APPLICATIONS OF THEVIRTUAL AND ENHANCED AIDS TO NAVIGATION IN INTEGRATED PORTS

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Abstract

The aids of navigation systems are vital important to assure the safety of ships, passengers, cargo, coastal waters and both the interior and exterior areas of marine ports. Aids to navigation should comply with of international standards and monitoring by the IALA, IMO and IHO organizations. Aids to navigation are a combination of visual and radio systems supported by roles, regulation and navigation services.

The types of aids to navigation in any particular area or port depends on a wide range of the regional and local factors, however, in general, aids to navigation must achieve the assurance of safety of navigation in the deployed area or port. Traditional aids for navigation, such as lighthouse, buoys, beacons and shore objects are long in deep history is being used for navigation.

The introduction of radio and communication systems has brought up many other new navigational systems such as radars, Global Navigation Satellite Systems, surveillance cameras and electronic charts. As such of the available wide range of the navigation system, the cost of building and construction, the maintaining and the replacing cost has become considerably high, especially in those areas and ports having difficulty of securing the implementing systems.

The introduction of the Virtual Reality Navigation System has become a much cheaper cost option to be used, replacing some of these costly ones. The IMO and IALA have recognized the virtual Navigation System as a solution supported by GNSS and Automatic Identification System AIS to be used temporarily in areas where deem to need navigation system as an important corner for enhanced the safety of navigation.

This paper discusses the pro and anti-parameters in comparison between conventional and enhanced Virtual Aids to Navigation, to show what elements to be considered in justifying the implementation of the Virtual Aids to Navigation in the Integrated Ports.

INTRDUDTION

Statics show that 90% of the world trades transported by sea. The increased size and volume of ships combined with relative low cost of ton/ mile of the maritime fright have given the great opportunity of maritime transport over the other transport models.

Navigation is the art and science of knowing the position, time, direction, speed and the distance made by the moving object. Good navigation equipment, systems and practice provide the essential safety of transportation of the ships and its content of cargo, passengers and also include, port infrastructure, and safety of the environment as defined by IMO.

The safety of navigation depends on the use of propernavigation equipment and system, on- board ships. However it should be also supported by adequate types and number of shore and radio aids to navigation. The specification of the shores and onboard aids for navigation are standardized by the international organizations such as IMO, IAIA and IHO. Safety roles and regulation are observed, controlled and regulated by member states of the maritime community.

NAVIGATION SYSTEMS AND AIDS TO NAVIGATION

Navigation Systems and Aids to Navigation are two groups of systems complementary to each other. The first term refers to the onboard systems and equipment which help the mariners to perform safe navigation. There are a wide range of these systems such as radars, paper and electronic charts, Automatic Identification System AIS, compasses, communication systems and the Global Navigation Satellite Systems GNSS, speed logs, depth measurements and a number of tables and publication made available to mariners to facilitate their safe navigation. The second, Aids to Navigation ATON, is introduced by the International Association of Lighthouses Authority IALA, which refers to all fixed shore and floating Aton and shore or space radio systems AtoN may include lighthouses, navigational buoys, and radio beacons. Lighthouses, shore beacons and navigational buoys are known as visual aids to navigation. The buoy symbol on a navigational chart is used to indicate the approximate position of the buoy. The approximate position is used because of practical limitations in positioning and maintaining buoys and their sinkers in precise geographical locations. The position of the buoy can shift inside and outside the charting symbol due to environmental conditions, besides they are subject to damage, failure and dislocation.

E-NAVIGATION

E-navigation is a broad strategic vision led by IMO for the harmonization of marine navigation systems and supporting shore services. The concept involves the utilization and integration of all available navigational tools to secure greater level of safety. Implementation of e-navigation will result commercial benefits. E-navigation system should support decision making, improve performance and prevent errors.

E-Navigation has been a dominant both the navigational aids and the Aids to Navigation. The International Maritime Organization has produced a strategy. IALA has been a key contributor through its e-Navigation Committee. Over the period 2010 to 2020, the biggest challenge for IMO is the development, implementation and introduction of e-Navigation.

E-Navigation aims at facilitating safe and secure navigation of vessels and communications, including data exchange between vessels and shore, integrate and present information onboard and ashore that maximizes navigation safety benefits and minimizes any risk of confusion.

Global Navigation Satellite System (GNSS) is a generic term for a satellite system that provides a world-wide position determination, time and velocity capability. GNSS is based on a constellation of satellites, which continuously transmit signals which can be received by users anywhere on the earth's surface to determine their position and velocity in real time.

THE ROLE OF IALA

IALA was formed in 1957 as a technical association to provide frame work for aids to navigation from all state members to;

- Harmonize standards aids to navigation systems worldwide.
- Facilitate the safe and efficient movement of shipping.
- Enhance the protection of marine environment.

IALA, related organizations are; International Maritime Organization (IMO), the world association for waterborne transport (PIANC), the International Electronically Commission (IEC), International Hydrographic Office (IHO) and the International Telecommunication Union (ITU). IALA, provides specialist advice or assistance on aids to navigation issues (including technical, organizational or training matters); and establishing committees or Working Groups to publish appropriate recommendations and guidelines to contribute to the development of international standards and regulations. IALA members are encouraged to develop policies that address the environmental issues associated with the aids to navigation, including issues such as preservation of historic lighthouses, and organizing conferences, symposiums, seminars, workshops and other events relevant to the Aids to Navigation activities.

AUTOMATIC IDENTIFICATION SYSTEM AIS

AIS is a VHF radio broadcast technology that allows vessels to automatically identify each other while underway and continuously share vital information such as course, speed, and destination, all in the interest of the safety of navigation. International maritime agreements have required AIS equipment on large commercial vessels (more than 300 gross tons) since 2004.

The Automatic Identification System is an internationally adopted communication protocol that enables a continuous exchange of tracking information used for identifying and locating vessels by electronically exchanging data with other nearby vessels, AIS base stations, satellites and aids to navigation. AIS typically supplements marine radar as a method of collision avoidance.
The AIS system is based on transponders located on Vessels and other locations that transmit and receive information on dedicated VHF frequencies. Once ship set up for a voyage, information is transmitted continuously from each vessel without requiring attention from the mariner. The introduction of AIS provides an alternative way of obtaining information for both collision avoidance and navigation. Also includes information of use to authorities, such as hazardous cargo identification. Communication stations include ships and shore station, search and rescue (SAR), and AIS Aids to Navigation (AIS AtoN), which will give position and other

data concerning navigational marks. The specifications for AIS system were adopted by IMO as part of the revisions in 2001 to SOLAS Chapter V.

AIS TRANSMISSION SYSTEM

Two VHF frequencies (161.975MHz and 162.025 MHz) have been dedicated for AIS transmission. The potential range of AIS is therefore similar to VHF voice communications. Thirty or 40 nautical miles are therefore typical for a VHF aerial mounted on a large vessel and less for a small craft. In order to allow all transponders to share the limited frequencies available, each transponder transmits for very short and precisely controlled time periods.

The transmission system is known as (TDMA) Time Division Multiple Access. The time is regulated by the Global Positioning System (GPS) clocks provided by satellite and it is divided into frames, each of 1 minute length. Each frame (one GPS minute) is divided into 2250 equal slots, allowing 2250 transmission to be made on each channel per minute. Approximately 256 bits, which can transmit the equivalent of 40–50 text characters, are sent in each slot. Thus there are normally 4500 time slots available for transmission in every minute over the two frequencies

The required ship reporting capacity according to the IMO performance standard amounts to a minimum of 2000 time slots per minute. The system allows to be overloaded by 400 ships within a radius of VHF coverage in a ship to ship mode. In case of system overload radius is automatically decreased, only targets far way beyond the VHF coverage will be to drop-out.

AIS AIDS TO NAVIGATION (AtoN)

AIS can be fitted to selected fixed and floating aids to navigation, such as buoys and landmarks. This can be in conjunction with RACONs or they could be used as the sole electronic marker. An AIS AtoN transmits a special message that includes its position, status, tidal and current data, and weather, visibility conditions. AIS have proven to be a valuable and versatile method of transmitting information in a relatively small geographic area. While VHF range is normally line-of-sight, or in a best-case scenario 25 to 30 nm.

THE THREE TYPES of AIS AtoN

- Real AIS ATON: The AIS signal is transmitted from a physical aid fitted with AIS transceivers and transponders.
- Monitored Synthetic AIS ATON: The signal originates from an AIS base station in another location, but broadcasts where a physical aid exists. This synthetic **AtoN** refers to a physical buoy, fixed marker, or other conventional aid to navigation that transmits its exact position to a shore station every three minutes. The shore station, in turn, broadcasts an AIS signal with the Maritime Mobile Service Identity (MMSI) number, similar to the one in ship's VHF radio that looks as if it is coming from the buoy mariner would see a real buoy bobbing in the sea, and would see the same buoy on the chart plotter even though the buoy itself is not equipped with AIS.
- Predicted Synthetic AIS AtoN is transmitted from an AIS Station that is located remotely from the AtoN. The AtoN physically exists but the AtoN is not monitored to confirm its location or status. A Predicted Synthetic AIS AtoN does not ensure the integrity of the data, and therefore is not recommended for use on floating AtoN. The use of Predicted Synthetic AIS AtoN broadcasts for fixed AtoN is acceptable as the location will not change.
- Virtual AIS ATON: The physical aid does not exist and is broadcast via AIS from another remote AIS base station location. Unlike physical aids to navigation, where no physical AtoN exists but is displayed on ENCs and ECDIS (USCG 2014; see also IALA G1062). the AIS ATON may appear on a display as though it was coming from a physical aid, but that physical aid is not physically there.

Both physical and synthetic AIS eAtoN share the characteristics depending upon the type and purpose of the AtoN, official nautical charts and electronic charts will use new standardized symbols for various conditions. The primary purpose of an AIS AtoN Station is to promote and enhance safety and efficiency of navigation by one or more of the following:

- Providing a positive and all-weather means of identification;
- Transmitting accurate positions of floating AtoN;
- Indicating if a floating AtoN is off position;

- Provide additional AtoN capability through the use of Virtual AIS AtoN, where installation of physical AtoN is technically or operationally difficult;
- Enable temporary marking of new hazards using Virtual AIS AtoN.

VIRTUAL AIDS-TO-NAVIGATION

The Virtual aid to navigation (AtoN) is defined by the International Association of Lighthouse Authorities as something that "does not physically exist but is a digital information object promulgated by an authorized service provider that can be presented on navigational systems" (IALA O143). IALA recognizes that there are various tools available for use by aids to navigation authorities to improve and enhance services to mariners. Among these are visual aids, radio aids and now, virtual aids to navigation.
Unlike traditional physical aids such as buoys, beacons and lighthouses, the new AIS ATON will appear on electronic charts and ECDIS via AIS. The surprising thing, however, is that the aids may no longer be physically present in the water or on land.

A virtual aid to navigation can be described as digital information, broadcast from an Automatic Identification System (AIS) station, to place an aid to navigation that does not physically exist in the water. Virtual aids to navigation inform navigators about dangers to navigation and safe waterways, as well as areas where extra caution is needed, or which must be avoided. Information from virtual aids to navigation should be considered in the same way as information from physical aids to navigation.

The AIS ATON appears on AIS-integrated electronic navigational displays via the AIS communication system. AIS, the Automatic Identification System, is an internationally adopted communication protocol that enables a continuous exchange of automatic tracking information used for identifying and locating vessels by electronically exchanging data with other nearby vessels, AIS base stations, satellites and aids to navigation. AIS typically supplements marine radar as a method of collision avoidance.

PHYSICAL AtoN, VS. VIRTUAL AtoN

Physical AtoN have been used for thousands of years to guide vessels along their routes and provide assurance of safe passage using known landmarks and structures to indicate safe waters. The modern Technology has provided us with buoys, lighthouses, light ranges, day marks and other devices to accomplish this capability. AtoN complemented with radar, depth sounders, precision positioning and timing devices broadens situational awareness by helping identify environmental features and tracking vessel progress while they are underway.

Virtual AtoN are intended to supplement and not replace existing AtoN in areas where the timely marking of hazards to navigation can be performed faster and more effectively than placing physical AtoN. This may be on a temporary basis until physical AtoN can be installed such as in marking new wrecks or where previously uncharted hazards to navigation are detected. They can also be installed on a permanent basis where the use of physical AtoN is problematic or not possible. This includes coral reefs where sinkers cannot be placed due to their adverse environmental effects, and along rivers and tributaries where water levels and channel locations are subject to frequent change. Another possibility is that AtoN functionality can provide flexibility in terms of purpose and positioning that may be tailored to the unique requirements of individual vessels for determining adequate widths of channels, placement locations and other capabilities such as aid to vessels having lost their way and in need of position assistance.

The identification of AtoN requirements is basedupon the combination of hydrographic survey results and the needs of vessel navigation. The main objectives to be achieved in defining requirements include assisting navigators in identifying their position, determining a safe route of transit, warning of dangers and obstructions, promoting the safe and economic movement of commercial vessel traffic.

The advantage of the virtual aid in the maritime here and now, is that it allows the maritime authoritiesto deploy navigation markers on a temporary basis, or in an emergency, like marking a temporary hazard or sunken vessel or remotely deployed virtual aids to mark the shipping channels.

INFORMATION PROVIDED by AIS AtoN

The maritime AIS Aids to Navigation Report message provide information about the AtoN in uses e.g. Type, name, position of the AtoN, and the off-position indicator. This information is typically broadcasted with a reporting interval of 3 minutes and can be received within the VHF coverage range of the transmitting AIS AtoN station or AIS shore station. In case any data sets are left blank by the user the application shall automatically use the default values as given by the Vessel Tracking and Tracing standard.

ADVANTAGES AND BENEFITS OF VIRTUAL AtoN

Implementing the virtual aids to navigation brings several advantages, chief of which are greater clarity of information and immediate positive identification. They offer improvements in first response time to wrecks and other new dangers, as well as a greater range (VHF) on Radar overlay than physical aid to navigation targets, thus giving an earlier warning of danger. Virtual aids to navigation are potential in enhancing safety and their use brings us several advantages. Some of the reasons why it is considered important to ship navigation are pointed out below:

- To immediately mark a wreck or new danger in areas where it is impossible to place a physical aid to navigation. Virtual aids to navigation are potential in enhancing safety and their use brings us several advantages.
- A virtual aid to navigation can be used in situations when it is not practically possible to equip or due to limitation of time a physical aid to navigation such as a buoy, beacon or a lighthouse cannot be set up. In this case virtual aid to navigation can be used whereby an AIS coast station can be configured to send information to mark its location and therefore help navigating officers to get the necessary information in real time.
- The implementation of virtual AtoN can be completed within a very short duration of time thereby aiding mariners to avoid unexpected hazards and dangers to navigation that can arise any time without any prior information by giving early warning and prevents accidents through proactive notifications.
- They can be extremely helpful in areas where physical buoys are seasonally lifted or misplaced due to swell or when a buoy is off station or damaged due to any natural disaster.

- Virtual aids to navigation are easy to install and do not require costly physical infrastructure unlike the physical aids to navigation. They also need less maintenance. This is yet another reason for its rapid growth and wide acceptance among authorities. They have the ability to move the marked locations as conditions change with ease and can also be removed when the wreck is no longer considered a danger to navigation.
- Virtual aids to navigation can also be used to mark anchorages, restricted or dangerous areas as well as in environmentally sensitive and isolated coastline where there are no beacons or buoys. They can provide additional information about reporting points to officers. Virtual aids to navigation can provide good coverage in spite of rugged landscape or when approaching from internal waters. Ships can identify dangerous underwater hazards well ahead before approaching and can know if they are on a collision course with any navigational hazard.

By far, the main benefit that governmental authorities put forward is the significantly lower cost of maintaining and repairing a virtual ATON as compared to a physical ATON. Examples of potential benefits as far as safety and security are concerned include:

- Timely "temporary" marking of a new wreck or obstruction whereby sea conditions or other factors may not permit the fast deployment of a physical aid.
- The use of virtual ATONs to "fill in gaps" in addition to existing physical ATONs or in locations where physical ATONs are challenging to deploy or maintain.
- Use for temporary operations or activities.
- Ease and speed of deployment to replace missing physical buoys due to natural disasters.

As with all methods of navigation, redundancy is important, therefore a synthetic ATON, which is coupled with a physical ATON, is a practical combination. Virtual aids can be used to mark shallows or obstructions, Vessel Traffic Separation Schemes, harbor approaches and restricted waterways channels, and even lighthouses.

POTENTIAL BENEFITS OF VIRTUAL ATON

Some of the potential benefits of Virtual AtoN in enhancing safety, environment and security are:

- Timely notification;
- Ease and accuracy of presentation, where displayed graphically;
- Ease and speed of deployment;
- Direct delivery to navigational systems; limited to relevant area;
- Information readily apparent to the user;
- Avoidance of misinterpretation through use of standardized symbology and IMO phraseology;
- Easily changed / amended;
- Low cost to install and maintain.

APPLICATIONS OF VIRTUAL AIDS TO NAVIGATION

There are numerous potential applications of virtual aids to navigation. They can be used not only to mark specific locations such as beacons or buoys do, but also to mark lines, areas and other forms. They are not intended to replace physical aids to navigation. However, they may be used to complement or supplement existing marks to improve the safety of navigation. Virtual AtoN is particularly useful in time-critical situations and in marking/delineating dynamic areas where navigational conditions change frequently or in applications where the use of physical aids is not practical or possible. For example, it may be appropriate to create a virtual AtoN to mark hazards to navigation on a temporary basis, until a more permanent AtoN can be established. Alternatively, virtual aids to navigation may be established to mark areas where navigation conditions change frequently and would require dynamic marking. The use of Virtual AtoN should be overseen by the appropriate authority. Notifications to mariners of the presence of Virtual AtoN, integrity monitoring and verification of the effectiveness of the virtual aid are essential elements of such oversight.

RISKS AND LIMITATIONS OF VIRTUAL AtoN

It should be considered the fact that positional data contained within the transmissions may be inaccurate. AIS data is also susceptible to spoofing or jamming. Also if the AIS unit is malfunctioning onboard the vessel, there are chances that the navigating officer may receive false data and thus might not be aware of the actual position of the virtual aid to navigation. There can be GPS errors as well causing positional inaccuracies. Much navigational equipment onboard may not show them at all. Last but not the least navigating officers are used to traditional buoys and beacons therefore; Officers should have a clear idea of virtual aids to navigation. It might happen that if not properly trained to use them, officers may overlook such information as they are not visible in reality.

Virtual AtoN can be detected around bends and behind islands and offer a more accurate positioning. However, they are also subject to disadvantages, mainly the fact that not all vessels are fitted with AIS. AIS are dependent on Global Navigation Satellite Systems (GNSS), and unusual atmospheric conditions could have an effect on range.

Virtual aids to navigation systems can be vulnerable to intentional and unintentional interference or inaccuracies. For example, if a vessel's AIS unit is malfunctioning or incorrectly installed, the mariner may not be aware of the position of a virtual aid to navigation, or may receive incorrect data. In addition, users will not be able to fully utilize AIS aid to navigation functionality if there is no ECDIS or Radar overlay. Care must be taken where AIS is overlaid on Radar or ECDIS, as some manufacturers have chosen only to overlay ship messages. In the absence of ECDIS or radar overlay, users will not be able to fully use the AIS ATON functionality.

Research and development has concentrated upon the commercial sector and has not taken into consideration the safety of smaller vessels such as yachts or recreational boats. Many yachts and smaller vessels do not have the technology to detect virtual ATON and may not universally have this capability for a long time. There is also a variance of information that will be displayed by different manufacturers on ECDIS or radar equipment.

There is also a concern that navigators may spend more time looking at the electronic displays to navigate and won't look outside, as a proper lookout should be. Too much reliance on electronics for navigation, especially if a vessel is not fitted with redundancy of the equipment and back-up power, could be dangerous, especially if virtual ATONs disappear when power is lost or a sole electronic navigation system crashes.

Virtual ATONs also cannot be seen on display equipment unless the vessel is in range of the AIS signal for that aid. These ATONs may not be seen on paper and electronic charts for pre-voyage planning if the vessel does not have the most recent released or updated paper or electronic charts.

Vulnerabilities of the Virtual AtoN

Potential limitations and vulnerabilities associated with the implementation of AtoN technology exist, some of which are described below. With careful planning and diligent design and implementation practices these limitations may be managed and overcome to ensure their reliable and verifiable operation is achieved. The range of AIS broadcasts in the VHF Frequency spectrum is limited to line of sight based primarily upon the height of the base station transmitting and vessel receiving antennae. The range of VHF signals is estimated at nominally 20/30 miles at sea (USCG 2015). This limits the placement of AIS eAtoN to achieve reliable performance at other than remote locations to a distance of less than 20 miles, especially inland where terrain and ground- based structures can interfere with signal propagation (Baldauf 2008).AIS are also subject to the effects of troposphere ducting that can propagate VHF signals hundreds of miles from their origin (Biancomano 1998). Such effects can introduce interference sources to signals from AIS stations within the nominal AIS reception range and can result in performance reduction of AIS both ashore and on vessels (ITU 2007).

AIS *Spoofing and Jamming*

The ability to spoof and jam AIS broadcasts has particular significance where AIS eAtoN signals are used for vessel navigation. A lack of security controls can facilitate a ship being diverted off course by placing AtoN in undesirable or even dangerous locations inadvertently, for hijacking or for other nefarious purposes (Simonite 2013).The vulnerabilities of AIS have also resulted in

its use by criminals to an attempt to evade law enforcement (Middleton 2014). Another report found that AIS data is being increasingly manipulated by
ships that seek to conceal their identity, location or destination for economic gain, (Windward 2014).

GPS Spoofing, Jamming and Outage

Similar to AIS, Global Positioning System (GPS) signals can also be spoofed and jammed causing unreliable and even deceptive navigation signals to be received by vessels and AIS, (Forssell B. 2009). This phenomenon was the subject of a recent articles and researches, (Thompson 2014). Jamming can have the same effects as an outage, when numerous, low power personal privacy jammers can severely interfere the GPS signals, (Grabowski 2012).All GNSS regardless of technology used are subject to the same atmospheric and signal propagation limitations, multipath interference, orbit errors, satellite geometry and orbital debris. One or a combination of such factors may degrade GNSS signals to reduce their accuracy or make their signals unreliable or unusable.

VIRTUAL AtoN DATABASE *HACKING*

One of the greatest vulnerabilities of eAtoN is their primary existence as data objects in cyberspace, without having a traditional physical presence to provide backup in the event of their electronic corruption or disappearance. This property makes them susceptible to hacking and denial of service attacks that can render them useless or even detrimental and hazardous to navigation. Widespread corruption can occur at the source
databases within which eAtoN objects reside at the authorized service provider.
Corruption can also occur at the local level, where individual or groups of eAtoN in the same geographical area may be corrupted.

VERIFICATION OF THE VIRTUAL AtoN

There are three levels at which verification of AtoN must be considered. The first level focuses on where

AtoNis represented in electronic form as data objects. Numerous vulnerabilities can exist ranging from simple data entry errors to the intentional hacking, manipulation or destruction of the data content. Compounding the severity of the problem is that AtoN data is represented in multiple data systems across the authorities that may be altered or modified from their original content, making the ENC a product of collaborative datasets.

The second level of verification is the actual technical performance of the AtoN device and mechanisms themselves. The third level involves verification of the physical AtoN characteristics as manifest at the deployed location on ECDIS.

The easiest and most risky means of verifying the AtoN characteristic associated with position is through the use of GPS to compare the measured position with the charted position. In the case of physical and synthetic AtoN there is a physical AtoN present at the location as well as an AIS/ECDIS representation to corroborate the GNSS fix, assuming that verification of AtoN position has already been accomplished.

IMPLEMENTATION OF VIRTUAL ATON

Once the AtoN requirements and design tasks have been completed, the products of these tasks must be forwarded to cognizant authority for inclusion into nautical charts. This is accomplished in parallel with preparing to deploy virtual AtoN through the performance of local surveys to confirm positioning and other tasks as may be deemed necessary prior to their introduction. In all implementation tasks it is vital ensure that the processes used during requirements definition and design ensure the correct virtual AtoN aid is created and translates into a proper implementation of the aid.

Requirement and design modification processes need to be established along with tracking of changes needed throughout development to facilitate metric reporting of requirement, design and implementation of the virtual AtoN. Metrics focusing on risk assessment of the quality and structure of the schedule, work breakdown structure consistency, critical path analysis and the identification of high risk activities and events, and risk mitigation scenarios should also be identified. The system is complete when all steps necessary to implement the virtual AtoN system have been identified and metrics established to ensure measurable progress indicates completion. This approach will ensure virtual AtoN feature and capability traceability to product specification and design, system configuration stability, adequacy of testing, and overall system maturity.

CONCLUSIONS AND RECOMMENDATIONS

1. Virtual aids to navigation can be used in situations where it is not practical to use physical aids to navigation, or where information is needed faster than a buoy can be placed. In this case, an AIS coast station or another physical AIS AtoN can send AtoN information on behalf of the hazard or AtoN, which will be shown on an electronic chart system.
2. IALA encourages authorities to consider the use of Virtual AtoN in the design and delivery of future aids to navigation services in accordance with its recommendation and guideline.
3. The introduction of virtual aids to navigation has been one of the greatest achievements in recent navigation history. Though many are presently under development, they are used by a number of administrations around the world.
4. Risk analysis should be performed before decision is taken to implement virtual AtoN system to determine which navigation routes are high risk or particularly hazardous.
5. The possibility to mix traditional physical AtoN technology with virtual AtoN may prove to be a feasible option for providing more cost effective and dynamic AtoN services.
6. AIS technology has already proven to be a successful supplement to traditional AtoN technology, in terms of rapid deployment and issuing of safety related text messages.
7. Significant limitations and potential vulnerabilities exist in the AIS and GNSS technologies that support eAtoN operations. Spoofing and denial of service attacks will accelerate due to the lack of security in both of these areas as states and criminal organizations gain experience in using and misusing these technologies.
8. Virtual aids to navigation are not meant to replace physical aids to navigation, however they address the need to make hazards at sea visible when costly physical structure is not appropriate or is difficult to deploy. They are invaluable in using radar or ECDIS to show critical data.

9. The IMO's e-Navigation development cycle includes some form of cost-benefit analysis during the architecture and analysis phases. Studies should be focused on benefits and costs with a keen interest in whether they are reasonable and equitable. The strategy of advancing benefits and deferring costs seems particularly pertinent.

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