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Research on new communication and navigation technologies on aids to navigation

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RESEARCH ON NEW COMMUNICATION AND NAVIGATION TECHNOLOGIES ON AIDS TO NAVIGATION

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: Research on new communication and navigation technologies on Aids to Navigation

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Compared with the AtoN in ancient times, people today endow AtoN additional functions. And the realization of these functions is based on new communication and navigation technologies, which are Network technology, Internet technology and Navaid technology. E-navigation is a concept for comprehensive maritime service, which cannot be separated with AtoN. It shows great potential value for ship and port because of its advance. When implements new technologies, people should consider the goal, path, possibility and issues. And in this case, the Shanghai North passage AtoN plan and E-port Yangshan project are introduced in this paper as examples to analyse the characteristics of current virtual AtoN and E-navigation.

KEY WORDS: AtoN, communication and navigation, E-Navigation, Shanghai Port, China maritime service, navigation aids.

LIST OF ABBREVIATIONS

AIS	Automatic Identification System
CDMA	Code Division Multiple Access
DGPS	Differential Global Positioning System
DNGSS	Differential Global Navigation Satellite System
ECDIS	Electronic Chart Display & Information System
ECS	Electronic Chart System
EGNOS	European Geostationary Navigation Overlapping Service
FDMA	Frequency Division Multiple Access
GIS	Geographic information system
GNSS	Global Navigation Satellite System
IALA	International Association of Lighthouse Authorities
IMO	International Maritime Organization
ITU	International Telecommunication Union
MSAS	Multi-Functional Satellite Augmentation System
MSP	Maritime service portfolio
NAVTEX	Navigational Telex
PTN	Positioning Navigation and time
RBN	Radio Beacon Navigation
SDMA	Space Division Multiple Address
TDMA	Time Division Multiple Address
TDSCDMA	Time Division Synchronous Code Division Multiple Access
VDES	VHF Data Exchange System
VHF	Very high frequency
VTS	Vessel traffic services
WAAS	Whole World Radio Navigation System
WCDMA	Wideband Code Division Multiple Access

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Chapter 1 Introduction

1.1 Background of the research

The Aids to Navigation (AtoN) have serviced people for thousands of years. In the ever beginning, people use nature geographical AtoN (such as rock, cliff and cape) to indicate the direction and position. 3000 years ago, there was a recordation of using natural geographical AtoN in East China Sea (Zhang,2007). And with the development of human civilization, the human made AtoN began to use to not only indicate position but also transmit information by sound and light. In the old time, the bell towers of the church, top of the castle and the light house are widely used as AtoN, and even people built great AtoN such as Alexander lighthouse and The Colossus of Rhodes.[1] In the recent years, various of electronic technologies are used on shipping industry and these technologies also come to AtoN area, such as AtoN telemetering and telecontrol, satellite AIS AtoN, virtual AtoN in electronic chart and etc. In this case, it can be said that the AtoN technology is always following the development of shipping industry and human civilization.

In the past of ten years, the communication and navigation technologies have been developing dramatic fast in personal computer, smart phone and car industry. And these technologies show great help for shipping. The ship becomes larger, deeper, faster and with the less crews and they need more accurate positioning, more efficient service and more convenient support. AtoN service as a very important part of maritime service should be updated for these new requirements from shipping. In this case, it is very significant not only for China but also for other Member States in IMO to develop these technologies.

[1] The Seven Wonders of The Ancient World

1.2 Main research content in this paper

The research content concentrates on introduction and analysis of new communication and navigation technologies on AtoN. And this paper will consider the requirement from both the users and the providers. This paper mainly includes,

(1) Net technology;

Includes 4G, full Netcom, AIS, VDES and NAVDATA.

(2) Data technology;

Includes the Web of thing, Big data, Cloud computing and video monitoring.

(3) Navaid technology;

Includes Beidou, virtual AtoN, PTN and etc.

(4) E-navigation

Includes S-100 standards, MPS and etc.

1.3 Purpose of this research

According to the "Chinese 13th five-year plan for maritime navigation safety system", China will basically establish a comprehensive navigation safety system, which orders wide coverage, efficient management, high quality service and timely (Ren&Luo, 2011). The purpose of this paper is to summarize and analyze new communication and navigation technologies on AtoN for China AtoN authority[2] to implement this plan. This paper also summarizes and analyzes the E-navigation system for the requirement for the authority in China. And it tries to propose some issues and suggestion in the period of implementation. Technology is a double-edged sword and this paper finally asks some limits and risks when processing these technologies.

[2] The AtoN authority is China MSA and technology support authority is local AtoN Department.

1.4 Research scope and methodology of this paper.

The paper of AtoN forces on communication and navigation aspects, which are network, data transmission, collection and analysis, and electronic navigation platform. And this research scope is mostly in China, especially East China Sea.

The methodology mainly used in the paper is summarizing method and importance, necessity and feasibility analysis. And the it includes some interview and investigation on the authority of AtoN in Port Shanghai (Shanghai AtoN Department[3]). The investigation also includes some local field study on the vessel for operating AtoN. And using a questionnaire to find some idea of local pilots and crews on watch. At the same time, this paper uses case study on virtual AtoN and E-navigation.

1.5 The structure of this paper.

There are 6 chapters in this paper. Chapter 1 is the introduce the background of AtoN and shows the significance of the research. Chapter 2 will review the definition of AtoN, specially the classification of AtoN and analyses their characteristics and functions. In Chapter 3, this paper will introduce some new technologies for AtoN. The first part is Net-work because the AtoN date transfer relys very much on mobile network. 4G and full Netcom will be introduced. The second part is Data technology, Web of Thing, Big Data and Cloud computing will be introduced and analyzed. The third part concentrates on the Virtual technology, and this part uses a case of AtoN plan in Port Shanghai to analyze and summarize the pons and cons. Chapter 4 will analyze the E-navigation technology as E-

[3] SHANGHAI AtoN department belongs to DNSA MOT which is on responsible of the AtoN in East China Sea

navigation is an integration of these communication and navigation technologies. And this chapter will also introduce the Yangshan E-port project as an example to analyze current Chinese condition on E-navigation. Chapter 5 will summarize the goals, paths, issues and feasibility of these technologies on AtoN in China. And this chapter also analyzes the E-navigation implementation in China and gives some suggestions. Chapter 6 is the conclusion of the paper while this chapter proposes some limits and asks some risks of new technologies for future study.

Chapter 2 Current Aids to Navigation

2.1 The definition of AtoN

Aids to Navigation is a device or system outside of a ship, designed for the purpose of promoting the safe and effective navigation of ships and/or vessel traffic. And AtoN should not be confused with navigation aids. Navigation aids are inside of a ship, for the purpose of navigation, such as a device, facility or chart. According to this definition of AtoN, IALA regards the AIS and VTS as a part of AtoN. (Saint,2013)

And in the current various of AtoN, in summary there are four functions,

(1) Positioning: Provide positioning information for ships;

(2) Warning: Provide obstructions and other navigational warning information;

(3) Traffic instructions: Direction of navigation in accordance with traffic regulations;

(4) Indications of special areas: such as anchorages, surveying areas, restricted areas, etc.

2.2 The technology classification of AtoN

2.2.1 Visual AtoN

The visual AtoN could be a sign natural or unnatural, including some building for short-range AtoN and as well as some special terrain and object. And this sign could be point, mountain, rock, tree or tower, top of church, mosque minaret, monument, chimney, etc. There is a huge long history for the visual in China. It could be dated back to the year of 1412 in Ming dynasty. The earliest light house in Shanghai was called Beacon Tower of Baoshan. And there is a stele for recording this building. And the purpose for this tower is for ships into Huangpu River which is a branch of Yangtze River across the city of Shanghai. (Zhu,1988)

The visual AtoN is designed to transmit information for the specially training crew on board. And the information is about the navigation safety. The visual AtoN usually mean the light house, light buoy, light ship, fixed beacon, traffic signal light, and board in narrow sense. (Xu&Tang, 2010) Visual AtoN are identified by the following characteristics: type, fixed structure, floating platform, position, auxiliary navigation aids inside, relationship with other observable features, characteristics, shape, size, elevation, color, presence or absence of lights, signal properties, light intensity, fan light, building materials, retroreflective properties, names, letters and numbers (Li,1996). The effect of visual AtoN depends on many factors, summarized as:

(1) The type of AtoN and the characteristics of such AtoN;

(2) The position of the AtoN relative to the typical route of the ship;

(3) The distance between the AtoN and the observer;

(4) Atmospheric conditions;

(5) Contrast associated with background conditions;

(6) The reliability and availability of AtoN.

(7) The training and experience of the observer.

2.2.2 Radar AtoN

Radar AtoN is made for improve effect of radar electromagnetic reflection capability. One hand it is a visual AtoN because Radar AtoN can be watching on the screen by the crew on watch, on the other hand it needs Radar as an equipment for sending waves and receive information, so it also belongs to radio AtoN. And the Radar AtoN can be classed by:

(1) Radar beacon, abbreviated as RACON, is a passive type active radar beacon. The coded symbols of the response symbols are periodically displayed on the ship radar screen, when it is scanned by the radar wave and it usually used to identify isolated objects.

(2) Radar marker, abbreviated as RAMARK, is an active type active radar beacon, which itself has the ability to automatically transmit electromagnetic waves. Whether or not it is scanned by radar, it will periodically continuously transmit a signal with a certain frequency.

(3) Search and Succour Radar Transponder, which is abbreviated as SART, is a kind of radar equipment for emergency according to the SOLAS convention. It belongs to the passive type active special radar mark. (Cooper, &Bertsche, 1981)

2.2.3 Radio AtoN

The Radio AtoN is not a new technology for navigation. Compared with visual AtoN, the radio AtoN have advance coverage. And if the ship has enough receiving machines, the cost-benefit is high for authority to use radio AtoN (Halpert& Basker, unknown year). And now, with the development of GNSS, and traditional shore-based Radio AtoN have fundamentally changed. And these changes obsoleted some old types of radio AtoN, such as Decca positioning system and Omega positioning system in the past recent decade of years (Powell,1985). These changes include,

(1) When ship sailing outside restricted waters, it provides an alternative to traditional positioning methods;

(2) Open the way for the ECS and shipborne AIS;

(3) Provide opportunities for some systems that can integrate location reference and information functions, such as ECDIS;

(4) The concept of multi-mode, which combines ship navigation with cargo management, and it can track from the port of departure to the port of destination.

Today the Radio AtoN combined with GNSS, DNGSS, ECDIS and AIS are tremendous used in this industry, and the IALA has introduced Radio AtoN system and its standard (Weintrit, 2010). These systems include,

(1) Satellite system: space-based obtaining positioning methods, such as GPS and GLONASS;

(2) Land-based systems: land-based obtaining positioning methods, such as loran C;

(3) Enhance the system: improve positioning space-based and/or land-based auxiliary methods, for example, WAAS/EGNOS, DGNSS and RAIM receiver;

(4) Radar beacon system: obtaining the identity and position of the AtoN;

(5) Hybrid/integrated system: any combination of the above, that can be used to improve positioning, such as Eurofix and hybrid/integrated receivers;

(6) Assist integrated bridge system: radio navigation system can offer position information for ship bridge system such as electronic chart display and information system (ECDIS) and the vessel data record system (VDR);

(7) Assist communication system: radio navigation system can offer position to ship and/or shore communication system, such as ship automatic identification system (AIS) and the global maritime distress and safety system (GMDSS). (Zheng,200)

And table 1 shows the pros and cons for provider and observer of this three AtoN and table 2 shows their accuracy.

Type	Observer		Provider	
	Advantages	Disadvantages	Advantage	Disadvantage
Visual AtoN	Can be used for positioning; Transmit messaging; If the user is familiar with the local situation, these signs can be used without the need of charts.	The operating distance depends on location, height, color, and background; Restricted by visibility; Floating beacon locations are not always accurate.	Flexible layout for danger warning, traffic rules, guidance, etc;	Maintenance cost is high; The maintenance plan depends on the weather conditions; A logistics system is required; Maintenance personnel need to be trained.
Radar AtoN	Radar transponder can be used for identification under poor visibility conditions; A radar transponder is used to identify low	Shipborne equipment is required; If the location of the radar transponder is not appropriate, the radar transponder may cause interference and	Can replace some visual AtoN; Warning danger.	Need a radar reflector. Some ships have no radar. Radar transponders invest heavily. Maintenance of radar transponders requires training.

	coastlines; Just one sign; Quick fix.	it is difficult to identify the beacon equipped with the radar reflector.		
Radio AtoN	The coverage is large; All-weather service; Automatic navigation; Be as accurate as possible.	Shipborne equipment is required.	Requires little maintenance; automatic monitoring;	It may not be under the control of the AtoN authority. Need monitoring. Maintenance personnel need training. Big investment.

Table 1. Summary advantages and disadvantages of three AtoN (source made by the author)

Distance from shore （mails）	Accuracy (meters)		
	>500m	100～500m	<100m
No limits	Astronomical position		Satellite
150～800	Astronomical position	Loran-C	Satellite
30～150	Radio beacon		Satellite Loran-C Accuracy system
6～30	Radio beacon Visual direction Radio direction	Radar direction	Satellite Loran-C Accuracy system
6 or less		Radio beacon Visual direction Radar direction	Satellite Loran-C Accuracy system

Table 2. Accuracy of different AtoN system (source from Shanghai AtoN department)

2.3 Satellite navigation system

2.3.1 GNSS

Global Navigation Satellite System (GNSS) is a general term for a satellite system with the ability to provide global positioning, timing and speed for a variety of usage modes. GNSS is based on a constellation of operating satellites that continuously emit coded signals at two or more frequencies. Users anywhere on earth can receive these signals to determine their location and speed in real-time based on distance measurements. If global navigation satellite system accords with IMO about Whole World Radio Navigation System (WWRNS) resolution a. 953 (23), the receiver should satisfy with what it ordered in the SOLAS Convention Chapter v. (Wang, Zhou &Quan, 2012) and then it could work.

Since 1996, the United States' navigation satellite global positioning system (GPS) and Russia's global navigation satellite system (GLONASS) have been recognized as components of the global radio navigation system. In the future, the global navigation satellite system could include other systems, such as Galileo, built by the European Union; Beidou, built by China.

2.3.2 DGNSS

Differential Global Navigation Satellite System (DGNSS) is an enhancement system to reduce GNSS signal error in a certain area. The process involves comparing the position of the DGNSS reference station accurately measured with that determined by GNSS satellites in the field of view. A message containing position error and satellite integrity information is then transmitted to the user with the appropriate receiver. Thus, users can enhance positioning accuracy within the service area. Satellite failure notification is almost immediately available. The wide area enhancement system (WAAS[4]) was established by the federal aviation administration for commercial aviation services. The system uses synchronous satellites instead of land-based radio stations to send GPS correction and improvement data. As a result, the system covers a larger area, even though it is complex to process messages. Similar systems have been developed in Europe and Japan, including the European Geostationary Navigation Overlapping Service (EGNOS[5]) and the Multi-Functional Satellite Augmentation System (MSAS[6]). (Zhao,2013) And, the DGNSS applications can be summarized as table 3:

General navigation	Commercial fishing nets and equipment positioning
Search and rescue	Offshore drilling survey
In and out of the harbor passage navigation	Ice-breaking and monitoring of icebergs and ice flows
Ship traffic services	Observe tides and currents
Management of dredged	Facilities in ports and passage
Aids to Navigation	Positioning of container

Table 3. The application of DNGSS (source made by the author)

2.3.3 GPS

GPS[7] standard positioning service is a system that provides 3D location, 3D speed and timing. It was fully operational in 1995. The system is operated by the U.S. air force on behalf of the U.S. government. GPS without identification based on the application of SPS is free to all users with the proper receiver, its location services can satisfy the needs of

[4] Details of WAAS can see http：//www.navcen.uscg.gov
[5] EGNOS can see http：//www.esa.int/
[6] MSAT https://en.wikipedia.org/wiki/MTSAT_Satellite_Augmentation_System
[7] Details of GPS can find in NAVCEN http：//www.navcen.uscg.gov

the general navigation, horizontal position accuracy of 15 ~ 20 m (95% probability) (Ji, &Sun, 2008).

The GPS receiver, in cooperation with other devices, can provide:

(1) Absolute positioning;

(2) Relative positioning, further acquiring ground speed (SOG), ground track (COG), etc.;

(3) Timing.

(4) Static positioning and dynamic positioning

2.3.4. GLONASS, Galileo and Beido system

The three satellite systems have similar potential customers, and they are built by Russia, EU and China. GLONASS[8] is administered by the Russian Space Agency on behalf of the Russian federation. If all 24 satellites are put into use, the positioning service will up to the requirements of general navigation, and the horizontal positioning accuracy will be 45m (95% probability) (Ren, Yang, &Huang, 2008). But for now, the service is not fully operational.

Galileo[9], the future European satellite navigation system, will be under civilian control. Galileo system is expected to consist of 30 satellites, of which 27 on work and 3 on standby. The satellite will be located in the middle earth orbit (MEO) with an equatorial tilt of 56 degree. The satellite will provide a standard dual frequency so that users can calculate its position with meter precision. Galileo will be provided services on its own performance standards: public service (OS), the safety of life at (SOL), business services (CS), the public management services (PRS), and search and rescue (SAR) service. Galileo is expected to provide complete failure warnings in a matter of seconds. One of the features

[8] GlONASS http：//www.glonass-center.ru

[9] Galileo http：//www.europa.eu.int/comm/dgs/energy_transport/Galileo

of the system is the ability to relay distress messages to the cospas-sarsat service center while keeping users informed.

Beidou[10] satellite navigation system has characteristic of global coverage, navigation and communication integration, and multi-system compatible services. China is steadily push forward the construction of Beidou satellite navigation system, has now completed more than 10 satellites in three track, built area navigation system, the formation of regional service ability, to the Asia-Pacific region to provide positioning, navigation, timing, and short message communication service. Around 2020, the Beidou system will be built by 5 geostationary orbit satellites and 30 non-stationary orbit satellite coverage of the global satellite system, the formation of global passive service ability, realize the independent and open compatible, advanced technology, stable and reliable.

2.4 AIS AtoN

A special AIS station installed on the AtoN will provide active identification without the need for a special shipboard display. In addition, AIS information and data provided to AtoN can:

(1) Supplement the existing AtoN, provide identification codes, working status and other information to ships surrounding or shore management authorities;

(2) Provide the position information of the AtoN through DNGSS to make sure the AtoN on the right position;

(3) Provide real-time information for AtoN working state performance monitoring, and use the linked data chain for remote control or change the parameters of the AtoN or open the backup equipment;

(4) Provide local hydrological and meteorological information;

[10] Beidou http://www.beidou.gov.cn/

(5) In the future, it may replace Racon to provide detection and identification under various weather conditions;

(6) Collect shipping traffic data. (Wang,2001)

2.5 VTS

As defined in the VTS guidance in resolution a.857 (20) of the IMO, VTS is a service implemented by competent authorities to enhance the safety and efficiency of ship traffic and environmental protection. The service should be able to coordinate shipping traffic and respond to traffic situations in the VTS area. (Liu, 2003)

The corresponding operating objectives include:

(1) Minimize the possibility of accidents such as collision and stranding;

(2) Minimizing the risk of human life, the environment, pollution and the surrounding infrastructure, including the identification and monitoring of ships carrying dangerous goods;

(3) Optimize the effective of ships, passages, associated services and other related services.

2.6 Chapter summary

This chapter review AtoN definition and its classification, which are visual AtoN, Radar AtoN and Radio AtoN. And in the modern navigation, AtoN is not only the buoy and light, it incorporates radar, communication, satellite and net-work technology. This chapter also list the current satellite navigation system, as a important part of AtoN, GPS is most widely used with the DGNSS technology, and its accuracy is appreciable. GLONASS, Galileo and Beido are still in building, but they show good prospect in some of the condition and they can be used as a supplement of GPS in some areas. On the other hand, VTS has been consider as AtoN by most of the Member State and its service should be integrated into the AtoN system and maritime safety service.

Chapter 3 New Communication and Navigation Technologies

3.1 Net-work technology

3.1.1 4G

Most of current maritime wireless data transmission stations use 3G technology, it overcomes some drawbacks of the GPRS or GSM system, such as transmission bandwidth, loss of data and information. But the current 3G technology exists issues like multipath fading, delay spread, multiple access interference and other technological drawbacks. At present, for example, video encoding is mainly use mpeg-2/4, h. 264. under the premise of constant transmission flow. (Liu, 2008) Low transmission frame rate is generally adopted to guarantee the clarity of transmission images. Therefore, 4G network technology for video monitoring image transmission becomes a solution for video transmission. In terms of 4G technology, the theoretical maximum speed of network download reaches 10014.4Mbps, which is one level higher than that of 3G (Zheng, 2007). At the same time, 4G not only has clear sound quality, but also can carry out high definition image transmission. In terms of capacity, 4G can be introduced to replace 3G, because it has 5-10 times capacity than that of 3G. (Ni, Wu&Zhao,2014) In addition, it can eliminate or reduce the interference between the signal waveforms, and it can be well handled for the multipath fading problem. The high speed 4G network will provide high prerequisites for video and other AtoN data transmission. And 4G network has been practiced in mobile network for some years and has already proved its stability.

3.1.2 Full Netcom

In order to access the network, the network communication module chip must be in the beacon. In China the G network version[11](WCDMA), T network version[12](TD-SCDMA) and the C network version[13] (CDMA 2000) are respectively need to installed with different communication module chips (Wen, 2011) The mobile communication network signal strength is different, so the authority should choose different versions of the beacon chip for different areas. It limits the using scope of a beacon chip because the versions are not compatible in the single beacon chip. And in most condition different regions use different versions. However, the emergence of full network connection provides a technically feasible solution to solve the incompatibility of different versions of communication models. Several full-network communication modules have been developed for the mobile network. And they can be used in the beacon chips because the basic theory of the two is the same. (For example, 4G industrial-level 7 mode all-network communication module ME3630 is based on Qualcomm's MDM9X07 platform.) Compared with G, T and C network communication module, full-Netcom communication module shows certain advantages on the size and power consumption. In the compatible network system, the module can be compatible with all the common communication modules and can achieve three networks seamless connection. And its system compatibility supports TCP/IP protocol stack, standard AT instruction set, Windows XP / 7/8, Android 2.3/4. X / 5. X, Linux 2.6.10 and later Windows CE system. (Tang, Zheng, Chen&ect,2018)

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[11] By China Unicom
[12] By China Mobile
[13] By China Telecom

3.1.3 AIS technology

3.1.3.1 Shore-based AIS

Shore-based AIS mainly uses message No. 21 and No. 6. Message. No.21 is a broadcast message for navigation safety of ships and for radio AtoN. Message No. 6 is a message that realizes the telemetry and remote control. The information content can be defined by itself. Through the application of AIS No. 6 message, the remote monitoring can be realized very simply. The function of AIS AtoN application is realized by AIS transponder, and the use of AIS transponder installed on different navigation facilities are also different. When the AIS transponder is on the float buoy, it will use No. 21 message to send the off normal information, such as float or failure. And the AIS station begins to identify the condition of this float buoys and broadcasts the navigation warning through this base. On fixed buoy, such as lighthouses and lamp, it can broadcast its own information, such as hydrological data and meteorological data.

AIS AtoN can receive information for monitoring from other AIS AtoN. It can also broadcast the information of synthetic AIS or virtual AIS system on offshore structures, fixed building, oil rigs, offshore gas drilling platforms, special purpose of offshore structures, and etc. (Yu, Wei&Zhang, 2010) An important use of shore-based AIS is network application. And its network applications mainly include:

(1) Supplement the existing signals of the AtoN.

AIS center can broadcast the AtoN information through the Marine 87B and 88B frequency (Stateczny,2004), no matter if the AIS transponder is installed within or without the AIS coverage.

(2) Broadcast the accurate position of floating beacon and report the distance. When float buoy drifts away from the established position for some external factors (typhoon, tsunami, etc.), AIS will broadcast its theoretical position through security

address information and No.21 message to the ships passing. At the same time, the out-of-position buoy information will be automatically broadcast and showed on the electronic chart of AIS management center.

(3) Supplement the Racon. When ship's radar scans the racon on the AtoN facilities, AIS transponder receives the information of this AtoN through the AIS transponder in the same time.

(4) AIS shore-based station can broadcast the information of warning to the vessels in the region.

(5) With the continuous development of shore-based network, the management of AtoN can use a mobile phone AIS information service platform and relevant APP through the existing commercial network.

3.1.3.2 Satellite AIS

Because AIS works on the VHF band, its coverage is limited, ranging from 20 to 30 nautical miles (Xu, 1994). In recent years, people urgently need to monitor vessels beyond ordinary VHF coverage in order to deal with risks of ship, improve security and monitoring records. Internationally, a few years ago, the United States, Norway and other countries began to develop satellite detection AIS technology (i.e., space-based AIS system). These countries proposed AIS information and used satellite surface in low earth according to the ITU&IMO relevant frameworks. Satellite AIS uses one or more low orbit satellite (satellite orbit height from 600 km to 1000 km) (Ding,2012), carrying on the satellite AIS receiver to receive and decode AIS message and forward the information to the corresponding earth station. Satellite AIS system is mainly used for transmitting AIS message information, mainly for short message data, and the number of operational satellites is small, so it belongs to low-orbit small satellite system (Song,2015). The communication service provided by satellite can be divided into non-real-time communication system and real-time communication system. Satellite AIS belongs to non-real-time communication system. In order to realize worldwide covered system and guarantee a certain number of earth stations being used, it is necessary to use a store-and-forward technology to transmit AIS data. The basic principle of satellite AIS technology is shown in following figure 1.

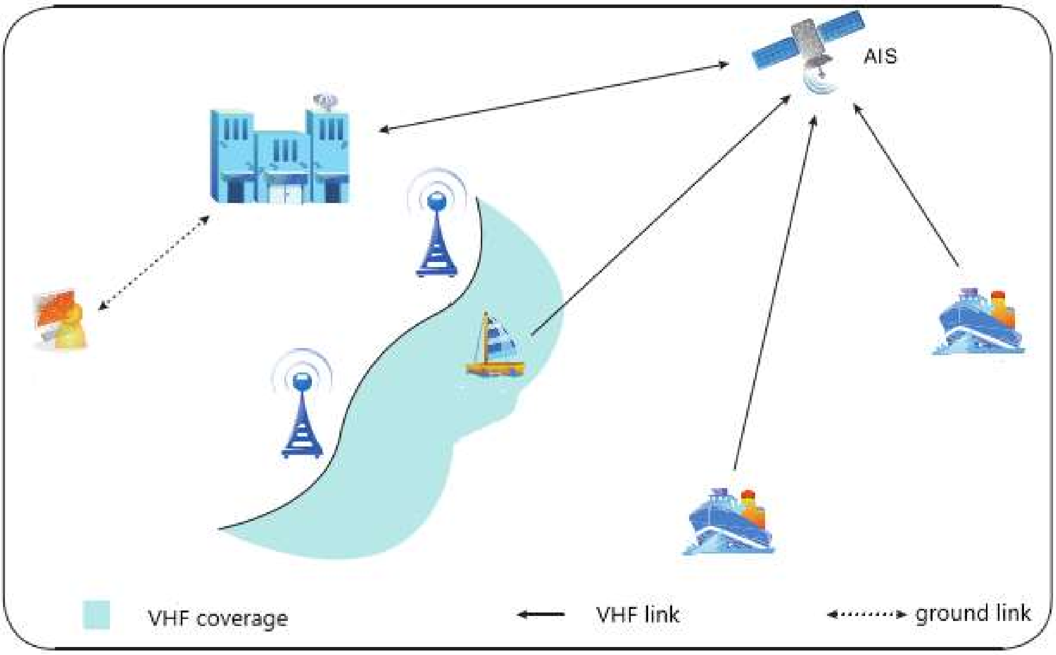

Figure 1.The AIS worldwide cover system (source from web of MSA)

3.1.3.3 IALA-NET

IALA-NET is provided through the Internet and is currently a real-time data exchange service based on AIS information, and it has the capability of AIS data storage to be used for statistical purposes. (Park, &Hwang,2010) It is a global, un-confidential, voluntary, network-based, open structure, maritime information sharing and exchange service, which is open to all national authorities that have provided AIS data in their own waters to exchange AIS data from other participating countries. The purpose of the service is to assist the national authorities to fulfil their obligations in the aspects of security, marine environmental protection and the efficiency of navigation. (Wang,2010) Its impact on the development of shipping mainly is reflected in the following:

1) Promote the process of shipping economic information. It is a very important information resource such as its position and dynamic state, goods, safety and other information at any time.

2) Enhance the control and operability of navigation safety. AIS provides an information exchange platform. Remote participation and control of navigation security are achieved. It is not a blind command.

3) Maritime Search and rescue and typhoon prevention are convenient for nationwide coordination. The maritime department makes full use of the coastal AIS data and reacts quickly.

4) Other uses. With the promotion of IALA-NET database, other information can be expanded, such as water security, environmental monitoring, traffic analysis, ship registration, radar data and so on.

3.1.4 VDES and NAVDAT

VDES is a system for AIS enhancement and upgrading and the figure 2 shows its structure. Compared with AIS system, VDES has more communication links. VDES integrates three functions of AIS, special application message (ASM) and broadband VHF Data Exchange (VDE). Compared with AIS, there are significant changes in the three aspects: first, the system gives the highest priority to the ship location report and the security related information, and it opens up the special frequency band information transmission; secondly, it is more flexible, VDES is different from the passive acceptance of information in the past, the users of VDES can push or take information to or from other ships, ports or chart center initiatively according to what information their need. Finally, relying on channel adjustment, the speed of information transmission is greatly enhanced, for example, an image of 300k needs several minutes through AIS but only 2 or 3 seconds through VDES (HU,2017).

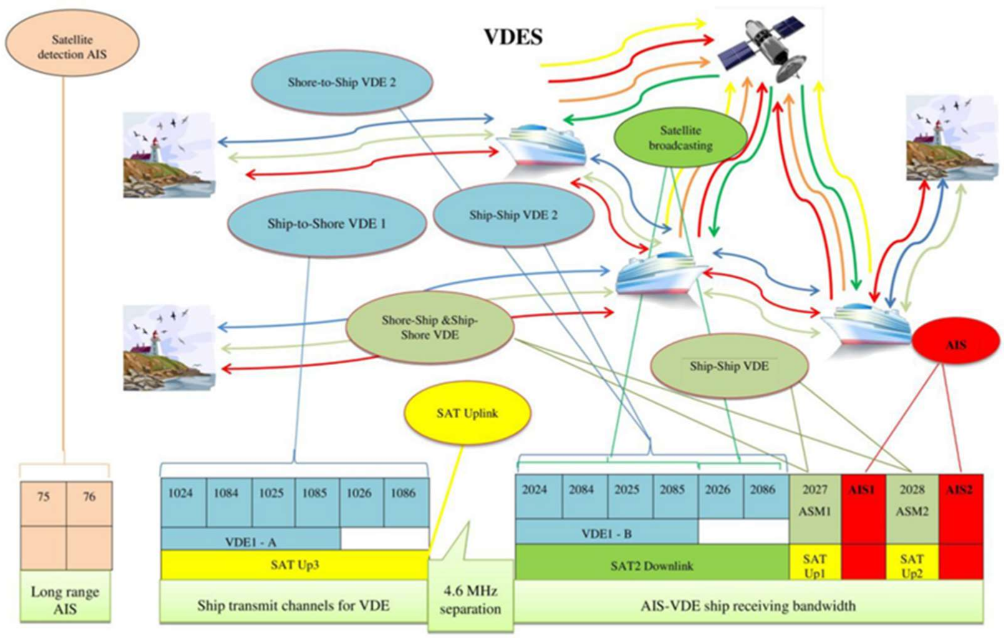

Figure 2.The content of VDES (source from the Internet)

NAVDAT is a new generation of digital maritime safety information broadcasting system, which operates in the 500K Hz frequency band. The NAVDAT system does not conflict with the existing global NAVTEX system, and the time slot allocation is similar to the existing NAVTEX, and it can be coordinated by IMO in a unified way (Lei, Liu, Peng&etc,2018). The data transmission rate is up to 12~18kbit/s per second, which is far higher than the existing 50bit/s of the NAVTEX system (Wang, &Xu,2017). NAVDAT can make about 300 times the transmission rate of the existing NAVTEX system, and the coverage offshore area reaches 400 nautical miles. (ITU,2012) It can transmit a variety of formats such as text, pictures, charts, images and electronic chart update packets at high speed, which can match the increasing data requirements of the coastal security information.

3.2 Data technology

3.2.1Internet of Things

The Internet of Things can real-time monitor any equipment or process that needs to be connected through sensors, radio frequency identification technology (RFID) and other perception layers. It collects all kinds of information, such as sound, light, heat, electricity and mechanics, and then links the equipments and people through network access. It realizes a network of intelligent perception, recognition and management of the equipments. And now Web of Thing is widely used in logistics Industry and it shows great potential in management of data on AtoN because both logistics and AtoN need to be monitored all the time.

3.2.2 Big data and Cloud computing

Combination of cloud computing and big data is the future to analyze and process large data of AtoN to assist managers in the maintenance and management. The application of Cloud computing technology in the AtoN field is the AtoN cloud, and the platform is expected to solve the problem in massive AtoN data generation, the management and maintenance. And it can also process personalized user resources, and it can handle the interaction between the platform and mobile terminal. The sharing of resources through Big Date can help the managers and users to handle the navigation information effectively, and then promote the reasonably using and distributing the data of AtoN. And now Big data and Cloud computing are widely used in data management industries, and the technologies are mature and have advantage in data sharing.

3.2.3 Video monitoring technology

The video monitoring technology system is based on the net and its performance is rely on the date arithmetic. It can perform real-time monitoring to dangerous cargo ships and passenger ships when they enter the key waters. Video monitoring and tracking algorithm will ensure ship picture is always on the monitoring screen and adapt the type of the ship. The factors such as water level, ship position, length, width, height, draught, course and speed are considered comprehensively during the monitoring and tracking. The video lens is installed on the AtoN, and the latitude and longitude and the height of the lens are measured. The height, width and length information of the monitored ship are obtained from the database of the VTS system, and the longitude, latitude, direction and speed of the monitored ship are obtained from the AIS system and the radar system.

3.3 Navaid technology

3.3.1 Positioning, navigation, and time (PNT) technology

The GNSS is the most widely used as PNT technology. At present, the GNSS system is becoming an important infrastructure of the national information construction, providing position, navigation, and time (PNT) service information for a variety of different applications. With the deepening of GNSS application, the shortcomings of GNSS system are gradually emerging. Although the PNT service provided by GNSS has the advantages of all-weather and error- free accumulation, the GNSS satellite is more than ten thousand kilometers away from the ground, and the transmission power is limited to the energy collection of the satellite platform, and the radio signal is very weak when it is transmitted to the ground. Therefore, the GNSS system cannot provide effective PNT services in physical occlusion (such as natural canyons, urban canyons, underwater, etc.), electromagnetic interference (unintentional interference, active interference), high dynamic (fast moving carrier) and so on (Liu,2013). For the vulnerability of the GNSS system, scholars have put forward the PNT implementation capability independent of GNSS system to solve the problem of getting high precision PNT capability without using the satellite. And we can apply the new technology of micro PNT system to the AtoN to ensure that the navigational vessels can provide high precision navigation information when the satellite navigation is not available in the future.

3.3.2 E-Loran

As the Loran-C system is a terrestrial radio navigation system independent of satellite navigation system, it has a strong complementarity with GNSS in working system, working frequency and signal intensity. They cannot be damaged at the same time when they are disturbed. Therefore, the Loran-C system can completely become an enhanced and backup system for satellite navigation. (Boer, Redmond, &Pettigrew, 1989)

Enhancement differential Loran (E-Loran) can simply understand that it has a modern Loran system that provides backup capabilities for the GNSS. It can provide navigation and timing ability far beyond the performance of the traditional Loran-C system, and it can be used as an important backup system of the satellite. The E-Loran system includes modern control centers, launch stations and monitoring stations as well as high-performance receivers, as shown in following figure 3. E-loran emission signal is synchronized to UTC time and completely independent of GNSS.

With the deepening of Loran system research, the E-Loran technology has gradually attracted the attention of scholars. In the enhancement differential Loran, the data transmission channel does not use Loran-C, but the common mobile network (mobile phone 3G/4G). And the update rate of the data correction is raised to 2 seconds. The infrastructure of the E-Loran is not connected to the Loran-C launcher and operates autonomously. The E-Loran's differential station is connected to the servicer through the

Internet. Its working principle is similar to satellite navigation network. (Wang, Yan,&Li, 2009)

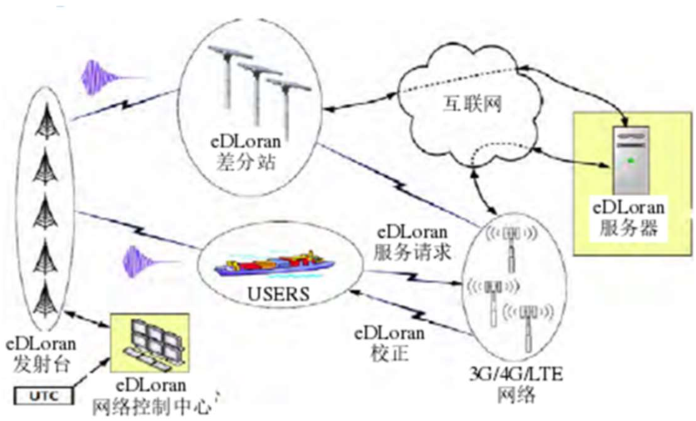

Figure 3. System of enhanced differential-Loran (source from the Shanghai AtoN Department)

3.4 Virtual AtoN

3.4.1 Virtual AIS buoy

In the broad sense, the virtual AtoN refers to the no physical AtoN and only marked on the electronic chart with the aid of the navigation symbol diagram; In the narrow sense, the virtual AtoN is divided into two kinds: One is the virtual buoy with the entity, the AIS platform is installed in the vicinity, contains only AIS transmitter, and only responsible for sending the position information of the buoy to the nearby ships. The signal can be integrated with the display equipment of the AIS and ECDIS on the ship and provides the accurate position of the navigation aids for the ship. The main purpose of such virtual AtoN is to extend the working life of AIS equipment. The other kind is virtual AtoN without entity, which does not exist in reality, but the department sets a virtual diagram on the corresponding position on the electronic chart as a warning. And now I want to take the north passage of Shanghai port as an example to analysis the disadvantages and advantages of virtual AtoN buoy.

3.4.2 Virtual AtoN plan in north passage of Shanghai

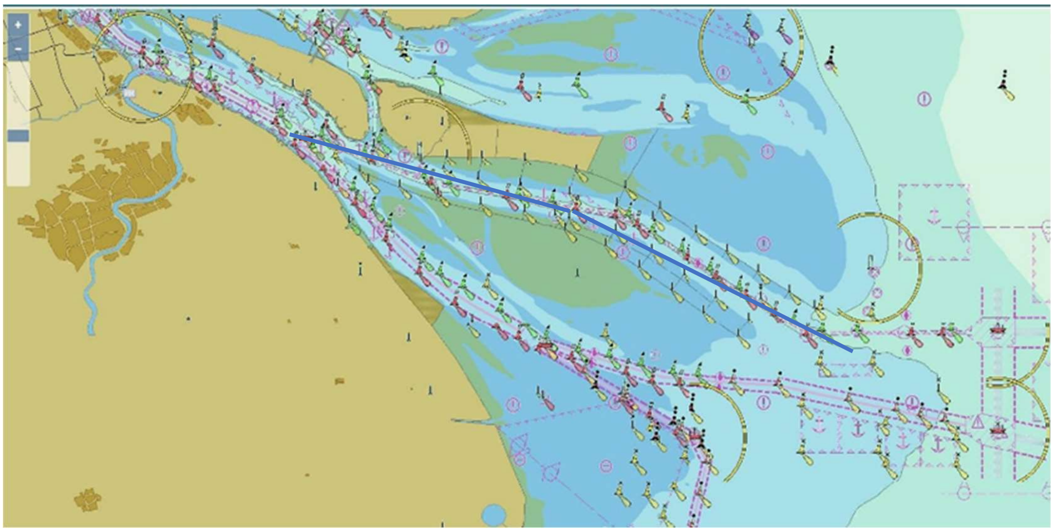

Figure 4. Chart of the north passage (source from e-chart of Shanghai MSA)

In 2017, Shanghai port decided to widen the north passage (figure 4) for the increase of the ships because the edge of the deep passage has a certain draft for shallow draft ships (figure 5). With research of the old AtoN plan (figure 6), there is an issue that the number of the buoys is too large and they take up the space of the passage. And over excess buoys have become obstruction and always confused the crew. For this reason, comes to the new plan (figure 7), which is using the virtual AtoN to replace the deep channel buoys in the middle of the passage. And the detail plan of these virtual aids is shown in the Appendix II.

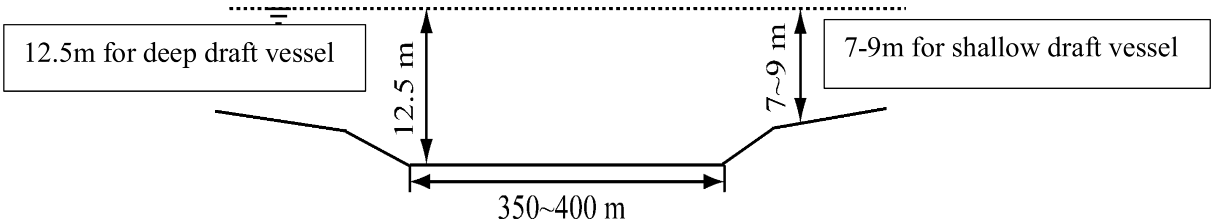

Figure 5. Structure of the north passage (source made by the author)

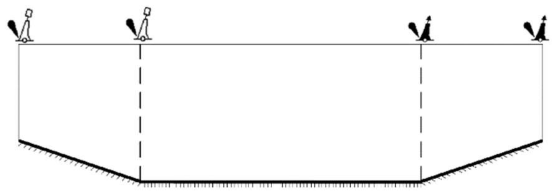

Figure 6. Old buoy setting plan (source made by the author)

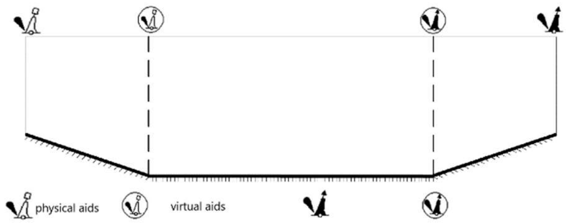

Figure 7. Hybrid buoy setting plan (source made by the author)

And in the new plan, only the side AtoN are reserved and the middle AtoN for deep passage are removed. The deep draft ship can adjust by the virtual AtoN to make sure its route in the deep channel and there will be more space for small draft vessels. In this case, the port will save a lot of money on maintain. From study of the case, the advantages of the virtual AtoN are:

(1) Virtual AtoN greatly reduce the installation and maintenance cost. Setting up physical buoys not only costs manpower and material resources, but also takes time. The research and development of virtual navigation standard does not require these complicated processes, which not only greatly reduces the setting and maintenance cost of the navigation mark, but also reduces the energy loss and environmental pollution.

(2) Virtual AtoN have changed the passive situation of traditional AtoN.

If there are strong winds, big waves or rainy days or if visibility is low and the crew cannot find the beacon lights in time, there will be some potential safety hazards. The installation of virtual AtoN will change this situation and provide a guarantee for the safe navigation in some conditions.

(3) Virtual AtoN overcome some physical weaknesses of aids. The physical aid could drift in some condition. If it exceeds its range, the indication is inaccurate, which may lead to erroneous guidance. Once the virtual aid is put in place, the location is determined, and it is impossible to move. This completely solves the problem of the buoy drafting.

(4) The virtual aids show greater advantages in setting in a short period of time. If there is a wreck accident in a certain sea area, software can set up a virtual aid in this area immediately to prompt the attention of nearby ships.

Despite these advantages, it has its own limitations and risks, for example:

(1) Ships must be equipped with AIS and ECDIS equipments. Virtual AtoN need to be effectively utilized and depend on equipment strongly. Due to working method, the ship must be equipped with an electronic chart and AIS receiving instrument, and not all ships are equipped those instruments at present. This leads to the limitation of the use of virtual navigation.

(2) It is risky to use it. The virtual AtoN use AIS to transmit messages, while AIS must ensure its reliability during its use. If the instrument is damaged or AIS information overload, it may lead danger by using virtual AtoN.

(3) Lack of relevant standards. At present, virtual AtoN has not been made relevant regulations and the define of virtual AtoN is not clearly. This may cause some confusion when the crews choose use or not in some conditions.

(4) The crew's is easy to over-dependence on instruments. At present, the general ship is equipped with AIS and ECS. But only believing the virtual AtoN on the electronic chart will decrease the good seamanship of the crew, and it will cause mistake in some conditions.

3.4.3 Virtual environment simulation technology and electronic fence

The current applications of AtoN based-on the geographic information system (GIS) have some drawbacks,

(1) The 2D chart does not reflect the real environment, the observers must check the chart with experience.
(2) 2D/3D information cannot be integrated.
(3) The current 3D AtoN systems are built by other related system and leak of copyright.

The 3D navigation system is based on the 2D AtoN web and telemetry and telecontrol systems. It integrates databases of chart and AtoN. By establishing a 3D model and using the technology of GIS and virtual simulation, the 3D sea ocean scene and 3D AtoN are generated. Users on the Internet can understand scientific, comprehensive, timely, accurate, vivid and intuitive AtoN information through the 3D simulation. Virtual simulation can also be used in training and combined with current navigation simulation technology to service the users.

The electronic fence is the technology of signal covering. (Zhang, &Chao,2009). It consists of several units delineating an invisible fence. The transmitter installed in the unit launches an intermediate frequency / high frequency early warning signal with its own location information. The receiver receives a warning signal when it comes to the coverage area of signal. And it will help the receiver to realize the danger ahead and make adjustment.

<u>Chapter 4 E-navigation</u>

4.1 introduction

The information of AtoN is no longer simple and passive through the visual and aural identification of the crew on board. And it requires more information and it provides standard service for different users. It is to say that E-navigation is a container of all the technologies of AtoN. In order to better understand the E-navigation framework, this chapter first introduces current E-navigation and its basic framework. And then introduce the MSP and S-100 standard system. After that, it summarizes the development trend and the influence on the AtoN. Finally, it will introduce the Yangshan Demonstration Project as an example.

4.2 Current e-navigation

E-navigation is a high priority strategy led by IMO. It represents the development direction of current navigation technology and covers a wide range. Maritime Safety Committee has passed the implementation framework and schedule of the E-navigation strategy and many potential users are proposed. According to the strategy, the core factors of E-navigation based on user requirements are architecture, human factor, convention and standard, positioning, communication and information system, electronic navigation charts, equipment standards and expansibility of this system. A conference on Navigation, Communication and Search and Rescue (NCSR) held in June 2014 passed the e-navigation strategy implementation scheme submitted by E-navigation communication working group. The scheme identifies 18 specific tasks showed in Appendix I. And the steps and core units are showed in the figure 8.

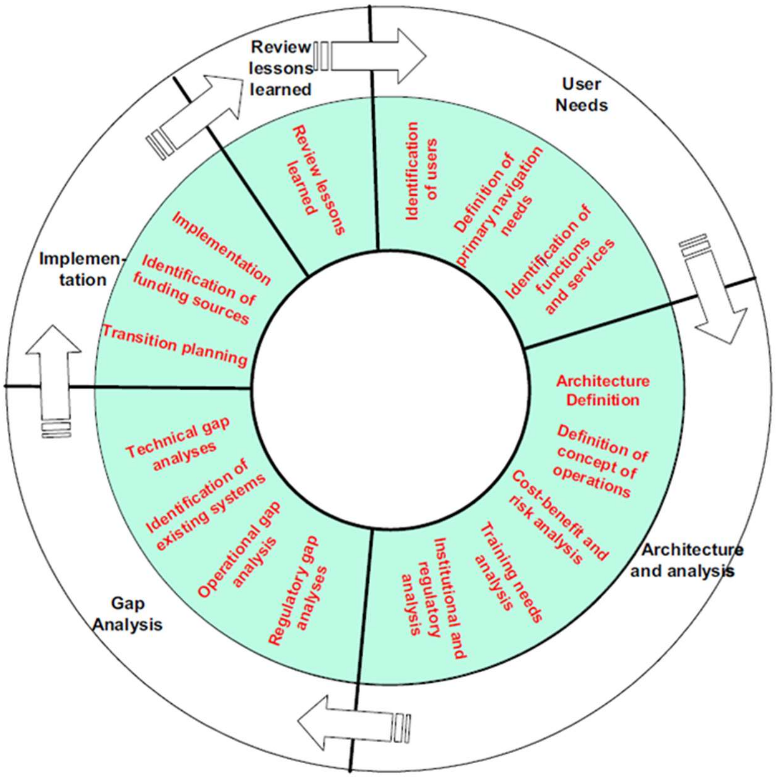

Figure 8. Core unit and implementation steps (serous from the paper of IMO Conference)

4.3 Maritime Service Portfolio

A Maritime Service Portfolio defines and describes the portfolio of operational and technical services and their level of service provided by a stakeholder in a given area, waterway or port, as appropriate (NAV 57/6, 2010). MSP is a standardized, operational, or technical maritime services provided by the shore to seafarers in a given sea, channel, port, or similar area. The figure 9 shows the MSP in the E-navigation system. And at the NAV59 conference held in September 2013, the ship and shore reports were unified and coordinated, and identified 16 services as follows:

1	VTS Information Service （INS）	VTS Authority
2	Navigational Assistance Service （NAS）	VTS Authority
3	Traffic Organisation Service （TOS）	VTS Authority
4	Local port Service （LPS）	Local Port/Harbour Authority
5	Maritime Safety Information （MSI）Service	National Competent Authority
6	Pilotage service	Pilotage Authority/Pilot Organization
7	Tug Service	National Competent Authority； Local Port/Harbour Authority； private tug service company
8	Vessel Shore Reporting	National Competent Authority and appointed service providers
9	Telemedical Assistance Service （TMAS）	National health organization / dedicated health organization
10	Maritime Assistance Service （MAS）	Coastal/Port Authority / Organization
11	Nautical Chart Service	National Hydrographic Authority / Organization
12	Nautical Publications service	National Hydrographic Authority / Organization

13	Ice navigation Service	National Competent Authority Organization
14	Meteorological information service	National Meteorological Authority Public Institutions
15	Real time hydrographic and environmental information service	National Hydrographic and Meteorological Authorities
16	Search and Rescue Service	SAR Authorities

Table 4. Maritime service portfolio (source from IMO Conference)

In 2017, at the first HGDM conference of IMO/IHO, considering the wide range of areas covered by MSP, it was suggested that the existing MSP were grouped into international organizations with different fields. The preliminary grouping is as follows in table 5:

Group	MSP	Domain/lead	Participants
1	MSP1 VTS Information Service (IS) MSP2 Navigational Assistance Service (NAS) MSP3 Traffic Organisation Service (TOS) MSP8 Vessel Shore Reporting	IALA	Member States，NGOs， etc.
2	MSP4 Local Port Service (LPS) MSP10 Maritime Assistance Service (MAS)	IHMA/IMO	
3	MSP5 Maritime Safety Information (MSI) MSP11 Nautical Chart Service Technical MSP12 Nautical Publication Service MSP15 Real-time hydrographic and environmental information service	IHO	
4	MSP6 Pilotage Service	IMPA	

	MSP7 Tug Service		
5	MSP9 Telemedical Assistance Service (TMAS) MS916 Search and Rescue Service	IMO	
6	MSP13 Ice Navigation Service MSP14 Meteorological Information Service	WMO	

Table 5. grouping of the 16 MSPs (source from IMO Conference)

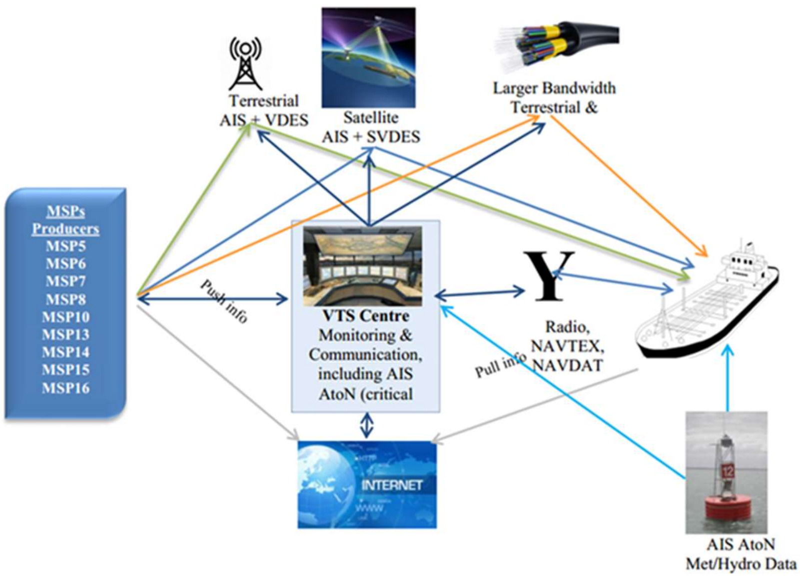

Figure 9. MSP in E-navigation system (source from Shanghai AtoN Department)

4.4 S-100 standard

In 2010, according to the research results of IALA's E-navigation Committee, IMO decided to adopt the S-100 standard as the basic data model at the beginning of 2011 and set up a new technical framework within the SOLAS scope to standardize and implement the acquisition, integration, processing and service of data in the E-navigation, so the S-100 standard will be more extensive in the field of maritime transport. As the basic data model of E-navigation, the main function of S-100 is embodied in the following three aspects:

(1) Defining the production standards of various kinds of data, regulating various multiple navigation data, in order to improve the service function of E-navigation information query.

(2) Providing navigation information registration platform to ensure the consistency of metadata, elements and library rules used by electronic navigation data producers.

(3) Providing general public data structure for E-navigation and improve the standardization of data exchange.

And the purposes of S-100 are:

(1) Building connection with the ISO standards;
(2) Making encoding standards to separate the format and the content;
(3) Offing digitization data, product and service for hydrographic;
(4) Making a registration mechanism according with ISO;
(5) Offering independent system for different users.

4.5 The development trend of E-navigation and what is required

At the beginning of the development of E-navigation has determined the purpose driven by the user's demand. In combination with the process of development and the latest working progress of IMO and IALA, the standardized maritime service is the next key direction of E-navigation. To carry out the standard AtoN service, the management department of the AtoN needs to update their hardware and software to provide more efficient and effective navigation and communication service for different users (including ships, port departments, pilot centers, management departments, etc.) to according with the E-navigation framework.

For Ships, seafarers and pilots, E-navigation is required to provide navigation services to fulfil the responsibilities of the IMO SOLAS convention. For the port sector, it is required to provide mooring services assisting port scheduling, traffic organization and other businesses. For the chart publishing and surveying department, it is required to provide standardized navigation data assisting electronic chart data production and data updating for improving the efficiency of charting, and the efficient marine publications.

4.6 E-Yangshan port demonstration project

Name: e-Yangshan Port[14] Location: East China Sea, Shanghai region, China Time: January 2014 - June 2016 State: ongoing Contact: Roadman9999@126.com. Testbed website: www.e-nic.cn Initial organization: China Maritime Safety Administration and Jimei University. Initial funding:20 million yuan

Table 6. E-Yangshan project (source from web of Yangshan Port)

Since IMO has fully promoted the e-navigation strategy, the Shanghai MSA has actively invested in the research and practice e-navigation strategy. From the support of the construction of the Shanghai international shipping center and the free trade test area, from the beginning of 2014, the Yangshan harbour area fog support system has been upgraded

[14] Details of the project can find in the web set of IALA

to an E-navigation project in Yangshan port area (table 6), as one of the world's 9 International e-navigational international test projects. At present, Yangshan port area is actively carrying out the second stage e-navigation project, which mainly covers the following 4 aspects.

(1) Improving the positioning accuracy in the Yangshan port area and its nearby areas, 4 new continuous operating satellite positioning service reference stations (CORS) are being built, and the existing AIS system is revamping, and the dual mode upgrading of the RBN-DGPS station of the radio direction mark differential global positioning system (RBN-DGPS) station of the Yangshan port area has been completed.

(2) Upgrading the ship navigation facilities to optimize physical and virtual AtoN distribution in port, complete the high-resolution data measurement and drawing of the passage and harbor, ensure the high precision positioning requirements under the poor visibility and developing intelligent navigator instrument for all the users.

(3) Improving the information transmission by developing 3G/4G/WIFI public network platform and other communication forms; transforming the existing VHF communication equipment; building digital marine safety information broadcasting system. And using directional voice broadcasting system to send safety massage to small ships and provide ships with a variety of information transmission channels.

(4) Strengthening the information of AtoN in the key positions of the navigation area, such as the warning zone, build hydrometeorology and visibility monitoring sensors to integrate the existing monitoring system and improve the broadcast of meteorological and hydrological information.

The investment of second phase of Yangshan project has reached nearly 30 million CNY, which has basically completed the upgrading of the infrastructure level and the collection basic data level. The positioning, navigation and communication ability of shore-based equipment has been greatly improved through the technical transformation and optimization of the existing tools.

Chapter 5 Goals, Paths, Feasibility and Suggestions of these technologies for AtoN

5.1 AtoN net-work

5.1.1 4G

The goal of net-work system is to have high transmission bandwidth, wide network spectrum, low information reception delay, low data blocking rate and high communication quality. And it can carry out high-definition image transmission at any address broadband Internet access, including satellite communications, comprehensive function of providing information communication timing, data acquisition, remote control etc.

It is proposed to replace and update the wireless infrastructure of the current maritime intelligent transmission system based on 3G mobile communications, and fully deploy the 4G mobile communications network. Upgrade infrastructures in the AtoN and speed up the implementation. 4G has popularized in most place in China, and transfer this technology is not very hard, but people should consider that the 4G single at sea is not as good as that on land and the investment of infrastructure will be a big cost for mobile network operator. So update these in the current 4G coverage is a good step.

5.1.2 Full NetCom

It is possible to realize the compatibility of different communication models. At present, the price of a full Netcom communication module is often several times expensive than that of an ordinary communication module, which greatly increases the cost of a beacon.

Secondly, there are still some problems on the technical level: the lamp main board circuit, the booster antenna, and the communication protocol. The hardware and software of the navigation beacon and related programs must be redesigned based on the new communication module. (Jiang, Chen, &Cui, 2017) Therefore, it needs further research and more investment on these issues in the future. Full Netcom technology is widely used in smart phones, and introducing this technology to AtoN will reduce the dependence on a single net-work operator.

5.2 AtoN data and video monitoring

5.2.1 Internet technology

Using Internet technology to maintain the data, improve the monitoring and develop maritime service is the future management of AtoN. By using of the Web of Thing, the information of the ship can be collected by the AtoN. and the information can go back to assist the ship in navigation and help the shore to make management. Big Data can solve the problem of data integration and exchange, improve work efficiency and service level. And it also provides broad application prospects for navigation aids departments. The buoy cloud computing platform can solve the problem of independent and interoperability of all kinds of data. But the premise of these technologies is the need of a big enough related database and a certain computer network. It will take a lot of time and money to collect the data and build such a network. Thus, I suggest:

(1) Using Cellular narrowband Internet of Things[15] instead of the traditional GSM network for the AtoN out of coverage. (Beyene, Jantti, etc, &Iraji, 2017)

(2) Using Zigbee[16] wireless network technology for realize ad hoc network and

[15] Details see https://en.wikipedia.org/wiki/Narrowband_IoT

[16] Details see http://www.zigbee.org/

placing the sensor nodes and the wireless sensor network on the ship to collect and transmit the traffic information of the ship. (Chen,2002)

(3) Embedding that sensors in the buoys and combine the Internet of Things with the Internet.
(4) Setting up a large Big Data platform by Hadoop[17] platform. (Shang, 2017)
(5) Building the sub and general database of navigation aids data.
(6) Combing Cloud Computing with big data and Web of Thing to deal with the problem of data in the existing information system

5.2.2 CCTV technology

Direct supervision with video recording is a means of information collection and it can complete real-time monitoring of specific areas and periods. But the requirements of different regulatory departments on CCTV are different, and the performance parameters, monitoring points and system structure of each device are not uniform. As a result, all kinds of inconveniences in the operation, monitoring and maintenance have resulted limits in the promotion of CCTV system. It is suggested to set a unified structure and standard CCTV system for all the departments. And this system should include port navigation environment, law enforcement and internal security monitoring. But cost-benefit will be considered during the implementation.

5.3 AtoN Communication

5.3.1 AIS telegraph

The purpose of application of AIS telegraph technology is to make an AIS sending drafting or error message to the ship nearby for warning. And the implementation path is to install the transceiver in the AIS transponder to transmit message. AIS telegraph standard could

[17] Details see http://hadoop.apache.org/

be made into AIS transponder for future AtoN value-add services. And the authority should consider using the satellite AIS as a method to track the AtoN, because the satellite AIS can cover more areas and it has little limits and quality service but over occupying the satellite communication band may be a problem.

5.3.2 VDES and NAVDAT

The goal of VDES technology mainly divides the communication frequency into multiple frequency bands, ensures the parallel transmission of communication, and disseminates the data to at different priority levels through different communication networks. But VDES is a new concept and VDES was put forward by IALA in 2013, so the establishment of VDES standard is the main technical path for the future implement. And it could not be used in the AtoN in a short-time.

According to the characteristics of radio transmission, the antenna length should match its wavelength, and the effect will be the best. 500 KHz NAVDAT by using the wave band should match the wavelength of 600 meters. And if it is no attenuate-stable communication, it usually uses half wavelength antenna, which requires the ideal antenna length 300 meters. But for offshore AtoN, it is almost impossible to have long antennas and transmit power. (Wang, &Xu, 2017)

5.4 AtoN Navigation

5.4.1 Beidou system

Beidou satellite navigation system can realize telemetry and remote control for AtoN far away from land because it has not only function of positioning but sending message. In order to realize the application of Beidou satellite communication technology on the existing navigation technology, it recommends that put the Remote Terminal Unit(RTU) in current AtoN (Fang, 2012). RTU is mainly composed of central control module, measuring module, communication positioning module, storage module and other functional units, and it connected with beacons through signal lines. RTU can collect and monitor the operational and location parameters of AtoN in real-time. RTU uses the GPS/ Beidou dual mode communication positioning module, which can receive Beidou and GPS signals simultaneously. The position service is based on the Beidou, and it is also compatible with the GPS. It can provide more accurate, reliable and stable information of the AtoN in the harsh working environment. (Xu, Hao, &Su, 2015). But from the investigate of the people on the operation vessel, the Beidou unite has a higher power consume than GPS and it has a higher energy requirement.

5.4.2 PTN

The goal of independent PTN on AtoN is to solve the problem of getting high precision PNT capability under the condition of unable to use the satellite navigation service. And the path of this independent technology need independent micro PNT system on the AtoN to develop a high stability and high precision chip, gyroscope, atomic clock, and integrated timing and inertial measurement unit (Peng, Zhai, &etc, 2013). And the research work of this independent micro PTN unit is difficult, long cycle, and high cost. Thus, it is difficult to implement independent PNT structure on AtoN because the cost-benefit and this difficulty leads to limit the popularization of this PNT technology.

5.4.3 E-Loran

The goal of E-Loran is becoming shore-based radio system independent of satellite navigation as a supplement. And the advantage of E-Loran is that it can work when the GNSS fails. Because the E-loran system and Beidou system are complementary in the signal frequency, signal intensity and working system, it can be constructed and transformed into an ideal land-based enhancement system for the Beidou system. However, we need to use the AtoN as the launching pad, and users should install the E-loran module in facilities. In this case, E-loran shows its development potential on AtoN. Infrastructure investment of E-loran would be a problem that the authority should consider.

5.5 Virtual AtoN

Virtual navigation is a proven technique but the efficiency strongly depends on equipment. Due to the crew need to see it on the screen, the ship must be equipped with electronic chart and AIS receiver, and now not all ships are equipped with electronic chart and it leads to the limitation of virtual AtoN. Therefore, to implement widely using virtual AtoN technology, the rules and standards of relevant equipment should be clearly defined. And authority should make a constraint to the ships to equip relevant equipments.

At present, 3D navigation information cannot be integrated together with the user habits and true environment effectively because of the lack of update mechanism of 3D navigation aids information. The current 3D navigation arrangement system mostly stays in the demonstration phase and there are many problems in the maintenance and upgrading. Therefore, it is difficult to guarantee the effectiveness of this system and related navigation facilities. The difficulty of realization has hindered the popularization of virtual simulation technology on AtoN. And virtual simulation still not shows its cost-benefit ability.

On the other side, electronic fence which is designed for prevent ships from entering through a number of buoys siege a warning area shows good potential. At present, this technology can be seen on sharing bicycle on land (Liu, &Chen,2018) and shows great advantage. Thus, the authority can carry out experiment and investigation of this technology at sea and introduce to AtoN as an additional function.

5.6 Implementation E-navigation in China

E- navigation now is still a concept for most of the ports. People want to use advanced information technology through the E-navigation platform to improve the navigation capability and the service level and achieve the ship and shore maritime information collection, integration, coordination, exchange and analysis. In this case, the E-navigation needs the support of AtoN information technology. And future AtoN direction is providing high quality and diversified service to E-navigation.

The choice of the implementation path needs to consider the current situation of AtoN in China. At present, Navigation Safety Department of China East Sea Xiamen office[18], has developed a remote control and remote-control system for AtoN, and it has built a platform to issue AtoN data on website. Yangshan Port Project platform has to pay attention to the IALA is developing S-201 product specifications. But domestically, it is still a difference between the IALA standard and China domestic standard. There are two main reasons of the difference: One is basic standard, the domestic management institutions lack of relevant data and technical standards; Another is the standard implementation, the institutions lack of related services at the current ship terminal. Therefore, it is necessary to build a unite application environment accordance with IALA, for example, establish a whole China navigation demonstration project, which can cover all systems in ships and ports, including communications, navigation and other services. In view of the above situation, it is suggested as follows:

(1) Tracking and promoting the development of relevant international and national standards and guidelines.

[18] Xia Men office is the part of AtoN department in East China Sea belongs to China MSA

(2) Expand the application functions of AtoN to enhance the quality and diversity of future AtoN by using new technologies in communication, navigation, energy, materials and other fields.

(3) Establishing a unified service platform to achieve standardization and harmonization of the AtoN.

Therefore, China should provide safe and reliable maritime services following relevant international standards, recommendations and guidelines, and China should cooperate with international organizations, governments and other groups to actively participate in the conference held by the IMO and IALA working groups, and make relevant suggestions, guidelines and other technical texts. China's AtoN management department should actively carry out relevant technical research and finance the experiments of new technologies. It is suggested that the relevant department should communicate with the users in order to understand their real requirements. Although China have established a number of E-navigation demonstration projects, Chinese E-navigation policy and strategy is still not clear and domestic research on E-navigation is not unified planning.

Chapter 6 Conclusion and its limits and risks.

6.1 Conclusion

Today the communication and navigation technologies progress are chance and challenge to AtoN. One hand, they could enhance the related ability of AtoN; the other hand, they bring changes or even revolution to this industry. People need to do technology transformation and make technology optimize for AtoN. But most of the time, the difficulty does not come from technology but from the path it implements. Cost-benefit sometimes dominates these implementations.

Sum up, Net-work technology will simplify and enhance the communication ability of AtoN, 4G and full Netcom will unify and update the current standard of AtoN data transmission. And the Internet technology such as Big Date, Cloud Computing and Web of thing will greatly enhance the ability of AtoN data collection, analysis, management and sharing. Beidou and E-loran technologies are necessary supplement to AtoN on navigation and communication ability. AIS telegraph and electronic fence can add new functions to current AtoN and they are worth tests. CCTV, NAVDAT, micro PTN and VDES have some limits or obstacle when implement on current AtoN but they will work on the other maritime services to support the AtoN.

The practice of these technologies is the path to implement E-navigation for the authority, and process of practice will great benefit the current AtoN system at the same time. In this case, it is necessary to develop the technologies on AtoN together with E-navigation project. As a future integration maritime service system, E-navigation project in China should consider related technology carft, the implementation of MSP and S-100 data standards. And there are a lot of work China should do to carry forward its E-navigation system.

6.2 Limits

The obvious limit is the energy and material. With the increase of additional functions on the AtoN, the consume of the power will increase. Thus, there will be a challenge to the current energy support on AtoN. And new equipment needs new material, and there will be also a requirement of material. If research of energy and material does not follow, the implementation of these technologies will be impeded.

New technologies bring new requirement of the operation and maintain. The installing and debugging of AtoN will change. And the current AtoN operation and maintain mechanism cannot adapt these changes. For example, the new equipment has installation requirement for the operate vessel and technician. And current installation accuracy[19] does not adapted for implement some of the functions. And all these limits will delay the implementation of new technologies.

6.3 Risks

With the implement of new technologies, the rate of the electronic elements in a single beacon will increase for additional functions. But more rate of electronic elements will cause the decrease of reliability of its basic function, which is the light. And overuse the electronic elements will cause the heavy dependence on the electronic chips, especially these chips are from one or two companies. Thus, it will cause technology monopoly.

The number of the virtual AtoN is dramatic increasing in recent years in some ports in China. There is still not an exactly standard about the rate of virtual AtoN to physical AtoN in a passage. And this will cause a potential risk for ships although there is not a report about this kind of case.

In the shipping industry today, the modern technology and traditional navigation technic are highly syncretic, and the new technology is for service the crews, sometime there is a condition that the new technology is hard to introduce to the crew because the research personnel does not know shipping. And the conflict between crews and research personnel will cause certain indeterminacy when implement these technologies. And it is risk to make the technology orientation thinking leading the design because the shipping is always an experience orientation industry for thousands of years. And technology without experience is activism. And these risks should be considered when implementation of these technologies.

[19] In Shanghai the accuracy of buoy is 15-30M

Appendix I Task of E-navigation by IMO

Task No	task	Expected deliverable	Transition Arrangements	Prioritized Implementation schedule
T1	Development of Draft guidelines on Human Centred Design(HCD)for e-navigation systems.	Guidelines on Human Centred design(HCD) for e-navigation systems.	None	2014/2015
T2	Development of draft guidelines on Usability	Guidelines on Usability testing.	None	2014/2015

	Testing. Evaluation and Assessment(UTEA) of e-navigation systems	evaluation and assessment(UTEA) of e-navigation systems.		
T3	Develop the concept of electronic equipment manuals and harmonize the layout to provide mariner with an easy way of familiarization for relevant equipment.	Guidelines on electronic equipment manuals.	Provide existing manuals as pdf	2019
T4	Formulate the concept of standardized modes of operation， and including store and recall for various situations.as well as S mode functionality on relevant equipment.	Guidelines on S mode.	None	2017
T5	Investigate whether and extension of existing Bridge Alert management Performance Standards(PS) is necessary adapt all other alert relevant PSs to the to Bridge Alert management PS.	(a) Guidelines on implementation of Bridge Alert Management. (b) Revised Performance Standards on BAM.	None None	2016 2019
T6	Develop a methodology of how accuracy and reliability of navigation equipment may be displayed. This includes a harmonized display system.	Guidelines on display of accuracy and reliability of navigation equipment.	None	2017
T7	Investigate if an INS as defined by resolution	(a) Report on the suitability of	None	2016

	MSC.252(83) is the right integrator and display of navigation information for e-navigation and identify the modifications it will need， including a communications port and a PNT module. If necessary， prepare a draft revised performance standard. Refer to resolution MSC.191(79) and SN/Circ.243	INS. (b) New or additional modules for the performance Standards for INS.	None	2019
T8	Member States to agree on standardized format guideline for ship reporting so as to enable “single window” worldwide (SOLAS regulation V/28 resolution A.851(20) and SN.1/Circ.289)	Updated Guidelines on single widow reporting.	National/Regional Arrangements	2019
T9	Investigate the best way to automate the collection of internal ship data for reporting including static and dynamic information.	Technical Report on the automated collection of internal ship data for reporting.	None	2016
T10	Investigate the general requirements resolution A.694(17) and IEC 60945 to see how Built IN Integrity Testing (BIIT) can be incorporated.	(a) Revised Resolution on the general requirements including Built in Integrity Testing. (b) Revised IEC Standard on General	None None	2017 2019

		requirements including Build.		
T11	Development of Draft Guidelines for Software Quality Assurance (SQA) in e-navigation. This task should include a investigation into the type approval process to ensure that software lifetime assurance (software updates) can be carried out without major re approval and consequential additional costs. Refer to SN/CirC 266/Rev.1 and MSC.1/Cire， 1389.	Guidelines for Software Quality Assurance (SQA) in e-navigation.	None	2014/2015
T12	Development Guidelines on how to improve reliability and re-silence of onboard PNT systems by integration with external systems. Liaise with Admissions to ensure that relevant shore-based systems will be available.	Guidelines on how to improve reliability and re-silence of onboard PNT systems by integration with external systems.	None	2016
T13	Develop guidelines showing how navigation information received by communication equipment can be displayed in a harmonized way and what equipment functionality is necessary.	Guidelines on the harmonized display of navigation information received from communications equipment.	None	2019
T14	Develop a common	(a) guidelines on	None	2017

	Maritime Data Structure and include parameters for priority source. and ownership of information based on the IHO S-100 data model. Harmonization will be required for both use on shore and use on the ship and the two must be coordinated(Two Domains). Develop further the standardized interfaces for data exchange used on board(IEC 61163 series)to support transfer of information from communication equipment to navigational systems(INS) including appropriatefirewalls(IEC 61162-450 and 400).	a Common Maritime Data Structure. (b) Further develop the IEC standards for data exchange used onboard including Firewalls.	Use latest IEC standards	2019
T15	Identify and draft guidelines on seamless integration of all currently available communications infrastructure and how they can be used(e. g. range， bandwidth etc.) and could be used for e-navigation. The task should look at short range systems such as VHF，4G and 5G as well as HF and satellite systems taking into account the 6 areas	Guidelines on seamless integration of all currently available communications infrastructure and what future systems are being developed along with the revised GMDSS.	Use existing onboard communications infrastructure.	2019

	defined for the MSPs.			
T16	Investigate how the Harmonization of conventions and regulations for navigation and communication equipment would be best carried out. Consideration should be given to an all-encompassing e-navigation performance standard containing all the changes necessary rather than revising over 30 existing performances standards	Report on the Harmonization of conventions and regulations for navigation and communication equipment would be best carried out.	None	2017
T17	Further develop the MSPs to refine services and responsibilities ahead of implementing transition arrangements.	Resolutions on Maritime Service portfolios	National/Regional Arrangements	2019
T18	Development of Draft Guidelines for the Harmonization of test beds reporting.	Guidelines for the Harmonization of test beds reporting.	None	2014/2015

Appendix II Table of virtual AtoN Plan in North passage of Shanghai

D3	994136454	31°06′16.9″N 、 122°29′37.6″E
D4	994136509	31°06′03.8″N 、 122°29′06.3″E
D5	999413296	31°06′16.3″N 122°27′08.0″E
D6	994136457	31°06′03.2″N 、 122°26′33.0″E
D7	999413299	31°06′15.6″N 122°24′35.5″E
D8	994136458	31°06′02.5″N 、 122°24′00.6″E
D9	994136459	31°06′14.9″N 、 122°22′01.5″E
D10	994136367	31°06′01.7″N 122°21′27.8″E
10	994136503	31°05′58.3″N 、 122°20′54.4″E
D11	994136460	31°06′14.0″N 、 122°19′15.8″E
D12	994136461	31°06′00.8″N 、 122°18′21.8″E
D13	994136462	31°06′38.0″N 、 122°17′42.2″E
D14	994136463	31°07′14.4″N 、 122°16′17.4″E
D15	994136464	31°07′41.1″N 、 122°15′55.6″E
D16	994136467	31°08′28.0″N 、 122°14′13.0″E
D17	994136468	31°08′54.7″N 、 122°13′51.2″E
D18	994136469	31°09′41.9″N 、 122°12′08.8″E

D19	994136471	31°10′09.1″N 、 122°11′47.5″E
D20	994136472	31°10′57.8″N 、 122°10′06.3″E
D21	994136473	31°11′25.0″N 、 122°09′45.0″E
D22	994136474	31°12′13.6″N 、 122°08′03.7″E
D23	994136475	31°12′40.8″N 、 122°07′42.4″E
D24	994136476	31°13′18.1″N 、 122°06′19.6″E
D25	994136477	31°13′54.8″N 、 122°05′42.7″E
D26	994136479	31°13′52.7″N 、 122°04′45.8″E
D27	994136480	31°14′21.5″N 、 122°03′02.3″E
D28	994136481	31°14′17.8″N 、 122°02′15.2″E
D29	994136486	31°14′46.0″N 、 122°00′34.6″E
D30	994136489	31°14′42.3″N 、 121°59′47.5″E
D31	994136490	31°15′10.5″N 、 121°58′06.9″E
D32	994136491	31°15′06.7″N 、 121°57′19.9″E
D33	994136492	31°15′34.9″N 、 121°55′39.2″E
D34	994136493	31°15′31.1″N 、 121°54′52.2″E
D35	994136494	31°15′59.3″N 、 121°53′11.6″E
D36	994136495	31°16′02.7″N 、 121°51′40.6″E
D37	994136496	31°16′17.5″N 、

		121°51′33.9″E
D38	994136497	31°16′38.1″N 、 121°50′04.3″E
D39	994136498	31°17′00.3″N 、 121°49′37.5″E
D40	994136499	31°17′29.2″N 、 121°47′45.2″E
D41	994136500	31°17′51.6″N 、 121°47′17.8″E
D42	994136501	31°18′27.6″N 、 121°45′05.9″E
D43	994136368	31°18′42.6″N 、 121°44′58.5″E
D45	994136478	31°19′15.4″N 、 121°43′29.1″E
D46	999413201	31°19′08.7″N 、 121°43′13.7″E

Reference and bibliography

Amato, f., Fiorini, m., Gallone, s., & Golino, g. (2011). E-navigation and future trend in Navigation. TransNav, *the International Journal on Marine Navigation and Safety of Sea Transportation*, 5(1).11-14.

Beyene, Y. D., Jantti, R., Ruttik, K., & Iraji, S. (2017). On the Performance of Narrow-Band Internet of Things (NB-IoT). *Wireless Communications and NETWORKING Conference (pp.1-6)*. IEEE.

Boer, a. h., Redmond, g., & Pettigrew, t. j. (1989). Loran-c: A navigation aid for aerial surveys. *Journal of Wildlife Management,* 53(1), 228.

Cao cao. (2016). The new power of the middle end explains the helio p10 processor of mediatek. *Computer enthusiasts (8)*, 108-109.

Chen Shujuan. (2004). Introduction to Zigbee technology and its application in wireless sensor networks. *Proceedings of the 2004 academic conference of the communication navigation committee of the Chinese nautical society.*

Cooper, r. b., & Bertsche, w. r. (1981). An at-sea experiment for the comparative evaluation of radar piloting techniques. Navigation radar.

DE Halpert, j., & Basker, s. Economics, shipping and Aids to navigation. Trinity House, *United Kingdom, General Lighthouse Authorities of the United Kingdom and Ireland.* Development of the IMO e-navigation concept -- common maritime data structure. In International Conference on Transport Systems Telematics(pp.151-163).

Ding Feng. (2012). Satellite ais detection technology and application. *Tianjin navigation (3)*, 36-38.

Era method & sun xiyan. (2008). Positioning accuracy analysis of China regional positioning system. Chinese science :(12), 1812-1817.

Fang Jie. (2012) Design of intelligent navigation mark remote telemetry system based on GPS and beidou satellite. *China water transport (second half of the month)*, 12(9), 48-49.

Hu Guangyu. (2017). Research on modulation and access algorithm based on VDES system. (dissertation, Beijing university of posts and telecommunications).

IMO.Development of an e-navigation Strategy Implementation Plan [R]. Norway, 2014:6-7.
Jiang yue, Chen guangtong, & Cui yongfa. (2017). Prospect and discussion of all netcom navigation beacon. *China water transport monthly*, 17(7), 139-140.

Jiao Xuewen. (2017). 2016 Shanghai port freight review. *Transportation and transportation*, 33(4), 41-42.

Lei bo, liu wen, peng hanguo, zhang kuo, Yang wei, & dong xiaofeng. (2018). Application of Navdat system in ship navigation support. Communication technology (2).

Li Wen. (1996). Discussion on the development policy of visual Aids to navigation in the 21st century. *China navigation (1)*, 23-26.

Liu chunbao. (2013). PNT service under Gps limitation. *Satellite application (4)*, 44-49.
Liu hu, & Chen wei. (2018). Electronic fence system for sharing bicycle based on intelligent terminal. *Electronic technology and software engineering (6).*

Liu lin(2017). Design and implementation of massive AIS data mining system based on cloud computing distributed technology. (Doctoral dissertation, dalian maritime university).

Liu Lin. (2008). *Research on the transcoding of mpeg-2 / mpeg-4 to h. 264. Dissertation.*
Liu yanhai. (2003). Development prospects of VTS. *Congress of the Sub Committee on AtoN of the Chinese navigational committee*.

Lu Minmin. (2017). The pilotage of Shanghai harbor exceeded 70,000 vessels annually. *China water transport (1)*, 79-79.

Ni zhongjiang, Wu hui, & zhao shufang. (2014). A brief analysis of the fourth-generation mobile communication technology. *Consumer electronics (4)*, 132-132.
Park, i. h., Lee, s. j., & Hwang, s. w. (2010). Design and Test of Communication Networks for Aids to Navigation based on AIS. Journal of Navigation and Port Research, 34(5), 337-342.

Peng Zhengqin, Zhai hao, Lu fang, Wang shiwei, Zhang jun, Liang yaoting...Cui jingzhong. (2013). Design and implementation of rubidium atomic clock frequency correction scheme based on multi-reference sources. *Aerospace measurement technology,* 33(4), 54-57. PE

Powell, c. (1985). Early history of the Decca Navigator system. *Journal of the Institution* *of Electronic and Radio Engineers,* 55(6), 203-209.

Recommendation itu-r m. 2010(03/2012) Characteristics of a digital system,Named Navigational Data for broadcasting had maritime safety and security related information from shore - to - ship in the 500 KHz band.

Ren kai, Yang li, & Huang jian. (2008). Glonass single point positioning and precision analysis. *Survey and mapping bulletin* (11), 4-6.

Ren Qinqin, & Rosa. (2011). China establishes global navigation system by 2020. *Navigation technology (3), 76-76*.

Saint Germain en Laye, f. (2003). IALA Recommendation a-124 On Automatic Identification sys-tem (AIS) Shore Station and Networking Aspect correlation to.

Song Jingfan. (2015). *Research and test of the performance of spaceborne AIS system*. (Doctoral dissertation, Beijing university of posts and telecommunications).

Stateczny, a. (2004). AIS and radar data fusion in maritime navigation. Zeszyty Naukowe/Akademia Morska w Szczecinie, 329-336.

Tang Nana, Zheng Xifeng, Wu Jinzhong, Chen hao, & Li hongxia. (2018). Design of off-line led control system based on 4g-lte. *LCD and display* (1), 55-60.

Wang Jie, Yan jianhua, & Li chuanzhang. (2009). International eloran development status and technological analysis of China's loran c modernization. *Marine mapping,* 29(3), 79-82.

Wang Tao sheng, Zhou yuxia, & Quan haofang. (2012). Feasibility analysis of beidou's inclusion in the imo global radio navigation system. *China satellite navigation academic annual conference electronic*

Wang Weishi. (2001). Applied research on AIS technical AtoN. *China harbor construction* (2), 42-44.

Wang Xiang, & Xu zhaorong. (2017). Research on navdat technology. *Navigation (1)*, 38-40.

Wang Yi. (2010). The impact of iala-net construction on China's shipping development. *China maritime (7*), 70-70.

Wen Lizhi. (2011). *Research on China mobile WLAN business construction and operation*. (dissertation, Beijing university of posts and telecommunications).

Xu Gaofa, & Tang qingyou. (2010). Reflections on the improvement of visual AtoN. *Jiangsu, zhejiang, fujian and Shanghai navigation academic seminar and 2010 jiangsu Hong Kong and Shanghai navigation BBS.*

Xu bohao, hao yongsheng, & su weipeng. (2015). Rtu remote monitoring system based on beidou communication. *Application of computer system, 24(5), 84-87.*

Xu Youfang. (1994). New progress in Marine safety communication systems (continued). *Boat (4)*, 19-20.

Yu hua, zhang xinggu, & wei wucai. (2010). Research on remote sensing and remote control of Ais beacon. *Navigation technology (5)*, 41-44.

Zhang jianguo, & Cao yinjie. (2009). Design and research of intelligent electronic fence system. *Science and technology information* (35), 21-21.

Zhang Lishan. (2007). A brief discussion on the protection of historical lighthouses. *2007 joint annual meeting of coastal and inland river navigation marks group, shipping marks professional committee of China AtoN.*

Zhao Shuang. (2013). Development of satellite navigation satellite-based enhancement systems abroad. *Satellite applications* (5), 58-61.

Zheng jiachun. (2008). Research on electronic navigation system based on wireless sensor network. *China navigation, 31(3)*, 214-217.

Zheng Kan. (2007). Interference coordination technology for broadband ofdm systems. *Modern telecommunications technology (6)*, 13-17.

Zhu Shaowei. (1983). The earliest lighthouse in Shanghai. *Navigation (3)*, 25.