guideline. Readers have to consider that some will be amended or revoked, and care should be taken to follow up with the most up to date information.

3. PURPOSE

The purpose of this Guideline is to inform AtoN competent authorities, mariners and equipment manufacturers of the value and uses of Virtual AtoN. It will assist competent authorities in determining the appropriate uses for Virtual AtoN and provide organizations with the means to establish and operate them. This Guideline will assist shipmasters, pilots, mariners, private AtoN owners and shore-based competent authorities in realizing the benefits, limitations and the inherent risks involved when using Virtual AtoN as a means of verifying their position and determining a safe course to steer or avoiding dangers. This Guideline will assist marine electronics equipment manufacturers in designing and upgrading shipborne navigational display systems. Finally, maritime training institutes may also wish to avail themselves of the information contained herein to assist with the development of syllabi better equipped to prepare seafarers to take advantage of this emerging technology. This may take the form of e-Navigation Guidelines provided by National competent authorities.

4. DEFINING A VIRTUAL AID TO NAVIGATION

4.1. DEFINITION

A Virtual AtoN does not physically exist but is a digital information object (symbol and text information) promulgated by an authorized service provider that may be presented on navigational systems. This is used to mark an object other than an existing AtoN or a non-object, such as a reference point in the water or on land.

4.2. AMPLIFICATION

Virtual AtoN should only be used after approval by a national competent authority, as stipulated in IALA Guideline *G1084 Authorisation of AIS AtoN* [25].

Virtual AtoN can be used to inform the mariner about dangers to navigation as well as safe waterways, areas in which extra caution may be necessary and areas to be avoided.

They may be used to represent a line, area, position or other forms that may be displayed graphically. The AIS ASM Area Notice message may replace or supplement this need for Virtual AtoN to delineate a graphical shape in the future.

The information, including geographic position, carried by Virtual AtoN may be fixed or may change over time (dynamic), depending on the intended purpose. A dynamic position may relate to the changing nature of a mobile object or an evolving situation. Virtual AIS AtoN used as Mobile AtoN for marking a moving hazard have to meet stringent refresh rates. Regular monitoring of such an evolving situation is necessary to ensure that the Virtual AIS AtoN position and information stay relevant.

Virtual AtoN should be used primarily as temporary deployments, where there is a time critical consideration. They may also be used in a permanent context, where permanent physical AtoN cannot be established or maintained. However, they are intended as an enhancement, not as a replacement for physical AtoN. Historically, as stated in the IMO Policy on use of AIS AtoN, permanent usage was restricted. National competent authorities, after gaining better understanding and experience in the use of AIS AtoN, have identified applications where use of permanent Virtual AIS AtoN are beneficial for mariners and, therefore, deployed.

These two applications of Virtual AtoN, temporary and permanent, should be reflected in Maritime Safety Information (MSI). The IHO recommends that any temporary status which continues for more than six months should be charted accordingly and treated as permanent. This should be shown on all relevant nautical paper charts, Electronic Navigational Charts (ENCs) and other relevant nautical publications in due course. In some countries, permanent status is sub-categorized into annual and seasonal periods.

Virtual is one of the three types of AIS AtoN that can be used for marking. Physical (Real) and Synthetic (Predicted and Monitored) are the other two types. More information on the three types of AIS AtoN is available in other IALA documentation, such as Recommendation *R0126 Use of the AIS in Marine Aids to Navigation Service (A-126)* [22].

5. APPLICATION OF VIRTUAL ATON

Virtual AtoN can provide early notification to the mariner of urgent, temporary or dynamic information. Virtual AtoN should not, in general, be considered as a replacement for other forms of MSI but can provide a valuable supplementary delivery mechanism, enabling an automated graphical display of MSI otherwise only available in textual form. Specific applications are described in Annex A of this Guideline.

5.1. USER NEEDS

Users will include mariners and shore side authorities. User needs may include presentation of information on:

- new hazards (fixed or dynamic);
- temporary channels or routes;
- temporary areas to be avoided (e.g., restricted areas (i.e., military exercises), survey, dredging, fishing, special marine events);
- changed hydrography, such as shifting banks;
- temporary replacement of gone from position physical AtoN;
- dynamic areas (e.g., reduced visibility, presence of protected species);
- polar navigation, provided there is sufficient means of radio communication broadcast and charting;
- ice conditions and navigation;

- incident response (e.g., environmental, search and rescue);
- port specific applications (e.g., passage planning, amended pilot boarding location, etc.);
- measures for the protection of the marine environment; and
- security.

5.1.1. ADVICE TO COMPETENT AUTHORITIES AND OTHER PROVIDERS

In using Virtual AtoN, the following are among the issues that need to be considered by providers:

- Carrying out a proper risk assessment to ascertain the need for Virtual AtoN over a more traditional physical aid.
- A sole economic reason should not be the justification for using them.
- Awareness of over-proliferation, using Virtual AtoN only where appropriate.
- Vulnerability of Global Navigation Satellite System (GNSS), etc.
- Quality assurance verification through monitoring, consideration of cyber security risks, etc.
- The limitations of shipborne navigational equipment required to be equipped with AIS (non-graphical display, old shipborne AIS firmware, wrong symbol or no symbol at all).
- It is not mandatory for certain vessels to be equipped with AIS equipment or vessels may be fitted with equipment not capable of receiving the AIS AtoN.
- Promulgation of the information widely to different users using MSI, AtoN competent authority Web or Portal, etc.
- Mixture of other types of AtoN located in such area.
- The limitation of Virtual AtoN technology with regards to the lack of flexibility in using free text to add complementary information.
- The limitations of data link load, numbers allocated, e.g., Maritime Mobile Service Identity (MMSI) numbers for AIS.
- That the primary function of AIS technology is to prevent collisions.

5.1.2. ADVICE TO MARINERS

In using Virtual AtoN, the following are among the issues that need to be considered by users:

- There could be some position offsets in the display of the Virtual AtoN due to shipborne equipment issues such as the quality of GNSS, GNSS smoothing, antenna offsets, gyro and radar error, etc. (section 10 provides further details).
- Reference to MSI to validate that the correct information is being broadcast.
- The possibility exists of different symbols on different systems.
- The limitations of Virtual AtoN provision and presentation.
- The difference between Virtual, synthetic and physical/real AIS AtoN.
- The need to maintain situational awareness by comparing electronic and non-electronic means and avoidance of reliance on single sources of information.
- The potential cluttering effect caused by too many AIS targets.
- Many systems, including AIS, are GNSS dependent for position and timing and subject to the same vulnerabilities.

- The possibility of ECDIS dangerous target alarms triggered by AIS AtoN. Shipborne systems require the capability of filtering for this through proper menu options.

5.2. BENEFITS

Some of the potential benefits of Virtual AtoN are in enhancing safety and environment protection. Other benefits are:

- timely notification;
- ease of presentation, where displayed graphically;
- quick deployment, easily amended depending on the situation (storms, marine incidents, etc.);
- direct delivery to navigational systems, limited to relevant areas;
- information readily apparent to the user;
- low cost to install and maintain; and
- marking where traditional physical AtoN or Physical (Real) AIS AtoN are not practical.

6. TECHNICAL DEPLOYMENT OF VIRTUAL ATON

Information from Virtual AtoN services should be broadcast to AIS receivers by more than one means. The navigation information provided for temporary Virtual AIS AtoN should be repeated in MSI broadcasts to ensure that all mariners receive safety information.

The AIS AtoN name is part of the information contained in the AIS AtoN digital message (Message 21). Given the lack of uniformity worldwide concerning the naming, some guiding principles will enable more consistency. Some of the important elements to consider are:

- Using a short name will prevent cluttering the shipborne display when users are displaying the name tag. Recognized international or national abbreviations or acronyms might help reduce the length.
- Use of numbering and lettering that respect IALA's Maritime Buoyage System (MBS) (e.g., even or odd, numbered from seaward).
- Avoid repeating some of the information already available in other fields of the Message 21 and/or Nautical Publications (Fixed, floating, MMSI, Virtual, colour, etc.).
- Message 21 has two name fields, the main field (20 char.) and the extended one (14 char.). Consider that not all shipborne navigational equipment may display the extended field.
- Consider that adding the MSI number as a reference in the Virtual AtoN name requires editing the information broadcast as it changes and that this might be limiting when using a stand-alone AIS AtoN mobile station.

The navigation information needs to be capable of being displayed on Electronic Chart Display & Information Systems (ECDIS), Electronic Chart Systems (ECS), PPUs and radar equipment based on the latest IMO, IEC and ITU standards. These displays should indicate the information graphically as well as providing a text display of detailed information.

There may be a limit to the number of Virtual AtoN and/or their reporting interval (refresh rate) that can be provided within a local area due to limitations in the capacity of the communication link. There may also be a limitation on the shipborne processing capability.

To mark areas, binary AIS Application Specific Messages (ASM) may be used, rather than multiple Virtual AIS AtoN (Message 21). There is a limit to the number of Virtual AIS AtoN that can be in the same area due to available

timeslots in the AIS system. Multiple Virtual AIS AtoN (Message 21) could increase clutter on the display. The competent authority needs to be aware that the number of MMSIs available for use by AIS AtoN is a finite resource (1000 per designated area code) and for this reason the Maritime Resource Name (MRN) should be considered as the means of linking Virtual AtoN to relevant MSI or chart objects (see IALA Guideline *G1143 Unique Identifiers for Maritime Resources* [26]).

MMSI numbers are normally assigned to a transmitting device. For a Virtual AIS AtoN using Message 21, the MMSI number represents the unique identity of the AtoN itself, rather than the transmitting source. The repeat indicator field is used to identify whether or not the signal is transmitted from another station. It allows an AIS base station to repeat the Message 21 of another entity which may extend the coverage of a less powerful mobile station. Competent authorities should consider broadcasting from more than one AIS base station to assure some redundancy.

7. REGULATORY ISSUES

7.1. AUTHORITY TO DEPLOY

SOLAS Chapter V Regulation 13 (Establishment and operation of aids to navigation) states, in part, that:

> "'Each Contracting Government undertakes to provide, as it deems practical and necessary, either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires."

Under SOLAS, Contracting Governments are obliged to provide aids to navigation, subject to IALA recommendations and guidelines and based on the navigational requirements for waters under their jurisdiction. However, SOLAS allows competent authorities significant discretion in determining what would be an appropriate mix of visual, radio and AIS AtoN, including Virtual aids to navigation, to meet the needs of mariners. Some national competent authorities have established their own policies and levels of service for the provision of AtoN services.

Section c of this document is intended to assist competent authorities in assessing the risks associated with Virtual AtoN for this purpose.

7.2. CAPABILITY

A Contracting Government has an obligation under SOLAS to provide AtoN. This obligation is exercised by the appropriate entity (usually a national administration). This entity should also be responsible for determining who may be permitted to deploy Virtual AtoN. Typically, a VTS, Harbour Master, Rescue Co-ordination Centre (RCC) or other entity may have the capability to deploy Virtual AtoN. Further guidelines may be necessary to help governments manage these other requests.

The lines of authority between the Contracting Government and the entity deploying Virtual AtoN should be clearly delineated. Roles and responsibilities at all levels should be clearly defined.

7.3. LIABILITY

Virtual AtoN are simply another type of Aid to Navigation. Having elected to deploy a Virtual AtoN, a competent authority should be able to establish that the Virtual AtoN are being provided as promulgated and are operating correctly, through direct monitoring or arrangement with another party.

It is likely that a competent authority exposure to liability from deploying a Virtual AtoN will be similar to that for any other Aid to Navigation. Therefore, noting the unique nature of Virtual AtoN, robust processes and procedures

for approval and promulgating information about them, together with integrity monitoring and record keeping, should be established.

8. DELIVERY METHODS

8.1. TECHNICAL ASPECTS

This Guideline addresses near-term and long-term options for delivery of a Virtual AtoN service.

In the near term, shore-based AIS networks provide competent authorities with the means to operate an information service for shore-based VTS, traffic management schemes, ship reporting systems and other shore-based safety-related services, including Virtual AtoN services. This service consists of information delivery from ship-to-shore and vice versa.

Technical details of the AIS technology and of the layout and local configuration of shore-based AIS are described in IALA Recommendation *R0124 The AIS Service (A-124)* [21].

In the longer term, competent authorities may expect that other media for information services will become available. This would enable Virtual AtoN services to be transmitted via means other than AIS, for example: satcom /internet; WiMAX; VDES, VDE-SAT, NAVDAT, IALA maritime beacon system; cell phone data transmission protocol, etc.

In the near term, not all vessels can be expected to be able to effectively display Virtual AtoN information. As of July 2008, SOLAS radars are required to interface to AIS and display AIS information, as in MSC Resolution *192(79)* [3]. Although ECDIS is capable of displaying AIS information, it is not required to do so. Based on current rates of navigational system upgrades, it is expected to take at least some years before a substantial percentage of the international commercial fleet will have this capability. Changes in mandatory carriage requirements may accelerate this development for SOLAS vessels. PPU Navigational Systems may facilitate implementation on the charting side for pilots but not on radar. Economic benefit to the shipping industry could also provide an impetus to early adoption of this technology.

The nominal report rate of Virtual AIS AtoN broadcasts is specified in ITU-R-M.1371. However, due to the limitations in data link capacity, IALA Recommendation *R0126* [22] recommends a more flexible approach to be considered, taking data link capacity and power consumption at transmitting stations into account.

In the longer term, different report rates may be implemented on different communication media, as appropriate.

A Virtual AIS AtoN should be considered lost after 15 minutes, unless updated on the shipborne navigational displays, as specified in IMO *MSC.1/Circ. 1473* [9]. A lost target symbol, as depicted in *IEC 62288* [31], should be shown on the AIS AtoN symbol. This consists of two crossed solid lines centred on the target symbol. Once acknowledged, the lost target symbol and its target symbol shall be removed from the display.

Figure 1 The lost target symbol shown over a physical AIS AtoN

The IMO e-Navigation concept includes the need to harmonize the presentation of both shipborne and shore-side safety-related information. Consideration should be given to implementing Virtual AtoN in the harmonization process within e-Navigation for future applications.

8.2. DISPLAY

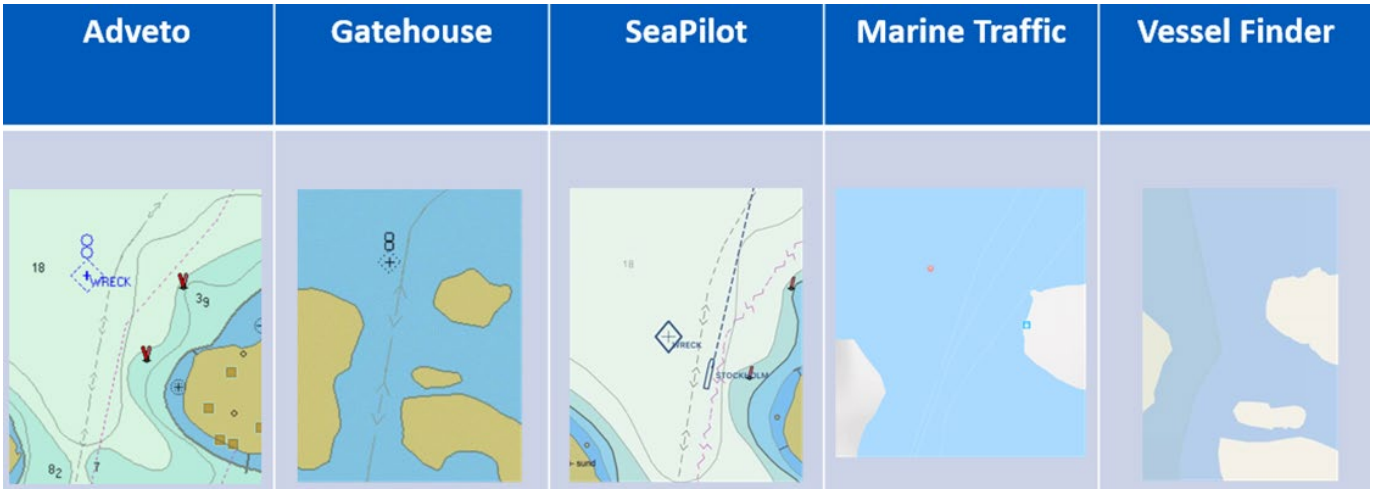
8.2.1. GENERAL

The Virtual AtoN should clearly indicate its name, other relevant attributes and MSI relating to the provision of the Virtual AtoN.

The display or representation of symbols for Virtual AtoN on shipborne displays and must comply with international standards.

8.2.2. LIMITATIONS

In short to medium term Virtual AtoN will not be visible on the displays of many ships and, if visible, the symbols may differ from one display to another (see section 10.2).



Source: Swedish Maritime Administration and Swedish Transport Agency

Figure 2 Variation of imagery due to software and type of ECDIS equipment or mobile application

The above images taken in 2018 show that the symbol of a Virtual AtoN varies depending on the software and type of ECDIS equipment or mobile application. Manufacturers may have subsequently edited their products, however.

8.2.3. SYMBOLS

IMO *SN/Circ.243/Rev.2 Annex 2* [5] provides guidance on the use of navigation-related symbols on all shipborne navigational systems and equipment.

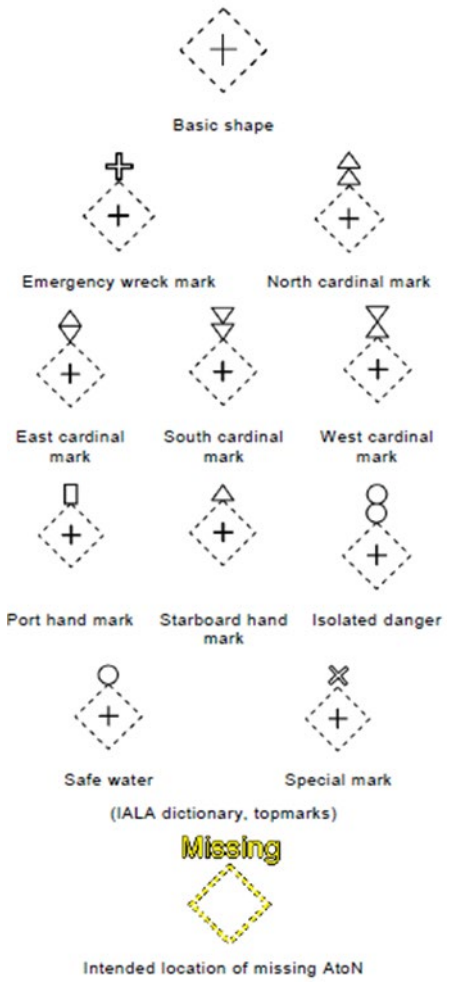


Figure 3 The symbology of Virtual AIS AtoN

A distinction is made between Physical and Virtual AtoN. These navigation-related symbols are not chart symbols.

In *IEC 62288 (Navigation Displays*) [31], which came into force in 2012, the thin dashed line diamond with crossed lines centred at the reported position of the AtoN is specified for AIS AtoN. This symbol will be implemented as an overlay on navigational equipment (ECDIS, radar etc.) compliant with these specifications. Generally, the symbols indicate the type of AtoN, and the attached text information indicates that the Virtual flag is active. The MMSI numbering scheme is another way to recognize that a Virtual AIS AtoN is being broadcast, with the number 6 being displayed right after the MID: 99MID6XXX.

New symbology for AIS AtoN has been issued where the type of AtoN, identified by a topmark (purpose), has been added to the basic diamond shape. The latest *IEC 62288* [31] provides further details.

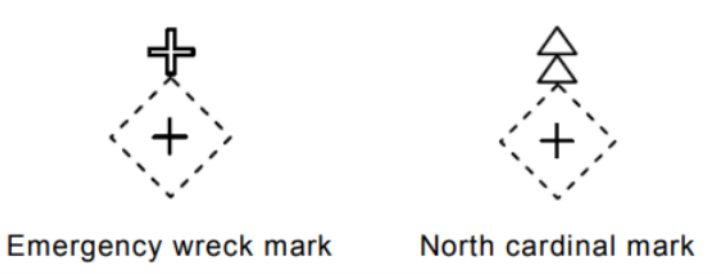
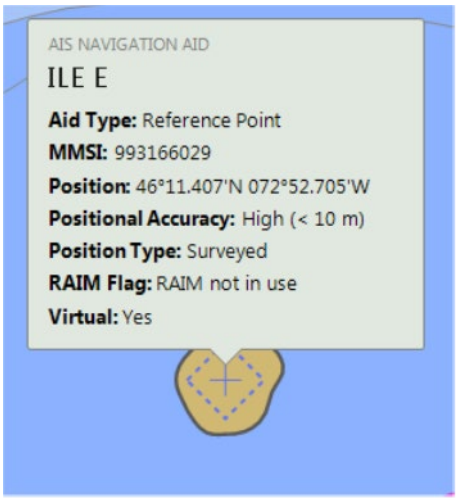


Figure 4 New symbology for AIS AtoN

The new symbol is distinctive and shows the purpose (characteristic) of the AtoN as a topmark on the diamond shape (ref. *IEC 62288* [31]).



Source: Canadian Coast Guard

Figure 5 Example of symbology information text

In Figure 5, the attached text information appears when the user clicks on the Virtual AIS AtoN symbol, in this example marking an artificial island. The user can authenticate the Virtual AIS AtoN by the thin dashed line diamond along with the Virtual flag as active (Yes) in the text information.

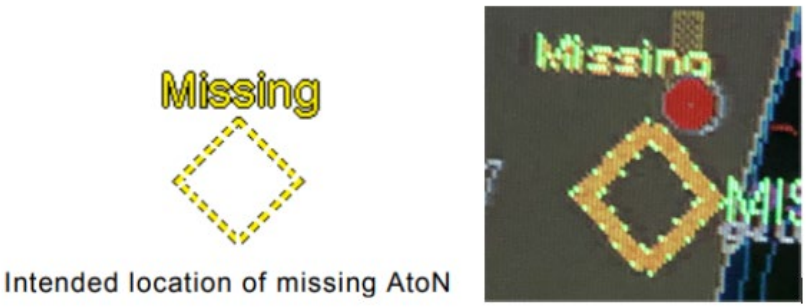
The ECDIS performance standard requires that overlay symbols be readily distinguishable from chart symbols. Chart symbols for Virtual AIS AtoN have been developed and chart manufacturers are free to incorporate them according to the existing *S-57 Appendix B.1 – Annex A (Edition 4.1.0)* [14].

Source: IHO

Figure 6 Examples of Virtual AIS as displayed on ECDIS

Figure 6 shows examples of the Virtual AIS AtoN portrayal that can be displayed on ECDIS.

The basic colour for the Virtual AtoN symbols is the normal colour of an AIS AtoN symbol. IMO does not specify exact colours but the interpretation is that it should be the same colour, for example, all being green, and avoid red and yellow which are reserved for special purposes. The absence of a charted physical AtoN is communicated as a combined state of “Virtual” and “off position”. This shall be indicated with yellow text “Missing” above the dotted outline diamond using the colour yellow. The symbol shall have no crosshair at the position centre.



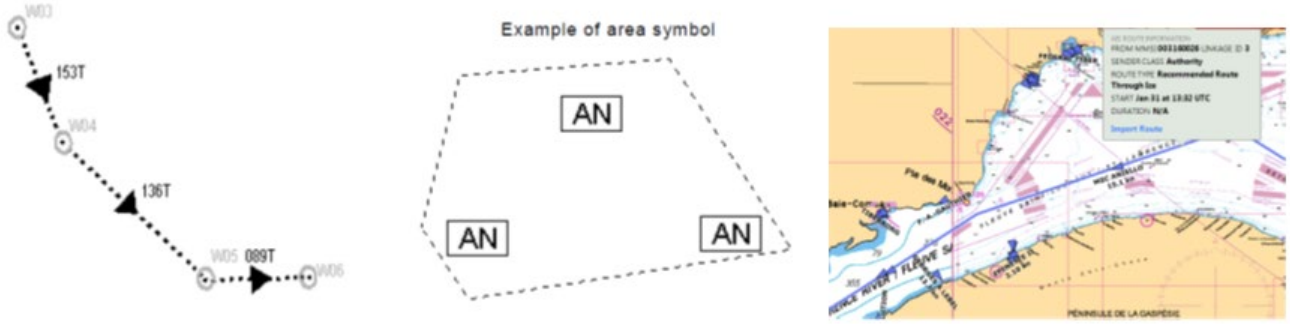
Source: Corporation des pilotes du Bas St-Laurent, Canada

Figure 7 Missing virtual AIS AtoN symbol versus display on ECDIS

In Figure 7, on the left, from the IEC standard, the Missing Virtual AIS AtoN symbol for an absent charted physical AtoN. On the right, an actual display on a vessel ECDIS.

8.2.4. POINT AND AREA REPRESENTATION

In addition to the use of the AtoN Report Message 21, emerging AIS Application Specific Messages (ASM) could be used to provide a representation of a point position, line, area, or other forms that may be displayed graphically. The portrayal has been developed in the latest *IEC 62288* [31]. As navigational display manufacturers incorporate them into their systems, users will be able to fully benefit from this feature.



Source: Canadian Coast Guard

Figure 8 Example (left to right) of ASM route, Area Notice and actual ASM ice route

In Figure 8 the ASM Route information from the IEC is shown on the left, the ASM Area Notice from the IEC in the centre and an actual ASM ice route is shown on the right.

8.2.5. EXPIRY AND CANCELLATION OF VIRTUAL ATON OBJECTS

Some Virtual AtoN objects like the Application Specific Messages (ASM) may themselves contain a definition of their own lifetime, such as a start date and time with a duration from a few minutes up to 182 days, with the capability to cancel at any time.

When the lifetime of a Virtual AtoN object is timed out or cancelled, it should be removed from the displays of shipborne navigational systems. Objects relying on repeated transmissions that have exceeded the nominal reporting rate but have not yet reached the timeout should clearly indicate that the information may not be current.

9. NOTIFICATION

Having elected to deploy Virtual AtoN, competent authorities should arrange for detailed information related to such aids to be made available to all concerned.

Competent authorities should use all available means to ensure that mariners have the necessary information concerning the presence and purpose of Virtual aids and notify their national hydrographic offices for inclusion and updates in nautical publications, including charts.

As with other aids to navigation, mariners have an obligation to report improperly or not displayed Virtual aids to navigation to the competent authority.

10. RISKS AND LIMITATIONS

Virtual AtoN are now becoming visible on the displays of many ships and, when visible, the symbols may differ from one display to another. The consequences may be confusion, lack of information for the user and undermining confidence in shipborne navigational displays and new technology. The implementation date of the revised standard for shipborne navigational displays on the bridge of a ship for radar equipment, ECDIS and INS should be 1 January 2024 and for all other navigational displays on the bridge of a ship 1 July 2025.

It is still possible that when an AIS AtoN is reflected in S-57 and S-52, existing ECDIS will only show a question mark (?), symbolizing an unknown object. The question mark symbol can be interrogated for further detail.

The Minimum Keyboard Display (MKD) should display AIS AtoN, including the Virtual flag, but it is known that some MKDs do not meet this requirement.

10.1. RISK MITIGATION

Table 1 Potential risk mitigation measures

Risk	Potential mitigation
Complete dependence of on Virtual AtoN.	Mariners should not rely solely on Virtual AtoN but cross-check with other data or information. Navigation should be by visual and radar reference from fixed aids on shore or other charted landmarks and through the use of navigation systems, whenever possible.
Not all mariners will receive or be able to display Virtual AtoN.	MSI should be maintained as primary notification. Virtual AtoN supplement MSI. Encourage integration with navigational displays, where fitted. Development of e-Navigation and S Mode.
Information overload	Use of lines and areas (such as ASM) versus points. Only competent authorities may approve. Area specific display. Development of e-Navigation. Limited use of Virtual AtoN in any area.
Lack of user awareness or understanding.	Training

	Clear promulgation of information. Development of educational material.
Confusion from varying symbology.	Standardisation of symbology by IMO, IHO, IALA, IEC.
Equipment may not be set up to show data.	Instruction and training. S-Mode Guidance from national competent authority.
Confusion from message options for locations, area and lines.	IMO / IALA to define message formats.
Loss of Virtual AtoN signal.	Published standards for availability, continuity, integrity. Verification of transmission by originator. Redundancy Integrity warning. MSI and chart. Shipborne navigational displays able to manage and display the lost target symbol.
GNSS vulnerability.	AIS semaphore mode. Satellite monitoring/RAIM DGNSS integrity message. Electronic terrestrial backup.
Virtual AtoN vulnerability; jamming/spoofing.	Verification of transmission by originator. Correlation with MSI and/or charts data link monitoring by competent authority. Counter-spoofing (cancelation methods).
No confirmation of receipt of message.	Repeated or addressed / acknowledged transmissions. Verification of transmission by originator. Multiple transmission paths (MSI). Development of e-Navigation.
Erroneous message transmitted.	Procedures for message checking. Verification of transmission by originator.
Dynamic prediction accuracy i.e., floating object.	Estimation of zone of uncertainty. Updated verification. Remove position from message after time.

10.2. LIMITATIONS

10.2.1. GNSS VULNERABILITY

Ships may lose their positioning capability when the GNSS service is lost due to jamming or interference unless they have an alternative positioning system. Poor installation or failure of shipborne equipment can similarly interfere with or degrade GNSS reception which could lead to a loss of the Virtual AtoN or a positional offset of the AIS AtoN symbol (more details in section c).

10.2.2. SPOOFING AND JAMMING OF VIRTUAL ATON

Some spoofing methods can be detected through careful monitoring of the transmission channel. One possibility is to monitor MMSI numbers within the service coverage area. Duplicated or non-existent MMSI numbers within the coverage area may indicate spoofing.

Increased spoofing detection capability can be achieved through regional co-operation between neighbouring countries, exchanging valid MMSI numbers and co-operating on identifying invalid MMSI numbers, for example, handing over MMSI numbers from one competent authority to another competent authority when vessels cross the administrative boundaries of these authorities. Such a scheme is implemented on the administrative boundary between the Malacca and Singapore Straits.

Competent authorities who provide Virtual AtoN services should maintain a database of all valid MMSI numbers assigned to Virtual AtoN. This database should be shared with such stakeholders as neighbouring countries.

Both spoofing and jamming can compromise and/or shut down a Virtual AtoN service. Jamming will typically block the service in a certain geographic region. Spoofing is more sinister since the targeted receiver cannot detect the deception (i.e., the signal appears to be genuine), which could mislead the navigator.

10.2.3. AIS VDL CAPACITY AND FATDMA PLANNING

Virtual AtoN services transmitted on an AIS VDL typically use the FATDMA protocol.

If the population of Virtual AtoN in a given area is too high, this may overload the VDL FATDMA slot capacity. This should be overcome through careful FATDMA planning - IALA Recommendation *R0124 The AIS Service (A-124)* [21].

10.2.4. DISPLAY LIMITATIONS

Although there are clear benefits that can be gained by providing safety information through Virtual AtoN, it must be borne in mind that not all SOLAS class ships, or other craft, may have the ability to display the Virtual AtoN. Some smaller craft may never have the ability to display Virtual AtoN.

MKD – All SOLAS class vessels are required to be fitted with a Class A AIS station and many non-SOLAS vessels voluntarily carry Class A AIS or Class B AIS stations. However, a growing number of vessels integrate the AIS data into a navigational display such as ECDIS or radar. The display of Virtual AtoN on an AIS MKD is limited to alpha-numeric text and, on some units, a graphic display, although there is no standard for such display.

Radar – Only radars that meet the revised performance standard, which came into force in 2008, have a requirement to be capable of displaying a Virtual AIS AtoN. However, there is currently no IMO requirement for the AIS to be integrated or displayed on radar.

ECDIS – ECDIS mandatory carriage requirement for certain classes of SOLAS vessel has been implemented in stages up to 2018, however, the current ECDIS performance standard *MSC 232(82)* [2] does not require AIS or other Virtual AtoN to be displayed, nor to be integrated.

Permanent deployment of Virtual AtoN will be represented on ENC/ECS with a charted AIS AtoN symbol. There will be overlapping since the charting symbol will be present at the same time as the broadcast AIS, with the exception of the issuance or cancellation time of the charted symbol. Some static information will be duplicated on both symbols. Some text information may also be present at the Virtual AtoN's displayed location in connection with a NAVTEX or SafetyNET for MSI.

Source: Irish Lights and Norwegian Coastal Administration

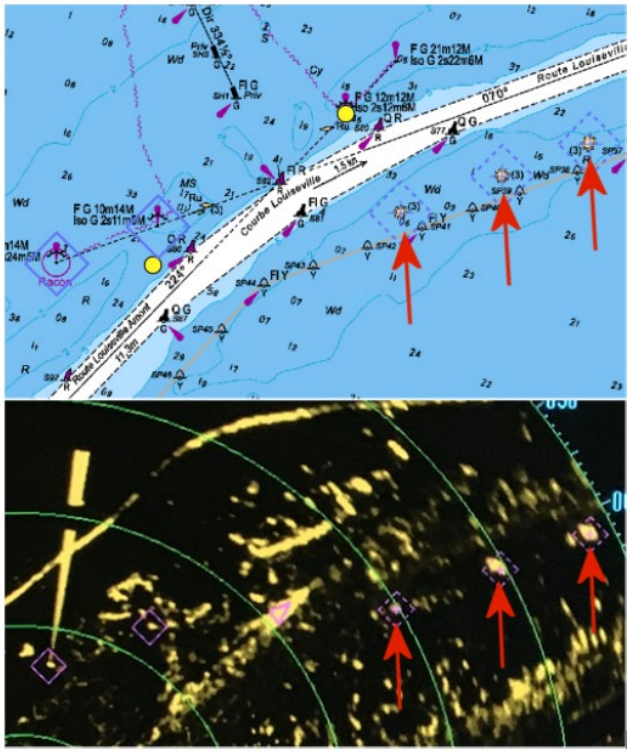
Figure 9 Broadcasted Virtual AIS AtoN port hand mark symbol displayed over the IHO ENC charted symbol

Competent authorities should take into account the limited display capabilities for AIS, or other forms of transmission, for all classes of seaborne craft when assessing the value and risks associated with transmitting Virtual AtoN.

10.2.5. USE OF VIRTUAL ATON IN CONFINED WATERWAYS

Navigation in narrow channels where there is less room to manoeuvre a vessel, such as in pilotage waters, requires the most accurate navigational marks possible for safety of navigation. Mariners have started incorporating the use of Virtual AtoN on radar, when such AIS interface is available, as a means of supplementing their existing navigational means.

Mariners see the value in the way Virtual AIS AtoN highlight and allow for the rapid positive identification of some natural or artificial navigational features. This is especially beneficial during weather, ice, and situations with traffic radar cluttering. Racons continue to be an essential element and should be the primary choice as they are isolated from any GNSS induced errors.

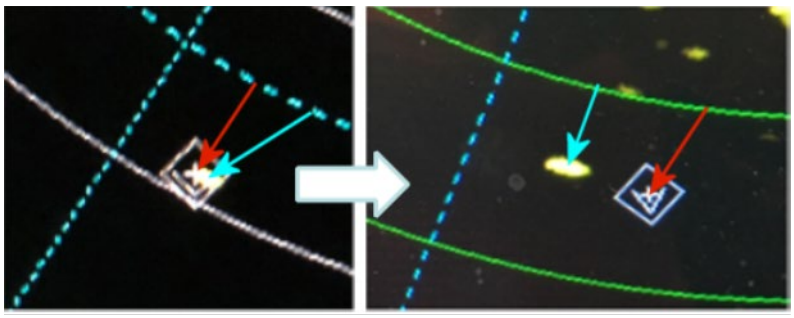


Source: Canadian Coast Guard

Figure 10 Virtual AIS AtoN shown on an ECS (top) and radar (bottom)

In Figure 10, three Virtual AIS AtoN are deployed to mark artificial islands used as target marks for winter navigation. The top sketch shows them displayed on an ECS, and the bottom sketch shows them on radar screen. The radar target appears right in the centre of the Virtual symbol, facilitating the positive identification through ice clutter for mariners.

There have been reports of Virtual AIS AtoN symbols appearing offset from where they were expected to appear on the radar. This is happening even when a precise and unaltered position is broadcast. This is usually represented by a mismatch between a definite radar echo, such as a fixed pillar, and the cross lines centred on the Virtual AIS AtoN symbol.



Source: Corporation des Pilotes St Laurent, Canada

Figure 11 Example of offset appearance of Virtual AIS AtoN symbol

In Figure 11, the centre of the Virtual AIS AtoN symbol almost matching the radar echo of a cellular tower on the left sketch. A position offset for the same radar target appears on the display of another ship on the right sketch. The older Virtual AIS AtoN symbol is shown.

An important factor to consider with AIS interfaced on radar, is the AIS positional process. The Virtual AIS AtoN position displayed on the radar PPI is based on the calculation that is made between the just-received Virtual AIS AtoN broadcast position and the ship's actual GNSS position through the process of Latitude/Longitude being converted to bearing/distance. Any error with the GNSS position, for example, an error caused by time lag, will directly impact where the Virtual AIS AtoN symbol will appear on the radar. This may mislead mariners into thinking that the Virtual AIS AtoN broadcast position is faulty, which is most likely not the case.

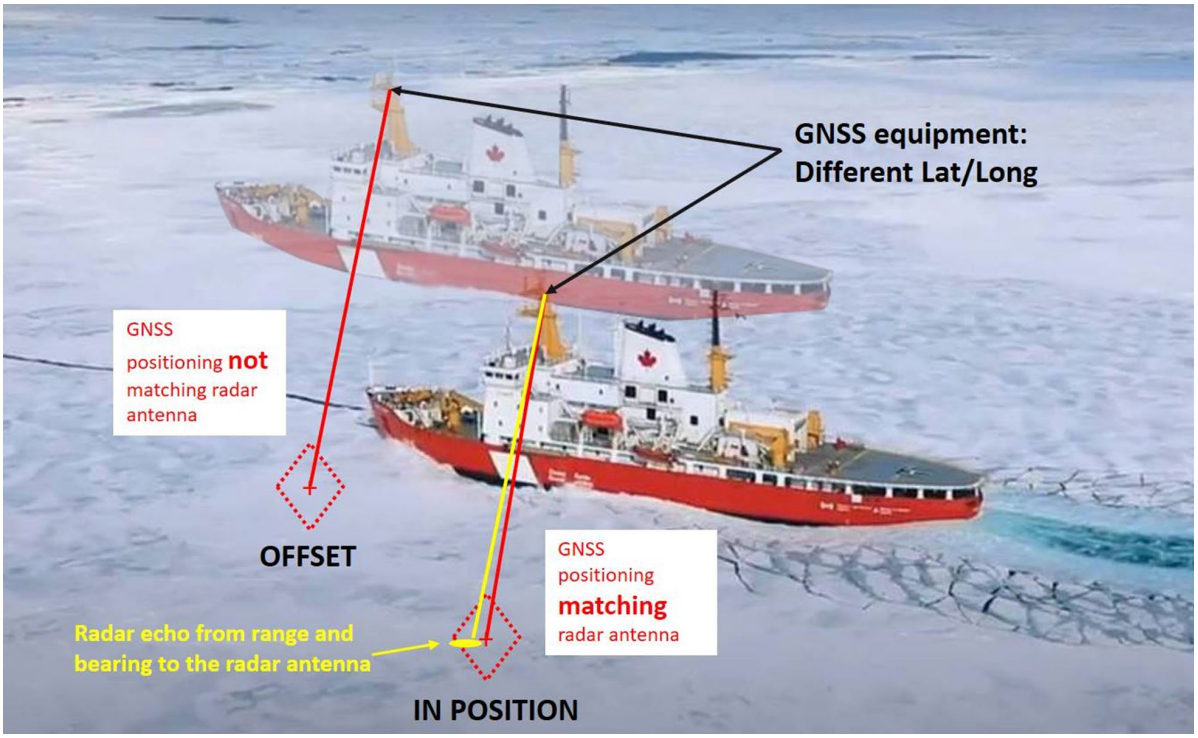


Figure 12 Example of effect of delayed GNSS antenna position on display of Virtual AIS AtoN symbol

In Figure 12, a matching ship's GNSS and radar antenna on a moving ship should translate into a Virtual AIS AtoN symbol at a close location to the radar echo target of the broadcasted feature. A delayed GNSS antenna position on the ship, shown as a ghost image, would translate into an offset Virtual AIS AtoN symbol displayed in comparison to the radar echo target.

Once the AIS AtoN provider has validated that the Virtual AIS AtoN broadcast is adequate and contains no errors, some assumptions can be made regarding the possible causes of shipborne-related errors. The ITU standard allows

for position accuracy in the magnitude of 20 cm in the broadcasted Virtual AIS AtoN message. This is an important process in order to help the user build confidence in the service.

The potential sources of errors can be classified into three categories:

1 Limitations of the GNSS interfacing with the radar system:

- Time delayed error (smoothing update too long, processing, etc.).
- Quality of the equipment and/or wrong settings (geographic datum, lack of upgrade in the firmware, non-supported model, etc.).

2 Limitations of the shipborne navigational system:

- Equipment truncating or rounding the precise coordinate being broadcasted.
- Small scale in use causes distance and bearing errors that degrade the accuracy of the comparative radar target.
- Gyrocompass errors leading to bearing errors for the comparative radar target.
- Physical position of the vessel in relation to the radar target.

3 Antenna offset:

- GNSS antenna and/or radar antenna location on the ship are not related precisely to the Consistent Common Reference Point (CCRP) of the ship, usually the conning position.

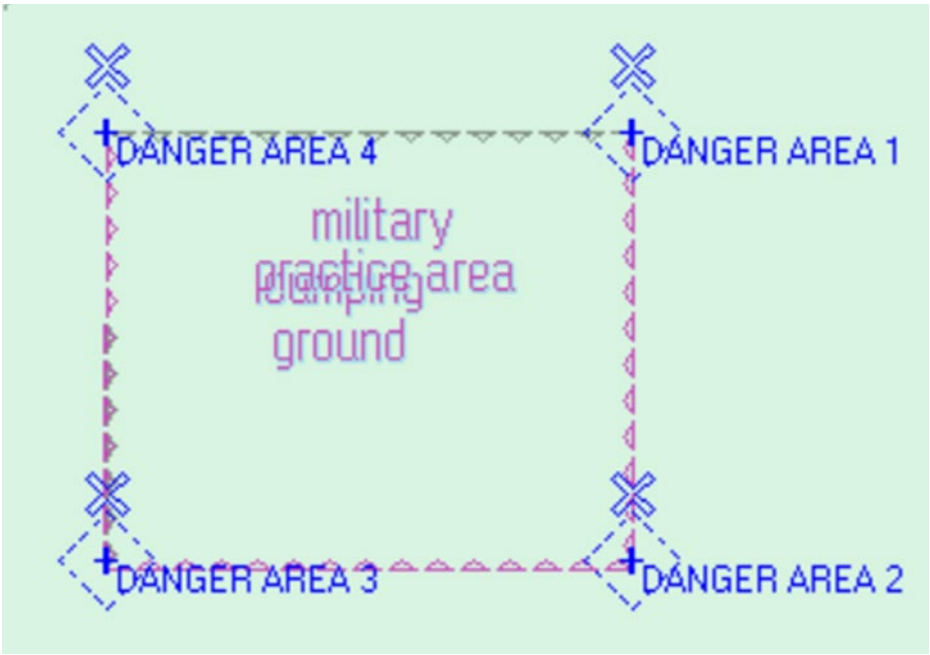
Competent authorities are encouraged to warn their users about these potential position offset situations. Some of the solutions and guidance proposed to manage these issues are listed below:

- Users may validate if the displayed Virtual AIS AtoN position in the information box of the radar is identical to the advertised one from MSI or official publications. Validating the location and the associated information of the AIS AtoN symbol on other display systems such as ECDIS, ECS, PPU, etc., can also provide meaningful information.
- Mariners may use the Target Tracking (TT) tool of the radar and place it directly on the AIS AtoN to validate that the TT coordinates displayed match those advertised for the Virtual AIS AtoN. The use of largest possible radar scale is recommended in order to get the best TT accuracy.
- Some competent authorities have started providing Predicted Synthetic and/or Virtual AIS AtoN schematic reference point patterns associated with well-defined navigational marks to assist mariners in assessing the magnitude of the position offset. Some radar tools, such as the EBL and VRM, can be used to validate that the displayed information is identical to that provided on the schematic reference point diagram.

10.2.6. USE OF VIRTUAL AIS FOR MARKING RESTRICTED AREAS

In addition to regular maritime safety enhancement measures, it may be advisable to use Virtual AtoN (Type Special Mark) to identify temporary restriction areas, to prevent intrusion.

If the area is marked with several Virtual AtoN, the name for each object should be the name together with the serial number or the weather dash.



Source: Swedish Maritime Administration and Swedish Transport Agency

Figure 13 Four virtual AIS AtoN marking the limits of a military area

This type of Virtual AtoN should not be established onshore to avoid misleading mariners. Similarly, establishment in Traffic Separation Schemes (TSS) or Deep Water Routes should be avoided if there are no specific reasons.

11. LEVEL OF SERVICE

11.1. AVAILABILITY

The basic principles for categorizing AtoN in accordance with their importance is described in IALA Recommendation *R0130 Categorisation and Availability Objectives for Short Range Aids to Navigation (O-130)* [23]. Virtual AtoN Services should be categorized in the same manner.

If a transmitting site is broadcasting signals for multiple Virtual AtoN, the most critical AtoN would determine the availability requirements for the service. It should be noted that Virtual AtoN transmitting sites must deliver a specified minimum signal strength at the user antenna within a specified service area.

IALA Recommendation *R0126 Use of the Automatic Identification System (A-126)* [22] defines the required availability for Virtual AIS AtoN and sets the service area criteria in terms of required signal strength.

Similar signal strength criteria should be defined for transmissions broadcast via means other than AIS.

Availability is determined by the ability to deliver the specified reporting rate, signal strength and valid information content. Virtual AtoN criteria should be specified for each of these elements in order to clearly define when the service is no longer available (failure state).

11.2. INTEGRITY ALERTING

Authorised service providers should have the ability to provide users with warnings within a specified time period when a Virtual AtoN service is not available.

The warning should be given within a time frame compatible with the criticality of the AtoN (IALA Categories 1, 2 and 3).

Warnings may be issued as MSI and, in the case of AIS using the flags of Message 21, using Message 14 or by any other appropriate means.

There is a requirement for integrity monitoring. Such monitoring schemes should be independent of the system providing the basic service. Integrity monitoring can take place both onboard a vessel and ashore.

Shipborne monitoring is limited to validity checking of the received data and the reporting rate of the Virtual AtoN.

11.3. CONTINUITY

Continuity is the probability that, assuming a fault-free system at the receiving end, the Virtual AtoN will be received and displayed on the navigational display over the time interval applicable for a particular operation.

The continuity of a Virtual AtoN service should be determined as described in IALA Recommendation *R0121 For the performance and monitoring of a DGNSS Service in the band 283.5 – 325 kHz* [20]. The time interval should be chosen as three hours, or a suitable time frame as determined by the competent authority providing the service. The probability should be according to the category (IALA categories 1, 2 and 3) of each Virtual AtoN. If a transmitting site is broadcasting signals for multiple Virtual AtoN, the most critical one would determine the continuity requirements for the service.

12. DEVELOPMENT CONSIDERATIONS

For the full benefits of Virtual AtoN to be realised, a number of issues must be addressed in consultation with other bodies, including:

- Appropriate instruction and training of all mariners and providers as to the provision of Virtual AtoN, symbology, display, and limitations.
- Harmonization of integration and shipborne navigational system specifications to enable the display of Virtual AtoN for SOLAS ships and other users.
- Development of a strategy for implementation of Virtual AtoN using non-AIS based systems.
- The harmonization of the use of MSI by Virtual AtoN within the context of the IMO's e-Navigation concept.
- Harmonized presentation of Virtual AtoN.

13. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) at http://www.iala-aism.org/wiki/dictionary and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

14. ABBREVIATIONS

AIS	Automatic Identification System
AtoN	Aid(s) to Navigation
CCRP	Consistent Common Reference Point
CPA	Closest Point of Approach
DGPS	Differential Global Positioning System
EBL	Electronic Bearing Line
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
EGC	Enhanced Group Calling
FATDMA	Fixed Access Time Division Multiple Access
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
HF	High Frequency
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBS	Integrated Bridge System
IEC	International Electro-technical Commission
IHO	International Hydrographic Organization
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite Organization
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunications Sector
ITU-R-M	ITU-R M series Recommendations and ITU-R M series Reports
LORAN	LOng RAnge Navigation
MF	Medium Frequency
MID	Maritime Identification Digits
MIO	Marine Information Overlay
MKD	Minimum Keyboard and Display
MMSI	Maritime Mobile Service Identity
MRN	Maritime Resource Name
MSC	Maritime Safety Committee (IMO)
MSI	Maritime Safety Information
MAtoN	Mobile Aid(s) to Navigation
NAV	Sub-Committee on Safety of Navigation (IMO)
NAVTEX	Navigational Telex
PPI	Plan Position Indicator
PPU	Portable Pilot Unit
RAIM	Receiver Autonomous Integrity Monitoring RCCRescue Co-ordination Centre
SafetyNET	Is in international automatic direct printing satellite-based service for e.g., navigational warnings
SAR	Search and Rescue

SN/Circ.	Safety of Navigation Circular (IMO)
SOLAS	United Nations Convention on Safety of Life at Sea
t.b.d.	to be decided
TCPA	Time to Closest Point of Approach
TSS	Traffic Separation Scheme
TT	Target Tracking
Virtual AtoN	Virtual Aid to Navigation
VDL	VHF Data Link
VHF	Very High Frequency
VRM	Variable Range Marker
VTS	Vessel Traffic Services
VTSO	Vessel Traffic Services Operator
WiMAX	Worldwide Interoperability for Microwave Access

15. REFERENCES

[1] IMO. (2015) Res. A.1106(29) Revised Guidelines for the onboard use of shipborne automatic identification systems AIS

[2] IMO. MSC 232(82) Performance Standards for ECDIS

[3] IMO. MSC.192(79) Performance standards for radar equipment

[4] IMO. MSC.191(79) as amended, Performance Standards for the Presentation of Navigation-Related Information on Shipborne Navigational displays

[5] IMO. MSC SN.1/Circ.243/Rev.1 Amended Guidelines for the Presentation of Navigation-Related Symbols, Terms and Abbreviations

[6] IMO. MSC.1/Circ. 1503/Rev.1 ECDIS – Guidance for good practice

[7] IMO. SN.1/Circ. 289 Guidance of the Use of AIS Application Specific Messages

[8] IMO. SN.1/Circ. 290 Guidance for the presentation and display of AIS Application Specific Messages information

[9] IMO. MSC.1/Circ. 1473 Policy on use of AIS Aids to Navigation

[10] ITU-R M.1371 Technical Characteristics for an Automatic Identification System using Time Division Multiple Access in the VHF Maritime Mobile Band

[11] IHO. S-4 Regulations of the IHO for International (INT) charts and charts specifications of the IHO

[12] IHO. S-52 Specifications for Chart Content and Display Aspects of ECDIS

[13] IHO. S-52 Chart Presentation Bulletin No. 10 (S-52-CPB-No 10): Portrayal of Virtual AIS aids to navigation

[14] IHO. S-57 Transfer Standard for Digital Hydrographic Data

[15] IHO. S-57 Appendix B.1 ENC Product Specification

[16] IHO. S-57 Edition 3.1 Encoding Bulletin 54: UOC Clause 12.14.1 AIS equipped aids to navigation

[17] IHO. S-100 Universal Hydrographic Data Model

[18] IHO. S-101 ENC Product Specification

[19] IHO. S-101 Feature and Portrayal Catalogues

[20] IALA. Recommendation R0121 For the performance and monitoring of a DGNSS Service in the band 283.5 – 325 kHz

[21] IALA. Recommendation R0124 The AIS Service (A-124)

[22] IALA. Recommendation R0126 The Use of the Automatic Identification System (AIS) (A-126) in Marine Aids to Navigation Services

[23] IALA. Recommendation R0130 Categorisation and Availability Objectives for Short Range Aids to Navigation (R-130)

[24] IALA. Guideline G1062 The Establishment of AIS as an Aid to Navigation

[25] IALA. Guideline G1084 Authorisation of AIS AtoN

[26] IALA. Guideline G1143 Unique Identifiers for Maritime Resources

[27] IALA. Recommendation R0125 The Use and Presentation of Symbology at a VTS Centre (including AIS)

[28] IALA. Recommendation R1016 Mobile Marine AtoN (MAtoN)

[29] IEC. 61174 ECDIS Operational and Performance Requirements, Methods of Testing and Required Test Results

[30] IEC. 61193-2 Class A shipborne equipment of the universal automatic identification system (AIS) - Operational and performance requirements, methods of test and required test results AIS Class A

[31] IEC. 62288 Presentation of navigation-related information on shipborne navigational displays

[32] IEC. 62320-2 AIS AtoN stations - Minimum operational and performance requirements -methods of test and required test results

[33] IEC. 62388 Maritime navigation and radio-communication equipment and systems – Shipborne radar - Performance requirements, methods of testing and required test results

ANNEX A APPLICATION OF VIRTUAL AIDS TO NAVIGATION

Note that the use of virtual AtoN is only suitable for vessels that have appropriate display equipment.

Application Mode	Function	Conditions	Suggested Type of Virtual AIS AtoN	Consideration
Permanent Marking	Marking of Shoals and Reefs, Fairway and its Limits.	Virtual AtoN can be effectively utilized where it is difficult to place or to maintain a physical AtoN due to meteorological, topographical or hydrographical conditions.	Isolated Danger Marks, Cardinal Marks and Lateral Marks	• Conditions could be sea state such as crashing waves and submerged reef, strong current, water depth, strong ice movement, poor holding ground, etc. • This implementation should be supported by a technical assessment study and avoid being driven by an economic aspect. • For existing AtoN, this must be supported by several discrepancy reports showing the repeatability of the event.
		Virtual AtoN can be effectively utilized in approaches to a harbour entrance where a ship changes its course and where it is difficult to install a physical AtoN. A clear marking of the point on approach will serve for an orderly flow of ships at an entrance and improve safety and efficiency of shipping.	Safe Water Marks	
	Marking of Fairways and Marking of the Limits of Safe Waters	Virtual AtoN can be effectively utilized where navigation becomes difficult due to a thick fog, heavy rain, etc. (This application can also be adapted as a temporary marking during limited visibility.) Marking of a recommendable fairway during times of limited visibility will serve to improve safety of navigation and efficiency of shipping.	Lateral Marks & Safe Water Marks	• Should be temporary

Application Mode	Function	Conditions	Suggested Type of Virtual AIS AtoN	Consideration
Permanent Marking	Special Area (e.g., anchorage area, area to be avoided)	Virtual AtoN can be effectively utilized where precaution or special caution required. A clear marking of special areas will improve safety of navigation.	Special Marks	• This measure will be effective only for vessels obligated to carry AIS equipment
Permanent Marking	Marking of Fairway	Virtual AtoN can be effectively utilized where it is difficult to deploy or maintain a physical AtoN due to vessel to vessel or vessel to AtoN interaction (collision and hits). Potential applications include unique shoal in centre channel for deep draft vessel, alongside a wharf, corner buoy in a steep curve, etc.	Lateral and Cardinal Marks	• Existing AtoN with history of multiple hits and with no repositioning options are good candidates. • Client engagement is necessary to validate ship movement pattern and the effectiveness of the solution. • Economic reason should not be a sole consideration.
Permanent Marking	Marking of Fairway	Virtual AtoN can be effectively utilized where it enhances vessel traffic flow patterns. Potential applications are to mark the centre of each traffic lane or the separation between two lanes of a TSS and other usual routes.	Safe Water Marks & Lateral Marks.	• This is not a substitute for a TSS zone as the implementation of these or the modification of it must be investigated first. • The efficiency of vessel traffic flow patterns is the goal of this application.
Permanent Marking	Marking of Fairway	Virtual AtoN can be effectively utilized where there is a need to verify if a potential AIS position offset exists on shipborne navigational displays through the use of schematic reference point patterns. This is generally a need in confined waters where high accuracy and performance of shipborne equipment is required.	Reference point used in conjunction with a Predicted Synthetic AIS AtoN associated with an existing fixed AtoN.	• The addition of a good radar mark as one of the reference points improves the efficiency of the reference pattern for ship radar validation. • Predefined accurate coordinates as well as distance and bearing between Virtual marks need to be used and made available through publications.
Temporary or Permanent Marking	Marking of Special Areas	Virtual AtoN can be effectively utilized where it enhances the protection of the environment and/or the protection of species.	Special Marks	• Risk of damaging the seafloor of a sensitive area with a physical AtoN might be a consideration. • Timely speed reduction zones or restricted areas for protecting mammals or other species.

Application Mode	Function	Conditions	Suggested Type of Virtual AIS AtoN	Consideration
Temporary Marking	Marking of a Navigational Restricted Areas (time critical only)	Virtual AtoN can be effectively utilized when navigation restriction is required due to military operations, marine accidents or when marking a wreck or offshore operations. A temporary navigation restriction can prevent subsequent incidents from developing.	Cardinal Marks, Emergency Wreck Marks, Isolated Danger Mark & Special Marks	• Need to be monitored/updated. • Timely deployment required where it is difficult to have the proper resource available for a physical AtoN deployment. • The dynamic nature of the event, i.e., short duration or having to relocate an AtoN, reinforces the use of a Virtual AtoN.
	Designation of Temporarily Recommendable Fairways (time critical only)	Virtual AtoN can be effectively utilized for indication of fairways when a large scale disaster hits the area. A clear marking of temporarily recommendable fairways will be expected to serve for the relief ships dispatched to the site and to support safe and effective relief activities.	Lateral Marks & Safe Water Marks	• Need to be monitored /up dated. • Timely deployment required where it is difficult to have the proper resources available for a physical AtoN deployment. • The dynamic nature of the event, i.e., short duration or having to relocate AtoN, reinforces the use of Virtual AtoN.
	Marking of Aids to Navigation that are Malfunctioning or Off Position	Virtual AtoN can be effectively utilized when a physical AtoN has lost its ability to perform regular functions due to a natural disaster. When a physical AtoN has lost its ability to perform regular functions due to natural disasters, recovery actions are required at the earliest opportunity. Virtual AtoN can respond to the circumstances, even if the actions by personnel cannot be achieved due to meteorological and/or hydrographical conditions and reduce the impact of the disaster on ships navigating to a minimum level.	Cardinal Marks, Lateral Marks, Isolated Danger Marks, Safe Water Marks & Other Position Marks	• Timely deployment required. • Pre-storm deployment can be effective as Virtual AtoN can provide timely radar marks from the moment the mariners are ready to proceed after the event. • If there is no post-event inspection, mariners must be warned of the risk of a disparity between the visual position of the physical AtoN and the displayed Virtual AtoN. • The absence of a charted physical AtoN is communicated with the yellow text Missing function. • Care should be taken not to use the Missing text function in cases where the AtoN is carrying a physical AIS AtoN, which is already

Application Mode	Function	Conditions	Suggested Type of Virtual AIS AtoN	Consideration
				broadcasting a state of Off Position in the area of the charted position.
	Marking of Areas to be Avoided	An area to be avoided by certain classes of ships or a vessel routing measure that comprises an area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties.	Special Marks	• This should be considered only as a supplementary measure when it is targeted to all users. • Timely deployment required.
	Marking of Drifting Objects that are not AtoN	Virtual MAtoN can be effectively utilized to mark a floating hazard.	A new MAtoN mark is being developed to be added to the Maritime Buoyage System. A new coding type will need to be used when broadcasting the Message 21	• Usage of Virtual AIS AtoN requires the application of firm rules regarding the position update, such as having the capability of reporting the moving object every three minutes at minimum. • This application will possibly require the utilization of an AIS base station network to cover the largest possible area for the broadcast. • Refer to IALA R1016.
Temporary	Pilot Boarding	Virtual AtoN will be useful in marking a pilot boarding station where the position is dependent on sea/ice. conditions.		• Timely deployment required.