WORLD MARITIME UNIVERSITY

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A Critical Review of Existing Chinese Maritime Surveillance Capability:

Research on Developing an Unmanned Aerial Vehicle (UAV) Maritime Surveillance System for China MSA

By

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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 Research Paper: **A Critical Review of Existing Chinese Maritime Surveillance Capability: Research on Developing an Unmanned Aerial Vehicle (UAV) Maritime Surveillance System for China MSA**

Degree: **MSc**

The maritime surveillance has become increasingly important in recent decades, due to the dramatic expand of various activities in maritime sector globally. As an important player in the global markets, China has set up a comprehensive maritime surveillance system accordingly. However, few studies have been conducted, by neither scholars nor the Chinese maritime authority, to assess and evaluate the current maritime surveillance system. To fill this research gap, this paper presented a critical review on the system and reached to a conclusion that the system needs enhancement and adjustment, as a result of the inherent problems and projected challenges. In order to solve the discovered problems and deal with the challenges ahead, relevant researches have been carried out for finding available solutions to enhance and improve the Chinese maritime surveillance system. The result of the researches indicate that maritime UAV system, which is detailed and studied in the subsequent sections, is considerably suitable for solving some underlying problems of the Chinese maritime surveillance system, and thus are recommended for the decision maker(s) of the China MSA, after a general feasibility analysis. At last, limitations and implications of the research paper are provided for future studies.

KEY WORDS: Maritime Monitor Technique, Maritime Surveillance System, Unmanned Aerial Vehicle (UAV)

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LIST OF ABBREVIATIONS

AIS	Automatic Identification System
BDS	Beidou Navigation Satellite System
CCTV	Close Circuit Television (System)
COMPASS	Former name of Beidou Navigation Satellite System
DWT	Deadweight Tonnage
EEZ	Exclusive Economic Zone
GEO	Geostationary Earth Orbit Satellite
GDP	Gross Domestic Production
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GT	Gross Tonnage
IGSO	Inclined Geosynchronous Satellite Orbit
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite Organization
IR	Infrared Ray
LOS	Length of Stay
LRIT	Long Range Identification and Tracking (System)
MARPOL	International Convention for the Prevention of Pollution From. Ships, 1973 as modified by the Protocol of 1978
MDA	Maritime Domain Awareness

MEO	Median Earth Orbit Satellite
MPA	Maritime Patrol Aircraft
MPV	Maritime Patrol Vessel
MSA	(China) Maritime Safety Administration
NBSC	National Bureau Statistics of P.R. China
NGOs	Non-Governmental Organizations
NM	Nautical Mile (s)
PLA	People’s Liberation Army
RPV	Remotely Piloted Vehicle(s)
SOLAS	International Convention for Safety of Life at Sea
SAR	Synthetic Aperture Radar
Sat-AIS	Satellite based Automatic Identification System
TOAL	Take-off and Landing
UAV	Unmanned Aerial Vehicle
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNCTAD	United Nations Conference on Trade And Development
USCG	United State Coast Guard
VHF	Very High Frequency
VMS	Vessel Monitoring System
VTS	Vessel Traffic Service
WIMAX	Worldwide Interoperability for Microwave Access

CHAPTER 1

INTRODUCTION

1.1 Background Information

Shipping, which carries more than 90% of world trade in volume (Ma, 2015; UNCTAD, 2015), has been playing a significant role in international trading for more than 4000 years (Stopford, 2009). The international shipping is vital to China, which is the largest international trading entity (NBSC, 2015) and greatly benefited from the international trade. During the last decade, Chinese shipping has been developing rapidly (Figure 1.1), ad hoc in 2015, throughputs of Chinese main ports and containers have reached record 8.147 billion tons and 212 million TEU, respectively.

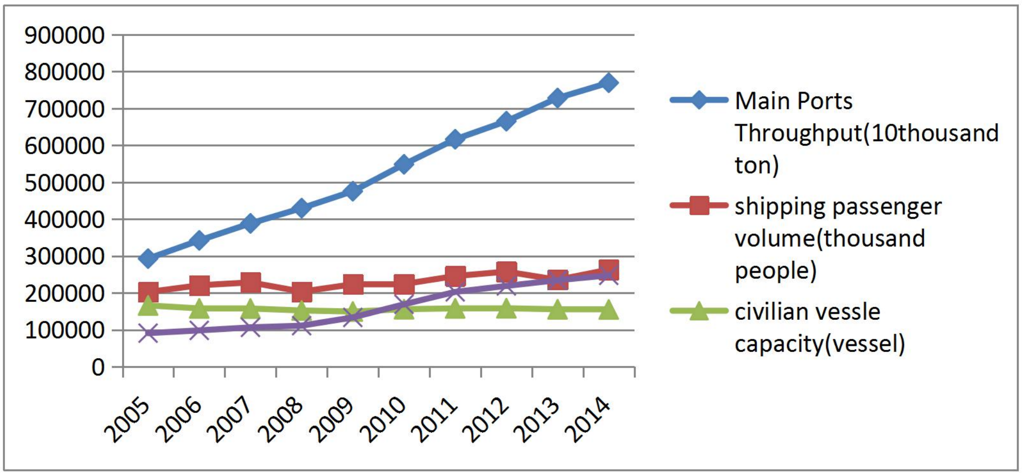

Figure.1.1 The performance of Chinese shipping in 2005-2014
Source: Compiled by the author based on the statistics from NBSC[1]

[1] See more from the Chinese Ministry of Transport: http://www.moc.gov.cn/

Correspondingly, the shipping related activities have been increasing drastically during the same period (Figure 1.2). According to the prediction of UNCTAD (2015), the world seaborne trade (especially China) will gain substantial development in near future. Additionally, China's continuous pursue of maritime power in this millennium, will undoubtedly lead to considerable increase of vessel fleet both in number and DWT, as the "ocean economy" accounts for 10% of China's GDP (Bo, 2014). Therefore, it is reasonable to forecast the trend of maritime activities within the coastal regions of China would be up-rise in the years to come.

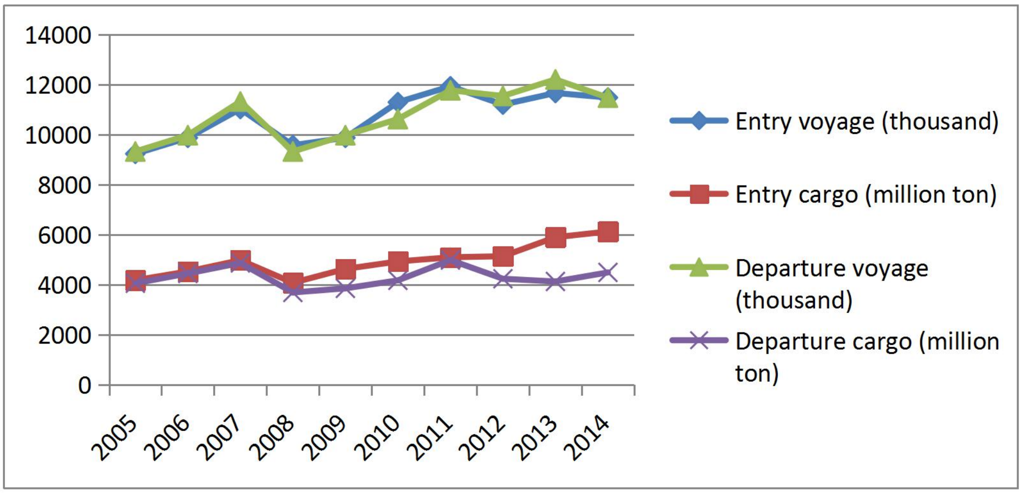

Figure.1.2 Vessel entered and left Chinese Port in 2005 to 2014
Source: Compiled by the author based on China MSA Statistics[2]

As maritime surveillance has been more of public safe, environmental and economical interest, which improves maritime safety and environmental protection, especially, monitoring vessels, illegal activities and oil spills are of grave significance (Bloisi et al, 2015; Braca et al, 2015), has drew worldwide attentions in recent decades, in order to effectively and efficiently enhance maritime safety.

Therefore, to cope with the rapid change of maritime industry, it is necessary for the

[2] Detail of the statistics are based on the internal sources

competent authority, namely the China MSA, to set up a comprehensive maritime surveillance (MS) system to monitor maritime activities so as to ensure maritime safety, marine environmental protection and maritime security. Indeed, MSA has been making great efforts to build up a nationwide maritime surveillance system, which consist of VTS, AIS, CCTV, LRIT, GPS/COMPASS and satellite based AIS systems, (Song, 2010; Cai, 2011b; Zhao, 2012; China MSA, 2016) and achieved remarkable progresses, for instance, in 2015 the number of maritime accident is 213, related casualty is 222 and direct economic loss is 349 million RMB, a 18.3%, 10% and 31.9% decrease, respectively, on an annual basis (Ministry of Transport, 2016). However, as maritime activities (including ferries, fishery vessels, yachts, oil drilling-rigs and etc) in China have been significantly increasing and expanding further away from shores, along with the shipping's trend toward mega-ships (Nakazawa, 2015), and more illegal shipping-related activities occur (Li, 2012; Cui, 2015), the risks associated with maritime activities soar thereupon. In line with report of Transport Planning and Research Institute (2014), the emergencies happened 50nm away from shore have grown substantially (Figure 1.3), which indicates an urgency to overhaul current maritime surveillance system to detect and tackle maritime emergencies in an effective and efficient manner.

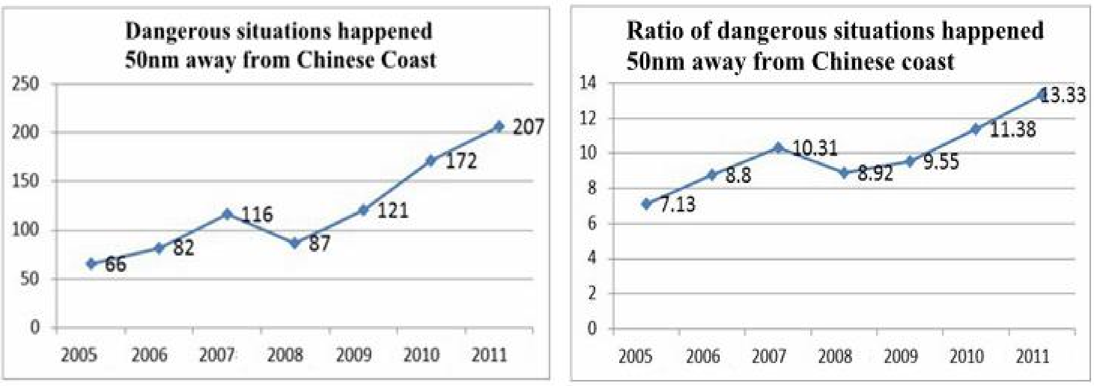

Figure 1.3 Dangerous situations (and ratio) happened 50nm away from Chinese coast (Source: TPRT, 2014)

However, to date, no comprehensive assessment or review of Chinese maritime surveillance (MS) system has been conducted. Hence, in order to fill this lacuna and further enhance maritime safety, security and the protection of marine environment, it would be imperative to critically review the Chinese MS system, using an applicable solution to improve it as necessary.

1.2 Objectives of Research

The Chinese Ministry of Transport has been investing heavily into the MS system, which has been renewed on the existing basis in previous years. Progress and achievement have been made, but the system still has constantly been criticized by many for its lack of effectiveness and efficiency. As one of MSA staff, who served in both front-line and technology infrastructure department, the author would like to take this opportunity to delve into the current Chinese MS system and try to find out an applicable solution to solve existing problems within MS domain in a cost-effective manner. Therefore, the objectives of this research paper are illustrated as followed:

a) Critically review the current Chinese maritime surveillance system;
b) Provide an applicable solution;
c) Conduct a feasibility analysis of the solution to facilitate the MS system improvement;
d) Draw attention to those concerned and provide constructive suggestions to the decision maker(s).

1.3 Methodology

In order to fully meet the objectives, several methods have been used in subsequent sections:

1. Literature Review:

A large amount of literatures, including IMO documents, relevant conventions, research papers, books and articles, which are mainly from archive of IMO, Google Scholar, CNKI[3] and libraries, have been reviewed, so as to gain a wholly picture of current Chinese MS system, its component systems and alternative technologies, to better support the research.

2. Qualitative Analysis[4]

To better delve into objectives mentioned and convey a more objective conclusion afterward, a qualitative analysis (Corbin and Strauss, 2014, p11), which mainly includes semi-structured interview (face to face and telephone) with current employed MSA staff, have been conducted. The findings will be used as the basis for further researches.

3. Theoretical Analysis:

In final part, a theoretical analysis will be carried out to analyze the proposed solution to the problems discovered, in term of not only the technical but also legal and practical aspects. To better strengthen the feasibility of the recommended solution, as one of the technology project members in the MSA, relevant analysis will be provided by the author therewith.

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[3] CNKI: Google Scholar's Chinese counterpart

[4] Qualitative analysis mainly takes the form of semi-structured interview

1.4 Structure of the Paper

The research paper is mainly comprised of six chapters: **Chapter one** provides background information, research objectives and methodologies to be used in subsequent parts; **Chapter two** broadly reviews the current Chinese maritime surveillance system, including its various component subsystems, their advantages and shortcomings will also be discussed respectively; **Chapter three** mainly focuses on analyzing the effectiveness and efficiency of the maritime surveillance system reviewed, a qualitative method will be conducted to further strengthen the objective conclusions; **Chapter four** offers an applicable and practicable solution, by comparing with different improvement measures, to enhance the effectiveness of Chinese maritime surveillance system, based on the conclusions obtained in previous chapters; **Chapter five** primarily analyzes the necessity and content of the recommended solution, relative analysis and data will be provided to further reinforce the argument; **Chapter six** makes final summary and conclusion, highlights and limitations of this research paper and implications for further researches also have been outlined.

CHAPTER 2

CRITICAL REVIEW OF THE CURRENT CHINESE MARITIME SURVEILLANCE SYSTEM

2.1 Introduction

Over the past four decades, the gradual establishment of China maritime surveillance system and advanced technologies are offering a staunch of foundation in guaranteeing maritime safety, protection and preservation of environment within Chinese coastal regions (Song, 2010; Cai, 2011b; Zhao, 2012; Zhang, 2015a). However, as the rapid maritime development (especially the shipping) in China and the west-Pacific region, pressures for MSA to ensure safety at sea and protection of environment has been rising substantially, the Chinese maritime surveillance (MS) system, which consists of different subsystems, plays an irreplaceable role in that regard. Therefore, in this chapter, the author will introduce the overall picture of current Chinese MS system and paves the way for subsequent researches, so as to overhaul and improve effectiveness of Chinese MS system.

2.2 Chinese Maritime Surveillance System

After years of efforts made by China MSA, the MS system is comprised of VTS, AIS, CCTV, SAR, SAT-AIS, LRIT, GPS, COMPASS and manned vehicle patrol subsystems (Song, 2010; Zhao, 2012), the following sub-paragraphs will introduce each component, their functions and effectiveness.

2.2.1 Vessel Traffic System (VTS)

The effectiveness and significance of Vessel Traffic System (VTS), which is mandated by the IMO (IMO, 1997), have long been recognized as a useful measure (Lin, 2006; Kao, et al, 2007; Maresca, et l, 2015). As one of the major player in global community, China has been paying great emphasis on the VTS development. Since the establishment of first VTS at Ningbo in 1982 (Hu and Yang, 2008), Chinese VTS has been undergoing a rapid development. To date, total 57 VTS centers and 266 radar towers are currently under operation, which include costal (41 VTS centers and 180 radar towers) and inner-water (16 VTS centers and 86 radar towers) (Figure 2.1), and total monitor coverage area is estimated 90,000 square kilometer (TPRT, 2015), basically covering all key areas in China.

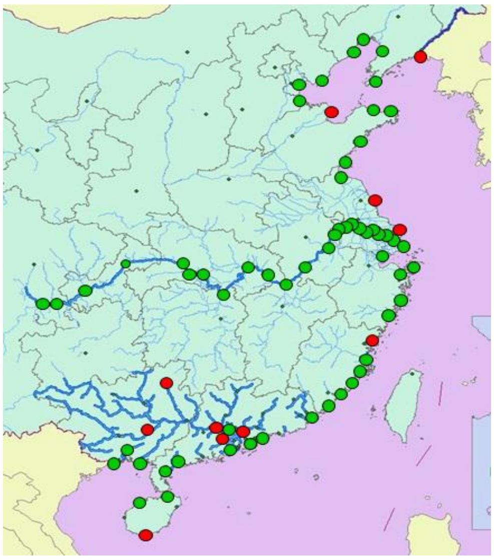


Figure.2.1 The Distribution of Chinese VTS centers (Source: TPRT, 2014)

According to Xi (2013) , the number of Chinese VTS centers and radar-towers, of which technical standards have reached international-level, account for one third of the world, and monitor coverage area is the world largest. In 2014, China VTS tracked and monitored approximate 3.5 million voyages, intercepted, corrected and handled more than 40,000 illegal traffic behaviors and provided at least 5 million navigation information services (Figure 2.2). The statistic from Hu and Yang (2008) also fortify the argument: along with 20% annual growth of vessel traffic flow in China, the accident rate in the VTS coverage has dropped remarkably 70%. Hence, Chinese VTS system plays a vital role in ensuring maritime safety, improving traffic efficiency and protecting marine environment, which in turn created enormous economic, social and ecological benefits (Zhu and Chen, 2008).

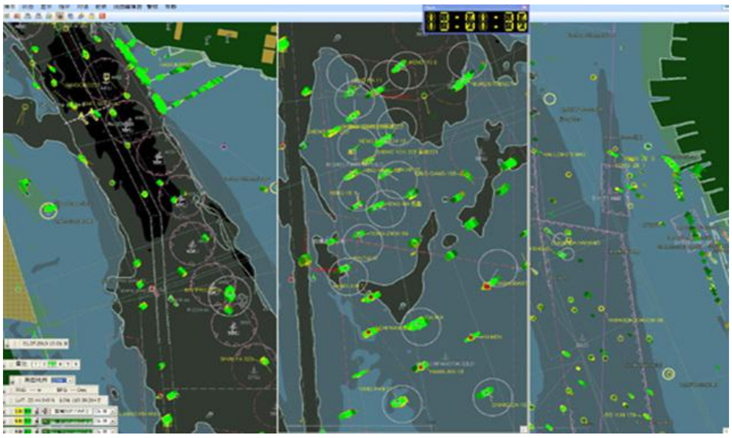


Figure 2.2 Chinese VTS display (Screenshot taken on VTS center)

However, the shore-based VTS, which usually located in harbors or channel entries, has been questioned by many (Kao et al, 2007; Xi, 2013; Maresca, 2015; Zhang, 2015a) as lack of effectiveness in maritime surveillance. **Firstly,** according to Kao et al (2007), due to technical characteristics of radar, theoretical range is 20nm (but not likely in many cases), that is to say VTS monitor range is highly restricted. **Additionally,** current VTS does not have enough technical capability to monitor crowded route areas to maintain maritime safety, because overcrowded vessels might interfere VTS operators and reduce effectiveness of ship monitoring (Praetorius, 2012). **Furthermore,** the backscattered signal is strongly affected by sea states (Maresca, 2015), for example currents can negatively affect radar detection capabilities, especially at the estuaries regions (i.e., Yangtze & Pearl River), which in turn significantly lower its monitoring capability. **Fourthly**, the rapid development of coastal regions in China also plays a negative role in affecting VTS performance, the report of Shenzhen MSA (2015a) indicates the harbor cranes and other infrastructures could block radar signals and create man-made "blind zone". **Finally,** information acquired by radar is limited, for instance VTS cannot effectively monitor small vessels (i.e., difficult to identify vessel type and size), neither can it distinguish ships (i.e., name, type and cargo) by radar alone (Cai, 2011b). Also, in the absence of automatic information judging system, VTS mainly relies on human to carry out surveillance duties, which is neither effective nor efficient (Xi, 2013; Zhang, 2015a).

2.2.2 Automatic Identification System (AIS)

Since the installation of AIS onboard, which originally designed for maritime safety and collision avoidance between vessels (Iervolino et al, 2015), became a mandatory requirement for relevant ships (IMO, 2000), China MSA has initiated the shore-based AIS network construction. Up to 2013， China invested more than 500 million RMB in establishing AIS: one national center, 7 regional and 32 branch-level AIS centers have been set up, managing 121 coast-based and 143 inner-water AIS stations (Liang, et al, 2013), of which covering all coastal regions and most main rivers (coverage rate up to 99.97% and signal usable rate up to 99.95%; Figure 2.3).

Figure 2.3 Chinese shore based AIS Coverage (Source: TPRT, 2014)

The AIS, which consists of shipboard AIS and shore-based station (Liu, and Dong, 2010), can be used to actively monitor ships' status, namely ship's name, IMO number, position, velocity, direction and voyage status by MSA (Figure 2.4).

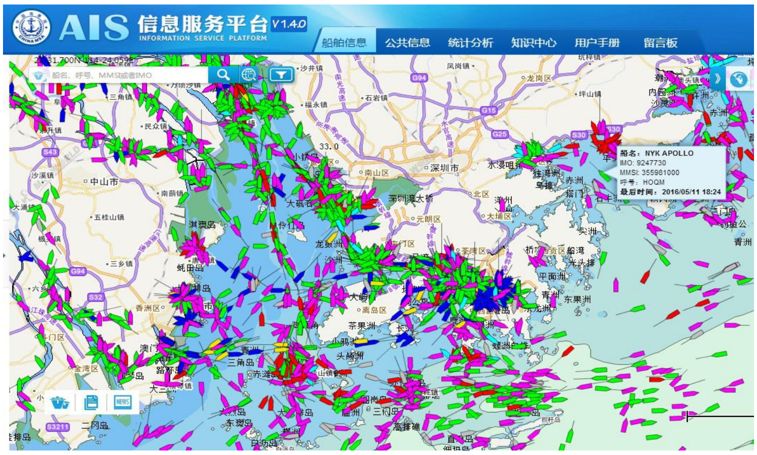


Figure 2.4 Chinese AIS information system screenshot (taken by author on 11th May)

In addition, the GPS, VHF and SOTDMA techniques dependent system (AIS) has been playing an important role in ensuring maritime safety, traffic control and supporting maritime governance for the following reasons:

Firstly, signal acquired by AIS is instant and relatively accurate, that is to say AIS is a real-time and reliable maritime monitoring system which is crucial for maritime governance. (Wang, 2011)

Furthermore, because of the characteristic of VHF communication, there is almost no "blind zone" in AIS coverage areas, also anti-jamming capability is superior, which can guarantee signal stability especially in severe weathers condition. (Cai, 2011a)

Finally, AIS can provide excellent monitoring performance in a cost-benefit manner, due to the remote control characteristic: one AIS control center can remotely control various AIS shore based stations and cover vast areas (Figure 2.5).

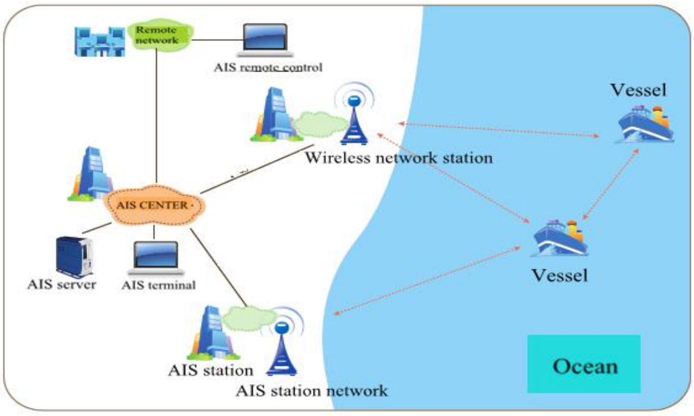


Figure 2.5 Chinese AIS system working principle (source: edited by the author)

As a complementary measure, AIS does improve maritime safety by complementing functions with existing VTS. However, after a couple of years in practice, certain deficiencies have been revealed:

First and foremost, due to the earth curvature AIS coverage, which is very dependent on antenna height, ambient radio noise and troposphere factors. (Lessing et al, 2006), is only 40km (Iervolino et al, 2015; Peng, 2015), that means the monitoring range of AIS is also restricted (Burzigotti et al, 2010), which is hard to meet the requirements of large-scale and long-range maritime surveillance (Liang et al, 2013).

Secondly, as a passive system (Wang and Wang, 2011), AIS can only detect the AIS-equipped ships or "cooperative vessels", which operate AIS correctly (Frazer et al, 2010). In addition, problems of AIS falsification emerge, which masks illegal transport and lead to disturbances of MS system and increasing associated maritime risks (Ray et al, 2015): some fishing vessels are practicing this offense to fish illegally by pretending to be yachts; many ships turn off AIS to escape from AIS monitoring, in order to carrying undeclared dangerous cargos (Harati-Mokhtari et al, 2007).

Finally, some technical issues affect the effectiveness of AIS, especially in crowded areas: **1)** as Zhang (2015a) claims, there might be overflow of AIS information and conflict of message in overcrowded ports, which might lead to AIS packet loss (no display of vessels); **2)** the VHF frequency based AIS might impair the capacity of neighboring vessels' equipments to receive and broadcast AIS message from/to distant designates (Ray et al, 2015), thus inter-channel interference phenomenon, which could totally block emitted or received AIS message and limit AIS service range, is specially serious in congestive areas.

In sum, the main drawbacks concerning land-based AIS systems are limited spatial coverage, impossibility of berth to berth tracking (Iervolino et al, 2015), and possibility of information falsification.

2.2.3 Close Circuit Television System (CCTV)

Visual surveillance (CCTV) in the maritime filed has been explored for long time (Fefilatyev et al, 2012), however, substantial application of CCTV system in China just began in 2011 (Hao et al, 2014), under the name of "intelligent maritime". After 5 years of experiments, a comprehensive CCTV system has been established (Figure 2.6), to effectively monitor inner water channels and key coastal ports (Tao, 2011).

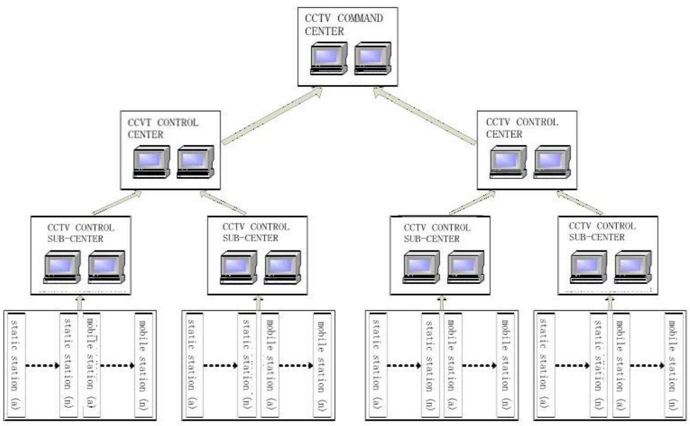


Figure 2.6 CCTV System Structure (Source: edited base on MSA internal source)

The system (CCTV) can achieve effective real-time visual monitoring (Figure 2.7), without the need to require additional equipments, to correct illegal activities (i.e., cargo overloaded, irregular mooring and navigational rules violation) and reduce accident rates (i.e., prevents dangerous situations from developing to accidents) happened in monitored areas. CCTV system facilitates the maritime surveillance and overall governance (by obtaining real-time situations), at the meantime effectively lower administration cost (i.e., reduce the number of vessels dispatch). (Wang, 2011)

In sum, the CCTV system's advantages could be summarized: **1)** CCTV can effectively reduce administration cost (including human and equipment), by remote sensing and control; **2)** the directness and uninterrupted characteristics of CCTV can achieve a real-time traffic monitoring; **3)** the record and replay function of CCTV provides a powerful tool for MSA to prosecute those suspects involved in maritime casualties and regulation violation (Hao et al, 2014).

Figure 2.7 Chinese CCTV display screenshots (source: Chinese CCTV system)

Contrarily, the drawbacks of CCTV system are showed in following:

Firstly, CCTV system's surveillance capability is highly affected by visibility condition, i.e., fog, night time (Wang, 2011), and infrastructures in front of the cameras, like the examples showed in Figure 2.7.

Secondly, the surveillance range of CCTV system is also highly restricted (Wang, 2010), according to Shenzhen MSA (2015b), the most advanced CCTV can only obtain distinguishable images from 2km away in fine weather. Therefore, CCTV monitoring system would only be limited to port areas (Fefilatyev et al, 2012) and cannot monitor situations far beyond the shores.

Thirdly, CCTV system can experience difficulties in detecting a vessel's real situation when a vessel is moving toward cameras (Figure 2.8) or is anchored off the coast due to small amount of inter-frame changes (Bloisi et al, 2015), which in term lowers the effectiveness of CCTV system and might generate new maritime risks.

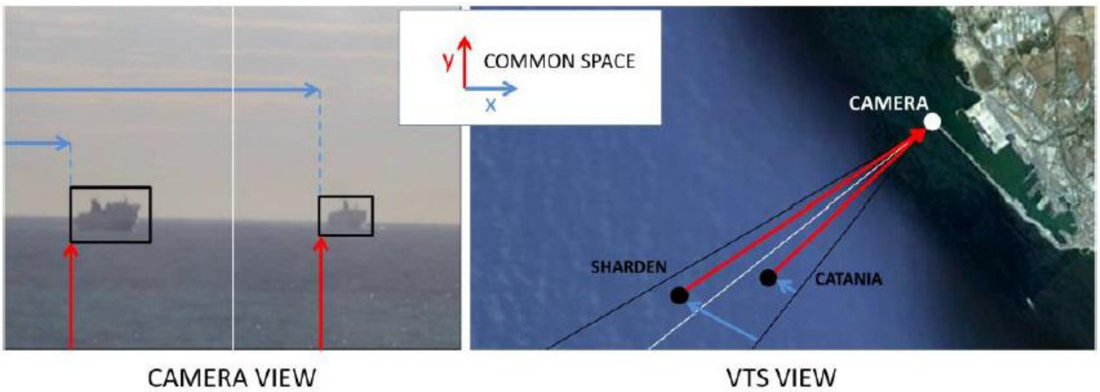


Figure 2.8 Visual and VTS data projection. (Source: Bloisi et al, 2015)

2.2.4 Long Range Maritime Surveillance System

Apart from the short-range coast-based MS systems discussed, MSA has been conducting numerous trials and established pioneering programs to promote long-range MS capability, so as to establish MDA system (Sun, 2015) to better enhance maritime safety, security and protection of environment. In subsequent parts, the paper will introduce techniques within the Chinese MS System domain:

2.2.4.1 Long Range Identification and Tracking of Ships System (LRIT)

Proposed by United State after 9/11, Long Range Identification and Tracking of ships system had been made mandatory by amending Chapter V of SOLAS in 2006 (IMO, 2006) and entered into force in 2009, so as to reinforce maritime security, safety and search and rescue in a global aspect (IMO, 2008a; IMO, 2008b).

The LRIT system consists of already installed ship-borne satellite communications equipments, communications service providers (CSPs), application service providers (ASPs), LRIT data centers, LRIT data distribution plan and International LRIT data exchange (Figure 2.9). The performance of LRIT system are reviewed by LRIT coordinator acting on behalf of IMO and contracting States (CTTI, 2015a): wherever the vessel, the flag State is entitled to acquire vessel's LRIT information; if the vessel want to enter coastal States or port States, relevant authorities are also entitled to acquired information from data exchange center (IMO, 2008a), disregard of its position (even the vessel is 1000nm away).

According to requirements of SOLAS, China has established LRIT system which consists of data center, back-up center, application terminals (Figure 2.10) (Du, 2010). Most of the LRIT communications are based on INMARSAT-C (Zhang and Bao, 2007), and display of current China LRIT system is illustrated in figure 2.11.

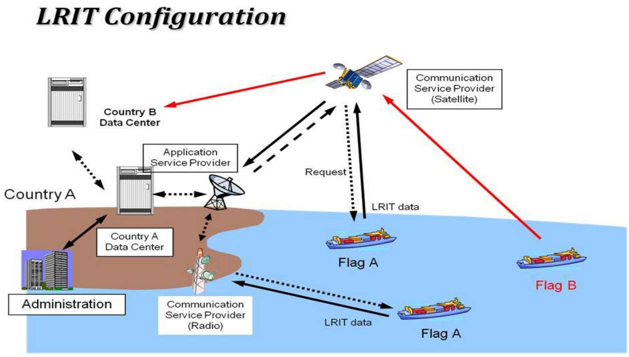


Figure 2.9 Configuration of LRIT system (Source: http://www.shipmates.in/)

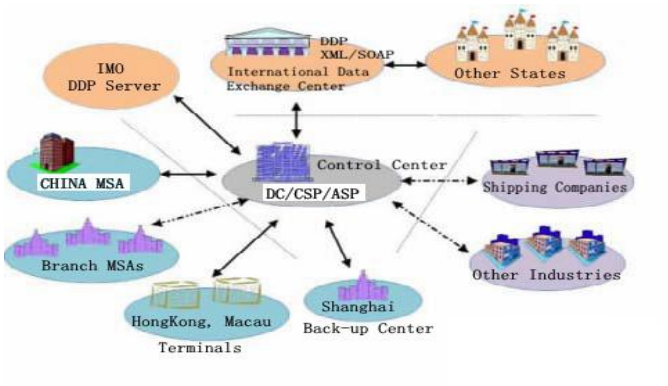


Figure 2.10 Chinese LRIT system structure (Source: China MSA, 2010)

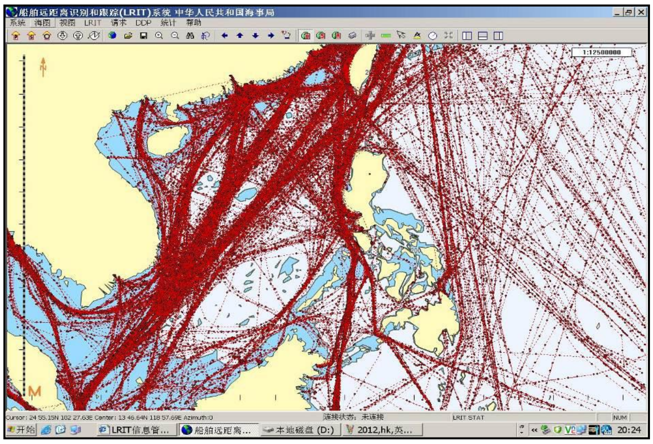


Figure 2.11 Chinese LRIT system display (Source; China MSA internal report[5])

According to Du (2010) and CTTI (2015b), Chinese LRIT system plays a role in the following aspects: **1)** enhance maritime safety and security in coastal regions, by

[5] Due to the limited usage of LRIT, the author acquire the Chinese LRIT display from one internal source

remotely tracking irregular and suspicious vessels; **2)** improve maritime search and rescue effectiveness, by providing information support, i.e., distress vessel's position and time; **3)** promote environmental protection, by providing auxiliary information supports (past ships in specific region during specific timeframe) to essentially tackle illegal oil/sewage discharges and oil-spills; **4)** complement existing MS system, by making the monitoring operations more effective; **5)** Provide additional information supports for Custom and Sanitary Quarantine department for other purposes.

Although LRIT has been recognized as a useful measure[6] which can complement the combination of VTS and AIS in term of long-range maritime surveillance and large-scale ships monitoring, shortcomings of LRIT are also apparent: **1)** LRIT can only acquire data from certain types of ships, vessels below 300GT will not be revealed in LRIT monitor display, thus large amount of vessels are out of reach (Du, 2010); **2)** the information, which only contains ship identity, position and time, acquired by LRIT is very limited, therefore the detection and tracking capabilities are also restricted (Zhang, 2015a); **3)** the time gap of the information intermittence is large (6 hours), which indicates potential risks during the period.

2.2.4.2 Satellite Based Automatic Identification System (Sat-AIS)

There are estimated 70,000 ships installed with AIS globally (Peng et al, 2015), combining with much larger amount of small vessels operating in different areas. The vast number of vessels and coverage limitation of shore-based AIS (Brusch et al, 2011) had prompted the demand for wider range AIS coverage (Liang, et al, 2013). In 2001, the idea of using near-earth-satellites（orbital altitude less than 1000km）as repeaters to increase AIS coverage was proposed by USCG, and the concept had

[6] Useful measure in term of maritime security

gradually became the nowadays Sat-AIS (Figure 2.12) which can monitor vessels in a wide range of areas in a real-time manner (Hannevik et al, 2010).

Although China's startup was relatively late, yet as of 2015, a functioning Sat-AIS system, which has 1 command center, 1 data back-up center, 3 regional centers and 14 branch-level centers, has been established (Zhang, 2015a) and effectively complemented the MS system (Figure 2.13).

First of all, wide-range coverage (about 20 million square kilometers (Iervolino et al, 2015)) and excellent information capability (maximum simultaneously handle 6,200 vessels signals) to track vessels from berth to berth are the main advantages that distinguish Sat-AIS from other MS measures (Peng et al, 2015). **Moreover,** Sat-AIS can receive signals from as far as Polar Regions, vastly extend the MS capability without geographical restrictions. **Finally**, Sat-AIS features the availability of all instant information contained in actual AIS signals as transmitted by vessels, providing a reliable and extensive information data on all parameters with respect to individual vessels. This enables a convenient and effective way of analyzing maritime traffic in certain areas of interest.

Also, an increase in the number of detected vessels per-area will lead to augment in the number of situations where Sat-AIS would be applicable, i.e., harbor traffic planning, search and rescue, vessel tracking, detection of illegal transports and maritime casualty investigation, combined with other data like SAR imagery (Brusch et al, 2011), which will be introduced in the next section.

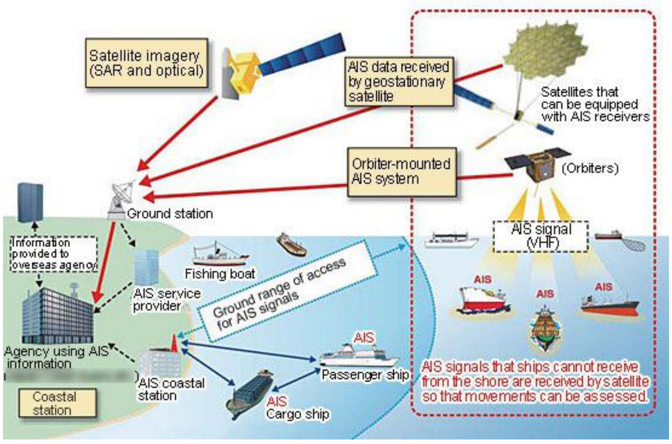


Figure 2.12 Sat-AIS working principle (Source: www.portvision.com)

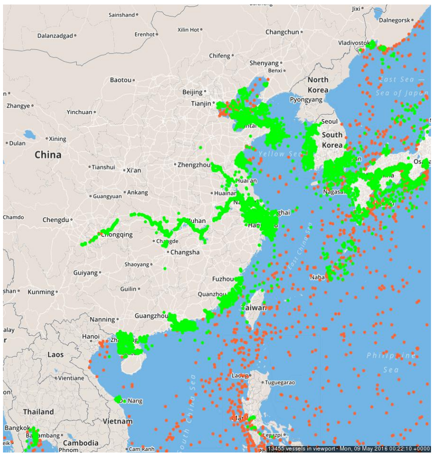


Figure 2.13 Sat-AIS coverage in Far-east Asia
(Source: https://www.fleetmon.com/global-vessel-coverage/[7])

Even though Sat-AIS makes up disadvantages of shore-based AIS, the system is far from perfect: **above all,** the passive characteristic of Sat-AIS is the same with shore-based AIS, which means Sat-AIS cannot detect and track those "non-compliance"; **second,** the real-time of maritime surveillance cannot be guaranteed by Sat-AIS, because of the way of satellite orbits work (Zhang, 2015b); **furthermore,** even within satellite coverage range, the effect of Doppler and problems of signal conflict in different zones pose challenges to the real application of Sat-AIS (Peng, 2015); lastly, China does not has AIS receiver-equipped satellite, that is to say the fees to use Sat-AIS is extremely high (Zhang, 2015a).

[7] The AIS data are obtained from commercial AIS display website

2.2.4.3 Synthetic Aperture Radar System (SAR)

As one of the traditional surveillance measures, Synthetic Aperture Radar (SAR) has been applied in various fields, i.e., landscape mapping, military reconnaissance and maritime surveillance (Crisp, 2004). In recent years, SAR (Figure 2.14) provides an alternative surveillance solution to maritime administration (Tello et al, 2005), allowing the maritime surveillance of broad expanses, independently from meteorological condition, national boarder and from the day and night cycle.

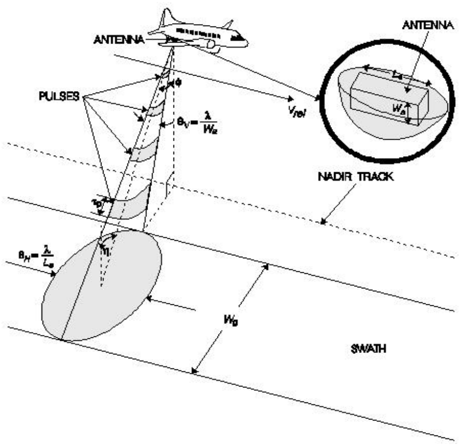


Figure 2.14 Working principle of SAR (Source: http://www.geo.uzh.ch/)

Although China MSA conducted experimental SAR trials in recent years (Sun, 2015), no comprehensive SAR system has been developed, due to the high false alarm rate (i.e., disturbances from current; Tello et al, 2005) and maritime surveillance requirements (Bloisi et al, 2015). But China MSA still possesses maritime aircrafts to carry out SAR surveillance missions for following reasons:

Firstly according to Iervolino et al (2015), SAR is effective in detecting non-cooperative vessels and tracking of small vessels without AIS (Figure 2.15). Modern SAR provides wide spatial coverage, consequently, a better control of open-sea regions. **Secondly**, as Hannevik et al (2010) pointed out, SAR combined with Sat-AIS would be suitable for monitoring remote regions. AIS identify vessels detected in SAR, and SAR can detect vessels not reporting through AIS. The combination enables authority to unveil non-cooperative vessels. **Finally,** using SAR to detect and monitor oil spills under most-weather conditions (Figure 2.16) have been an applicable option for MSA (Shirvany et al, 2012).

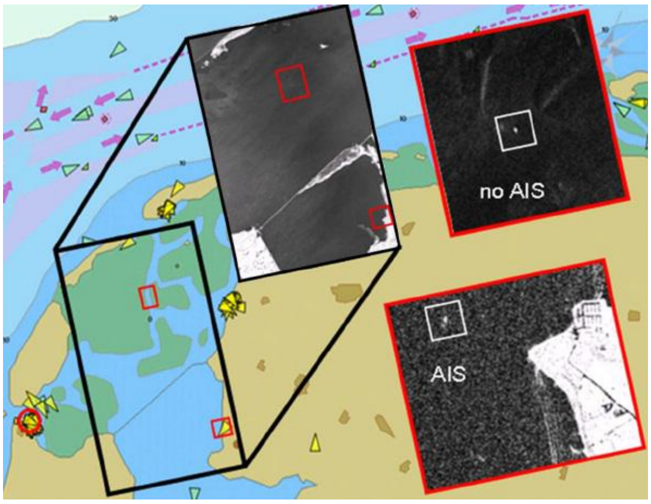


Figure 2.15 SAR complements with AIS surveillance (Source: Brusch et al, 2011)

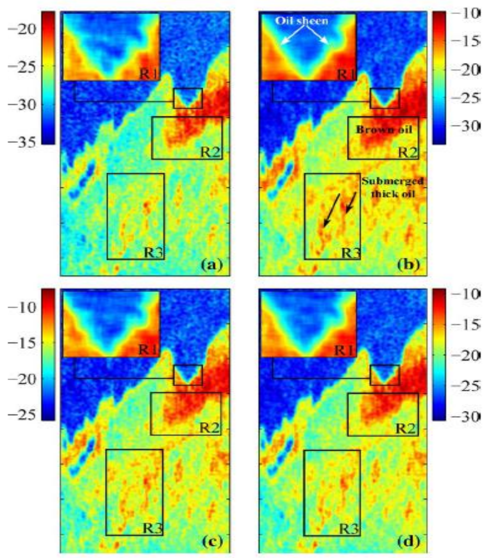


Figure 2.16 Oil-slick Property Type Recognition in SAR image.
(Source: Shirvany et al, 2012)

2.2.5 Navigation System

The main measures of Chinese MS system are briefly discussed, and many of the techniques, namely AIS, LRIT and Sat-AIS, are based on satellite-based navigation systems, like American initiated Global Positioning System (GPS) and Chinese launched COMPASS (Beidou) navigation system (Figure 2.17). This part will introduce navigation systems which are already incorporated into the MS system.

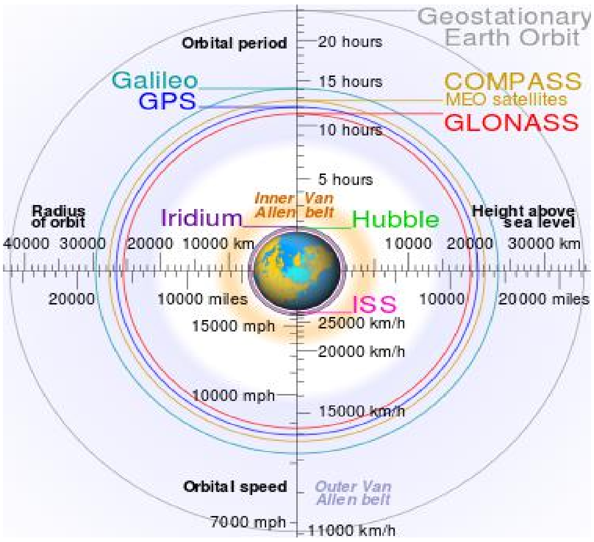


Figure 2.17 Comparison of Different Space based Navigation System

Source:https://en.wikipedia.org/wiki/File:Comparison_satellite_navigation_orbits.svg

2.2.5.1 Global Positioning System (GPS)

GPS, which was first launched in 1978 and currently has total 31 satellites in operation (USCG, 2016), is the most popular and mature navigation system, which providing global coverage, high precision (5 meter) and freely accessibility to anyone with a GPS receiver (Zhang, 2015a). Along with the navigational purpose, GPS also provides an effective mean to track and monitor vessels which are out of the range of existing shore-based surveillance system. China MSA has long recognized the benefits of applying GPS into MS system (i.e., all maritime patrol vehicles and aircrafts are equipped with GPS), which effectively expand the monitor range. However, there is a growing recognition in Chinese maritime field (Kang and Quan, 2013) that GPS alone cannot provide robust positioning and reliable surveillance service for maritime industry. Therefore, China had begun to set up its own navigation system since this new millennium[8].

2.2.5.2 Beidou Navigation Satellite System (BDS)

Beidou Navigation Satellite System (formerly known as COMPASS) was an independent Global Navigation Satellite System (GNSS) developed by China. The BDS, which the first satellite was launched in 2000, has a three-phase development strategy namely, 2000-2007: experimental; 2007-2012 regional coverage; 2012-2020 global coverage (Kang and Quan, 2013). Current BDS (precision is about 10 meter) satellites are illustrated in Table 2.1.

Table 2.1 Summary of Beidou Satellites (As of 2015)

Block	Launch Period	Satellite launches			Currently in orbit
		Success	Failure	Planned	
1	2000–2007	4	0	0	0
2	2007-2012	16	0	0	14
3	From 2015	6	0	18	6
Total		26	0	18	20

Source: www.beidou.org.cn

[8] See more from www.beidou.gov.cn

Figure 2.18 BDS service coverage area (Source: www.beidou.org.cn)

The current BDS became operational in China in December 2011, with 10 satellites in operation, offering services to customers in Asia-Pacific region since December 2012 (Figure 2.18). BDS is now under construction to move toward the final phase, which will be a global navigation system consisting of 35 satellites (5 Geostationary Earth Orbit Satellites (GEO), 30 Median Earth Orbit Satellites (MEO) and Inclined Geosynchronous Satellite Orbit (IGSO); Wang and Wang, 2011) as of May 2016. (See more from Appendix A)

The BDS plays a more and more important role in Chinese MS system, search and rescue, maritime casualty investigation and fishery monitoring, ad hoc, the application of BDS can reinforce the maritime safety in channels and vessel routes (Figure 2.19), in the absence of GPS (i.e., positioning error). In 2014, BDS has been recognized by IMO and being taken into GNSS (UN recognized maritime satellite navigation system; Zhang, 2015a).

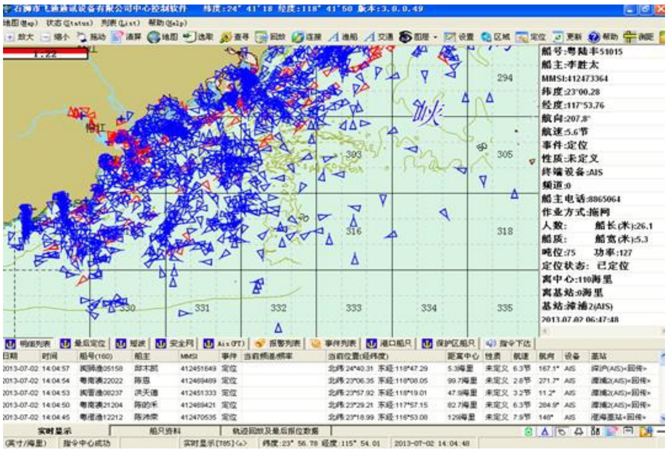


Figure 2.19 Application of BDS in ship monitoring (source www.cnssjz.org)

In service areas, BDS can provide geographical information, two-way short message and precise timing service. Combing with other surveillance measures, BDS can remedy some of the deficiencies of other MS system, especially in remote regions (Wang and Wang, 2011): **1)** BDS can improve the whole reliability of the Chinese maritime surveillance, by adding sufficient abundance (in case of GPS equipments malfunction); **2)** BDS terminals have positioning and communication functions, which are ideal for vessels monitoring in high seas.

2.2.6 Manned Maritime Patrol System

The final kind of maritime surveillance mean introduced is Manned Maritime Patrol System, which is the main measure for maritime law enforcement, emergency respond and search and rescue. The current Maritime Patrol System is primarily comprised of two parts, namely Maritime Patrol Vessel System (MPV) and Manned Maritime Patrol Aircraft system (MPA).

2.2.6.1 Maritime Patrol Vessel System (MPV)

Chinese Maritime Patrol Vessel System is consisted of various kinds of maritime patrol vessels which main missions include maritime monitoring, daily patrol to enforce relevant laws and emergency responses. To date, China MSA has up to 370 different kinds of patrol vessels (Table 2.2) which operate in coastal regions, harbor and inner waters

Table 2.2 Summary of Existing Chinese Maritime Patrol Vessels

Ship Type	**Navigating Area**	**Applicable Water**	**Number**
100/80 meter MPV	High Sea	Open Sea Area	6
60 meter MPV	Greater Coastal Area	Areas 50nm From Shore	24
40 meter MPV	Coastal Sea	Key Channels, Water ways and Islands	59
30/20 meter MPV	Shelter Area	Harbor and Adjacent Areas	281

Source: Compiled by the author based on the information from (China MSA, 2011a).

Presently, as the main measure to directly carry out law enforcement by MSA, the MPV system is regarded as an effective outreach of existing MS system, ensuring the maritime safety and protection of environment.

Deficiencies of MPV system are, however, obvious. Disadvantages could be categorized as 4 kinds: **1)** restricted operation range, as showed in Table 2.2, most vessels are small boats which can only voyage in shelter areas; **2)** limited surveillance capacity due to characteristics of ships and weather dependence (i.e., severe weather, fog); **3)** slow reaction to emergencies, because of long startup time and low speed (maximum 20 knot); **4)** high maintenance cost (Wang, 2010), according to MSA statistics, one 100 meter-level patrol ships costs at least 15million RMB (2.3 million USD) annually, which is expensive in term of per-ship region.

2.2.6.2Manned Maritime Patrol Aircraft System (MPA)

Apart from MPV system, MPA system, which was started in 2000 and mainly comprised of surveillance aircrafts and maritime helicopters, has been developing rapidly. In 2014, there are 2 aircraft bases with 2 fix-planes and total 15 helicopter base with 28 maritime helicopters for China MSA (Figure 2.20; China MSA, 2011a).

MPA system overcomes many shortcomings of MPV, by providing a wide range of surveillance, in terms of navigating (100-500 km) and monitoring range (12 times the size of MPV) (Liu et al, 2014) and readily emergency response capability (90-300 km/h), to enhance maritime safety and ensure environmental protection.

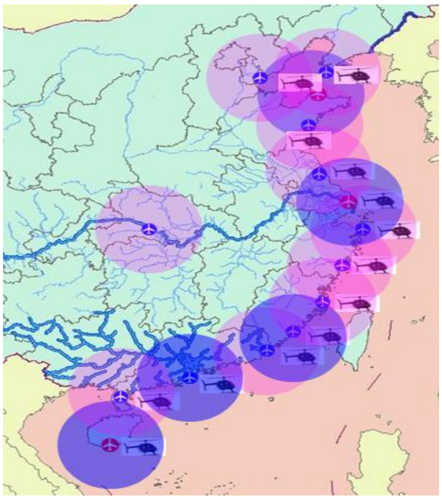


Figure 2.20 Distribution of Chinese MPA system (Source: TPRT, 2014)

But similar with MPV system, drawbacks of MPA system are noticeable: **1)** MPA's operations are also largely effected by weather conditions, for instance MPA cannot carry out daily duties in heavy weathers unless in extreme circumstance; **2)** the long-winded procedures (startup) for flight permission counteracts the expeditiousness of MPA; **3)** The risks (i.e., human and property) associated with MPA operations are relatively high; **4)** The costs for retaining flight crew and maintenance are extremely high.

2.3 Summary of Applied Maritime Surveillance Measures for China MSA

The maritime surveillance measures applied by China MSA have been briefly introduced, different system has its own advantages and disadvantages, which plays its own unique role in enhancing maritime safety, security and protection of the environment. In order to give a whole picture of the applied maritime surveillance measures for China MSA in a clear and concise manner, the author compiled the Table 2.3, to further facilitate the research afterward.

Table 2.3 Summary of existing maritime surveillance techniques for China MSA (Source: Made by the author)			
Technique	**General Situation in China MSA**	**Advantages**	**Disadvantages**
VTS	**1**.Total **57 VTS centers** and **266 radar towers**: costal region (41 VTS centers and 180 radar towers) and inner water (16 VTS centers and 86 radar towers) **2.** Monitor coverage: about **90,000 square kilometer**	**1.** Real-time radar surveillance; **2.** All weather & 24/7 surveillance capability; **3.** Track and monitor all vessels basically in radar coverage areas;	**1.** Limited coverage range (20nm) **2.**Low effectiveness in crowded port areas; **3.**High false information rate; **4.** man-made "blind zone" ; **5.** Acquired data is limited
AIS	**1.**1 national, 7 regional and 32 branch AIS centers: **121 coast-based AIS stations** and **143 inner-water AIS stations;** **2.** Monitor coverage: all Chinese coastal regions and most main rivers; (Coverage rate **99.97%** and signal usable rate **99.95%**)	**1.**Instant surveillance capability; **2.**All weather & 24/7 surveillance capability; **3.** Track and monitor all vessels in network coverage areas; **4.**Accquired information sufficient; **5.** Cost-effective	**1.** Limited coverage range (40nm) **2.**Passive surveillance measure; **3.**Possibility of data falsification; **4.**Difficult to monitor in the congested water areas **5.**Signal interference might create new maritime risks
CCTV	**1.** 1 national command center and 14 regional center **2.** Monitor coverage: key areas in key ports, channels and inner waterways	**1**.Visual and direct monitor capability; **2.** Cost effective in term of maritime surveillance	**1.**Limited monitor range (1nm); **2.** Easily affected by weather; **3.** Image can easily be blocked **4.**Diffuclt to monitor certain kinds of vessels
LRIT	**1.** 1 national center and 2 regional center, one data and back-up centers **2.** Monitor coverage: all seas administrated by China MSA	**1.** Long range detect and monitor capability; **2.** Complement existing systems; **3.** Provide additional information	**1.** Data and information is limited; **2.** Applied vessels are restricted; **3.** Intermittent gap is too wide

Technique	General Situation in China MSA	Advantages	Disadvantages
Sat-AIS	**1.** 1 national and 2 regional centers, 1 data and back-up centers (similar with LRIT); **2.** Monitor coverage: all seas administrated by China MSA	**1.** Long-range & large-scale vessel detection and tracking capability; **2.**Near-real-time surveillance;	**1.**Passive surveillance measure; **2.** Not real-time surveillance; **3.** Affected by Doppler effects and satellite orbit work; **4.** Difficult to track in busy waters **5.**High associated cost
SAR Radar	No comprehensive system has been established by China MSA	**1.**Large-scale vessel detection capability; **2.**Complement with other measures	**1.** Not real time surveillance; **2.** Difficult to distinguish (image) in some cases **3.**High cost for deploying aircrafts
GPS	**1.** American navigation system; **2.** Service coverage: global	**1.** Global coverage; **2** Reliable and mature technique	**1.** Foreign reliant technology;; **2.** Inaccurate data in some regions
COMPASS/ BEIDOU	**1.** 1 national center and 3 regional center: 37 coastal aid stations; **2.** Service coverage: Asia-pacific	**1.**Reinforce signal coverage in Asia-Pacific region; **2.**Independent technology	**1.** Not global coverage; **2.**Not reliable and mature enough
MPV	**1.**4 different kinds of total 370 MPVs; **2.** Coverage: mainly in port areas	**1.**Traditional maritime surveillance measure; **2.** law-enforcement measure	**1.**Limited coverage ranges **2.** Slow reaction time; **3.** High maintenance cost
MPA	**1.**2 different kinds of total 30 MPAs; **2.** Coverage: mainly in coastal areas	**1.** Long-range coverage; **2.** Expeditiousness	**1.**Prolonged procedures **2.**High associated risks **3.** High maintenance cost

2.4 Chapter Summary

Maritime Surveillance systems for the maritime domains (safety, security and protection of environment) are becoming more important in recent years along with rapid development of global maritime transport industry. Therefore, as discussed in previous sections in this chapter, China MSA has established a functional maritime surveillance system, to detect and track the vessels enter and leave Chinese coastal regions, by various kinds of monitoring measures, which have their own advantages and disadvantages. In order to carry out effective maritime surveillance, the combination of systems have been applied by China MSA, for instance, VTS combine with AIS, are often equipped with long-range CCTV system (Bloisi et al, 2015). However, the available techniques can only provide limited support to the MS system which is not sufficient to ensure a practical and effective solution for maritime surveillance challenges ahead (more details will be introduced in following chapters).

CHAPTER 3

ANALYSIS OF EXISTING CHINESE MARITIME SURVEILLANCE SYSTEM'S CHALLENGES

3.1 Introduction

During the past decades, systematic Chinese maritime surveillance system has gradually been set up to cover coastal regions and inner waterways, ensuring the safe, security and integrity of marine environment. However, current system is far from faultless: no single surveillance measure can provide the real-time consolidated maritime surveillance capability, neither the combination of different monitor techniques can offer an effective and cost-effective solution to form a overall MS system. The requirements of proposed MS system are summarized by Guerriero et al (2008), including three substantial components: **a)** multi-sensor signal and information processing generates contact-level data for available sensors; **b)** large-scale multi-senor data fusion and tracking which is capable of processing vessels tracks and contact-level or track level data from various surveillance source to produce a consolidated surveillance picture; **c)** anomaly (irregularity) detection capability that significantly increase the efficiency of MS system, to further improve the effectiveness of Chinese maritime surveillance and promote the maritime governance. Therefore, in order for China MSA to move towards real-time consolidated maritime surveillance, existing problems and potential challenges should be dealt with careful investigations and in-depth analysis. In this chapter, the paper tried to discover problems and provided thoughts for further research.

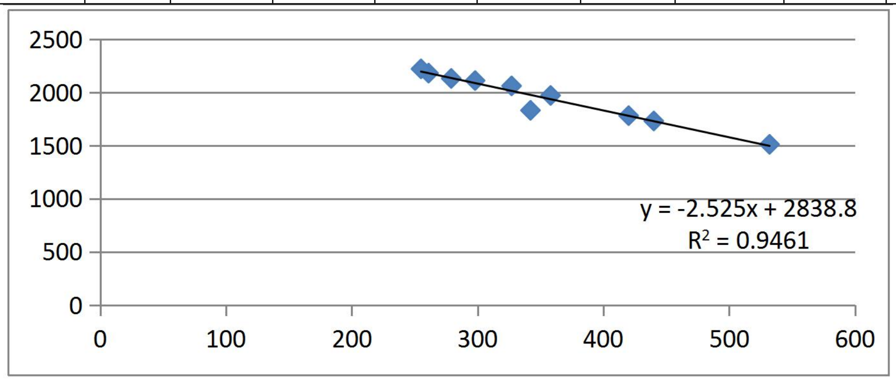
3.2 Overview of Chinese Maritime Surveillance System's Role

3.2.1 Relationship Between Maritime Accidents and Chinese MS System

In last 10 years (2005-1014), major maritime casualties in China have been significantly reduced, thanks to the combination efforts of maritime technology advancement, seafarers training and relevant maritime safety measures, among those, maritime surveillance system is credited as the crucial factor which lead to the continuous drop of maritime casualties. Table 3.1 and figure 3.1 have proved high negative correlation ($R^2 = 0.9461$) between maritime casualty and MS system (which capability is simplified by annual financial input), and indicate MSA should continue to invest greatly into the system to promote capabilities of MS system, and further prevent maritime casualties from happening.

Table 3.1 Statistics of Number of Accident and Budgets for Chinese MS system (Source: Compiled by author based on statistics from China MSA)

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Number of Maritime Casualties	532	440	420	342	358	327	298	279	261	255
Budget for MS system (million RMB)	1510	1730	1780	1830	1970	2060	2110	2130	2180	2220



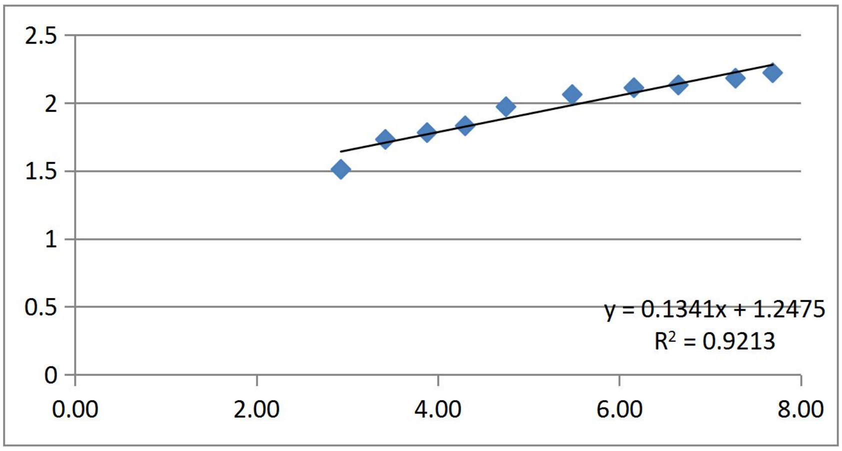
Regression analysis of number of accident and China MSA annual budget

3.2.2 Relationship Between Port Throughput and Chinese MS System

During the same period, the drastic increase of port throughput in China has also been attributed to the gradual modernization of Chinese MS system which effectively guarantees the safe and rapid development of Chinese maritime industry (ports, shipping lines and related industries). Table 3.2 and figure 3.2 reinforces the above statements and prove the high positive correlation ($R^2 = 0.9213$) between Chinese main ports throughput and Chinese MS system development.

Table 3.2 Statistics of Main Ports Throughput and Budgets for Chinese MS system (Source: Compiled by author based on statistics from China MSA)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Main Ports Throughput (billion ton)	2.93	3.42	3.88	4.30	4.75	5.48	6.16	6.65	7.28	7.69
Maritime Budget for MS system (billion RMB)	1.51	1.73	1.78	1.83	1.97	2.06	2.11	2.13	2.18	2.22



Regression analyses of main ports throughput and China MSA budget[9]

[9] The reviews indicate MS system is highly positively related to maritime safety and maritime industry

Flowing from the above analysis, it could be concluded that Chinese MS System does have a significant role in improving maritime safety in China, thus the Chinese MSA should continue to engage in modernizing the current MS system.

3.3 Qualitative Study of the Chinese Maritime Surveillance System

As noted from Chapter 2, Chinese MS System is far from perfect, in order to improve its performance and effectiveness, more researches are required. Therefore, a qualitative research method, which includes discovering problems from people's perspective (Caelli et al, 2003), is utilized to enquire information about the current Chinese MS system performance and find out associated problems and challenges.

3.3.1 The Method for the Qualitative Research

A semi-structured interview was designed for the qualitative research, thanks to the characteristics of the semi-structured interview which allows the author to have a degree of control over responses of interviewees during the processes. Also, considering the chosen interviewees are working at different positions in different China MSA departments and the current location (Dalian) of the author, semi-structured interviews mostly took the combined form of face-to-face and telephone interview to perform an investigation.

3.3.2 Procedures and Participants Sampling

In the semi-structured interviews, to better know and compare the cognition of different MSA staff about MS system, 6 members are selected from management level, while the others have been chosen from the frontline staff randomly (detailed information please view Appendix B), subsequently 12 interviews were conducted, 5 out of which were face-to face interviews and 7 were telephone interview. Two days prior to interviews, the interviewees were given an overview of a list of questions, which is prepared in advance (for full version, please see Appendix C), to be informed about the objectives of the research. After gaining permission from interviewees, the interviews were recorded for accurately collecting the required data. One sample interview transcripts can be seen in Appendix D.

3.3.3 Results

The information obtained from the Semi-structured interviews could be broadly categorized into following categories:

3.3.3.1 Data Source

The general performance of Chinese MS system has been confirmed by most of the participants, however, all the interviewees have expressed concerns, like interviewee A, C and F:

'Although we have a nominal comprehensive MS system, the sub-systems are usually seperated and the information obtained cannot be effectively utilized, therefore the system is not effective as it may seem'. **(A)**

'We have so many VTS centers and AIS stations along the coasts, however, when something odd happen offshore, we still cannot rely on the system as there is no cross-checking mechanism'. **(C)**

'We can only rely on what we have here, if something (accident) happens beyond the reach of the system, for example AIS, we can do nothing about it. LRIT and Sat-AIS are just too distant (and expensive) for us to use'. **(F)**

The information provided reveals that the Chinese MS system lacks of data fusion system, cross-checking mechanism and down-to-frontline implementation of new techniques, which are also stressed in 2.2.4.1 and 2.2.4.2.

3.3.3.2 Accuracy

According to the interviews, the accuracy of vessels detection, tracking and monitoring has been emphasized by many participants, for instance interviewee B and F have said:

'The problem I encounter the most as a VTS operator here is the inaccuracy of the monitor data, which sometimes cannot tell the really position or the ship type, even I use AIS as complementary tool (which is also not really reliable). Without the accurate data, it is hard for me to carry out the daily duty'. **(B)**
'False alarm is concerned, because the (MS) system is not really reliable, for instance the currents or small floating objects might easily be recognized as vessels by the VTS radar, sometimes is difficult for us to discern especially in busy water' .**(F)**

The above statements coincide with the disadvantages presented in 2.2.1 and 2.2.3, which indicate the accuracy of the acquired data needed to be adjusted.

3.3.3.3 Readiness

During the interviews, frustrations have been expressed by the participants in regard to the readiness of existing system, as interviewees E, F and I have stressed:

'In case of emergency, the current mean we can use is the maritime patrol ship, which is too slow in reaction and speed, it is too late for everything sometimes!' **(E)**

'The problem bothers me the most is the evidence gathering for illegal discharge of vessel-source pollutants, the existing means are either no use or too slow, many times we can only watch pollutions happening without arresting those responsible'. **(F)**
'We can only rely on human power and patrol ships to tackle those illegal transports and sand dredging, which are not effective and adding a lot of burdens onto us'. **(I)**

The arguments presented by these participants have also reinforced the statements introduced in the 2.2.1, 2.2.2 and 2.2.6.1, which reveal the needs for Chinese MS system to actively improve its overall readiness.

3.3.3.4 Falsifying Data

The other problem raised by the participants is the current system does not have an effective way to counter falsifying data, as participant D and G stated:

'It is extremely hard to prosecute those suspects (in cases of oil pollution) unless we can catch them at scene, because they will usually operate beyond the system's monitoring range and falsifying AIS data'. **(D)**
'Without doubts, the most difficult things in managing maritime safety at sea is those fishing boats and sands-gravel ships, which don't have AIS or intentionally switch-off their AIS in order to escape our monitor, we don't have so many resources to verify the overall situation in our jurisdiction'. **(G)**

The problem, which has been recognized by others (Ray et al, 2015), is not unique in Chinese MS system and corrective measures are imperative, in order to enhance maritime safety, security and protection of environment.

3.3.3.5 Cost Effectiveness

The final issue concerned is the cost associated with maritime surveillance, as pointed out by interviewees A, C and J:

‘’A lot of innovative techniques have been inserted into the system, but the cost-effectiveness is a concern, like the SAR and manned MPA which account for a lot of resource but provide only limited support for the maritime surveillance’. **(A)**
‘The so call long range surveillance measure is not really helpful, we don’t use it at all, but I heard we pay a lot for their usages. It is pity, we should focus on improving the coast based system like VTS and AIS’. **(C)**
‘As a frontline staff of maritime law-enforcement, the current law enforcement measure is a bit outdated and expensive too, for instance, to catch those illegal sand transport ships we have to stay in the middle of the seas, like cats and mice’. **(J)**

The quoted lines indicate that the Chinese MS system needs more cost-effective measure to improve its efficiency and effectiveness, which are emphasized in the previous sections 2.2.4.3 and 2.2.6.2.

3.3.4 Discussion

The problems found during the qualitative research are summarized in table 3.3:

Table3.3 Summary of the problems gathered. (Source: made by the author)

Number	Problems within the MS system	Participants
1	Data fusion is yet in place, and lack of cross-checking mechanism and long range surveillance capability	A,C,F
2	Many acquired data is not accurate and the false alarm rate is a concern for wasting administration resource	B,F
3	Slow in reaction to emergency, ineffective in gathering	E,F,I

	evidence in terms of pollution or maritime casualties	
4	Acquired data could easily be manipulated; current measures cannot pinpoint those suspects	D,G
5	Generally expensive and not cost-effective for providing support for maritime surveillance	A,C,J

Based on the findings, there are some implications for the decision maker(s) of MSA and the usage of Chinese MS System: **firstly** it is imperative for MSA to effectively combine different vessel surveillance systems and thereby enable them to implement maritime surveillance performance more effectively; **Secondly**, the establishment of a expeditious maritime response system is paramount for MSA in its next phase of development; **Finally**, a more proactive and cost-effective MS system should be in placed to overcome the problems encountered by MSA.

3.4 Overall Maritime Risk Analysis

Beside the problems mentioned, the general maritime risks in the years ahead is becoming an upward trend which requires China MSA to take additional efforts and measures to deal with.

3.4.1 Maritime Dangerous Situation Risks

According to the China MSA[10] (2011a), the maritime dangerous situation index includes the number of major maritime accidents and casualties, and the influence factors can be categorized as vessel, crew, waterway, metrology and management aspects, based on the statistics from 2005-2014 (3.2.1 & 3.2.2), the relevant factors are calculated in the following sections.

[10] The report calculated and summarize the maritime related risks based on the model proposed by TPRT

1. Vessel Influence Factor

The vessel influence factor is mainly consisted of vessel structure change rate (the variance is -0.0238) and maritime casualty change rate (the ratio of this element in maritime casualty is 0.0453), considering the ratio of the factor related accident (12%), therefore the vessel influence factor change rate (β_1) can be calculated as:

$$\beta_1 = (-0.0238 + 0.0453) \times 12\% = 0.0026$$

2. Seafarer Influence Factor

This factor is consisted of crew structure change rate (0.0117) and crew accident change rate (-0.1178), considering seafarer influence factor related accidents are about 61% of the total sum, the factor can be calculated:

$$\beta_2 = (0.0117 - 0.1178) \times 61\% = -0.0647$$

3. Waterway Influence Factor

This factor mainly considers the change rate (0.0735) of the ratio of this element related accidents in total strand and groundings cases, combining the 2% waterway related accident ratio, the factor is calculated as:

$$\beta_3 = 0.0735 \times 2\% = 0.0015$$

4. Meteorology Influence Factor

This factor focus on the change rate of the ratio of meteorological factors in collision and sinking accidents (0.0987), considering the meteorological factors related accidents' ratio (13%), the factor could be calculated as:

$$\beta_4 = 0.0987 \ 13\% = 0.0128$$

5. Management Influence Factor

The factor mainly includes the change rate of the ratio of management factor in fire and explosion accidents (0.1571), considering the ratio of management related accidents (1%), the factor can be calculated:

$$\beta_5 = 0.1571 \ 1\% = 0.0016$$

6. Comprehensive Influence Factor

To sum up the all the influence factors discussed, the comprehensive change rate of influence factor can be calculated as β:

$$=\beta_1+\beta_2+\beta_3+\beta_4+\beta_5=0.0026-0.0647+0.0015+0.0128+0.0016=-0.046$$

Therefore, the predicted risks (U_t) associated with maritime transport in China could be calculated as:

$$U_t = U_{t\,(2005\text{-}2014)} \times (1+\alpha_i)^5$$

And the predicted risks (U_c) associated with maritime casualty in China could be calculated as:

$$U_c = U_{c(2005\text{-}2014)} \times (1+\alpha_i)^5 \times (1+\beta)$$

The Annual variance α can be deducted from 3.2.1 and 3.2.2

In sum, the calculations all point to the increasing trend of overall maritime risk in China for the foreseeable future, and thus China MSA should really be prepared.

3.5 Chapter Summary

This chapter introduced the relationship between maritime surveillance system, maritime development and related accidents, which proved the positive influence from the modernizing Chinese MS system. In addition, the author also carries out a qualitative research to find out problems related to the MS system which were summarized into 5 categories for further study (three implications for system improvement). In final part, the author briefly calculated the predicted overall maritime risk in China for the foreseeable future, which should be carefully managed and dealt with by China MSA.

CHAPTER 4

ANALYSIS OF ALTERNATIVE SOLUTIONS

4.1 Introduction

The protection of coastal areas is becoming an essential requirement for MSA because of increasing risks like illegal transport and oil spills. Moreover, the control of vessel traffic is often correlated to environment protection issues, since vessels carrying hazardous cargos can cause catastrophic disasters[11]. As discussed, no single system can provide a completed maritime surveillance solution. Therefore the Chinese MS system needed improvements to overcome its inherent problems and address the challenges ahead. As noted earlier, three implications are needed by the system: **a)** a high degree of data fusion system should be established, the challenge of advanced MS systems is not about quantitative gathering capability, but is processing and integrating information gathered in a clear and concise way to give a adequate information support for decision maker(s); **b)** a high level of readiness should be reached, which allows timely detection and prevention of events threatening maritime safety and environment; **c)** a high rate of cost-effectiveness should be promoted, since cost-effectiveness is a one of the vital prerequisites for a public domain organization like China MSA. Hence, in this chapter the author will find some alternatives solutions according to implications mentioned, and determine the most suitable solution for China MSA maritime surveillance system.

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[11] i.e., Exxon Valdez, Prestige and Erica

4.2 Alternative Solutions

As mentioned earlier, Bloisi et al (2015) contended modern maritime surveillance by maritime authorities is a very challenging task, which include wide monitored areas, high dynamic background (i.e., waves and wakes) , weather issue (severe weather) and night-time monitoring. Therefore, the author will take these relevant criteria into consideration during the search for alternative solution to enhance Chinese MS system. In following sections, several innovative potentials and off-the-shelf solutions will be analyzed.

4.2.1 Ship Board VTS

The effectiveness of VTS has been emphasized by many，thus in order to enhance the functionalities of current VTS, ideas of ship-board VTS has been brought up. As Wu (2008) proposed, the combination of VTS and MPV system can be a powerful tool to overcome some drawbacks of VTS (i.e., limited coverage, blind-zone and false radar signal), in addition with the visualization of VTS (i.e., Transas; Figure 4.1), this combination seems to be an appealing approach.

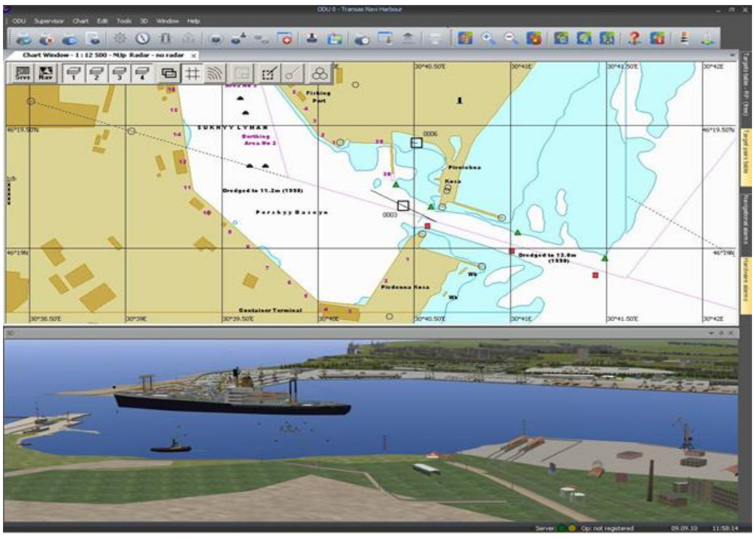

Figure 4.1 3D Visualization of VTS system (source: Transas.com)

In fact, MSA has conducted several experimental projects of shipboard VTS, one of those was in Shenzhen MSA, but the results showed this method was neither effective nor cost-effective: **1)** although the vessels seemingly enlarge the surveillance range, the altitude of the vessels severely restricts the radar signal coverage (i.e., block by islands); **2)** the deployment of vessels is highly depended on weather conditions, which in turn affect the effectiveness; **3)** the usage of this proposal is not cost-effective, due to the high expenditure of fuel consumption and maintenance of MPVs.

4.2.2 Buoy-mounted Maritime Surveillance System

The short range of the mostly shore-based MS measures have been a deficiency in current MS system, so as to enlarge the monitor range, a buoy-mounted system has been propose, for instance, Lessing et al (2006) claimed that buoy-based AIS system would effectively improve the shore-based AIS shortcomings. While Fefilatyev et al (2012) suggested that an open-sea visual MS system could be built by non-stationary CCTV cameras via existing buoys, which could generally increase visual monitoring range of current system[12].

Nevertheless, as Sat-AIS system has already reached the goal of enlarging AIS coverage, and problems of CCTV surveillance like limited footage range, high weather dependence and difficult in monitoring certain vessels (Bloisi et al, 2015) have not (or would not) been resolved. In addition, the bottlenecks of data transport of off-shore CCTV system and high costs associated with the system's maintenance further lead to this proposal not suitable.

[12] Pilot programs have been established in the United States of America

4.2.3 *Satellite-based SAR [13]Surveillance System*

With the smooth development of Beidou System (Wang and Wang, 2011), the establishment of satellite-based SAR surveillance system (Foged et al, 2015) has been made possible for China MSA, and with satellite-based SAR's complementation, which further provide a large-range and near real-time monitoring capability, the current Chinese MS system can become more comprehensive (Figure 4.2).

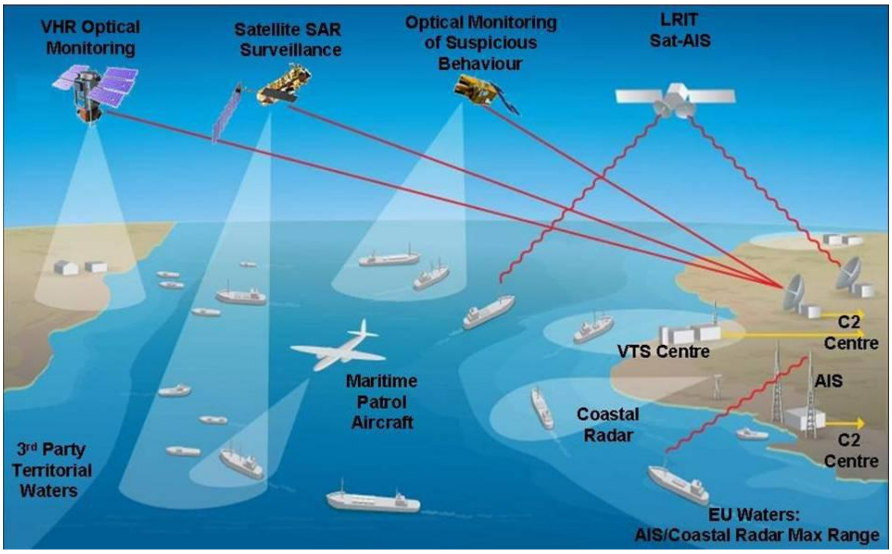

Figure 4.2 Satellite-based MS System (Source: spie.org)

But according to Fischer and Bauer (2010), satellite images can provide photos over a wide-range of area, yet the temporal resolution is relatively low, and images are only a snapshot at a certain time. In addition, as MSA requires more (China MSA, 2011a) real-time, vessel/waterway specific and cost effective maritime surveillance measures which satellite-based SAR system cannot provide. Therefore, the current satellite-based SAR technique might falls out of the option basket.

[13] Or named space-borne SAR

4.2.4 *Over-The-Horizon-Surface Radar System*

The other kind of option for long-range maritime surveillance measure is Over-The-Horizon Surface Radar (OTHS), which was originally designated for ocean remote sensing but have been demonstrated to be very reliable in detecting and tracking vessel at over-the-horizon distances (Figure 4.3), overcoming many limitations derived from the application of shore-based surveillance systems. Additionally, the usage of OTHS radar combines with other maritime surveillance methods, i.e., AIS and SAR, can grant continuous-time coverage of large areas and provide tracks for non-reporting vessels or detect anomalies in the far-away-from shore vessel-routes. Hence, OTHS radar can contribute to national-level MDA (Frazer et al, 2010; Braca et al, 2015).

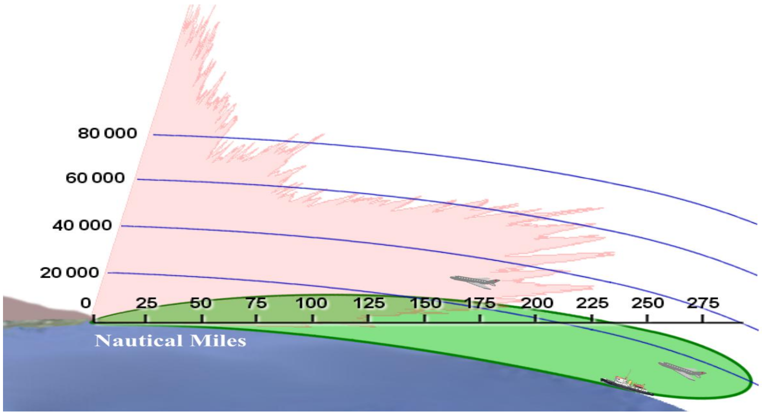

Figure 4.3 OTHS radar coverage range (Source: http://www.radartutorial.eu/)

Current OTHS-Radar possesses significant but limited wide-area maritime surveillance capability. However, the application of OTHS-Radar system has been applied exclusively to military purpose, civilian OTHS radar has mostly remained in theoretical testing state and far from practical application, basically due to the weak echo signal, noise and interference effects (Maresca, et al, 2014). Therefore, MSA should not incorporate OTHS radar into MS system in the near future.

4.2.5 Unmanned Aerial Vehicle (system)

After analyzing the proposals above, it is difficult to find one suitable complementary solution to Chinese MS system. Nevertheless, one of off-the-shelf solutions is still appealing and promising for maritime surveillance application, which is unmanned Aerial Vehicle (UAV) system. In order to delve deeper into this technique, the following sections will detail UAV's background, advantages, role of maritime application and limitations.

4.2.5.1 Background Information

According to Ashworth (2001), the UAVs are "*Powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry payloads*", and "*these aircraft would usually carry mission-specific sensor payloads or dispensers. Inclusive vehicles could fly either autonomous, pre-programmed profiles, or be remotely piloted vehicles (RPV)*". A typical UAV is consisted of different components, namely aircraft body, processing unit, power unit, sensing unit, communication unit and remote control unit, and the detailed UAV configuration is illustrated in Figure 4.4.

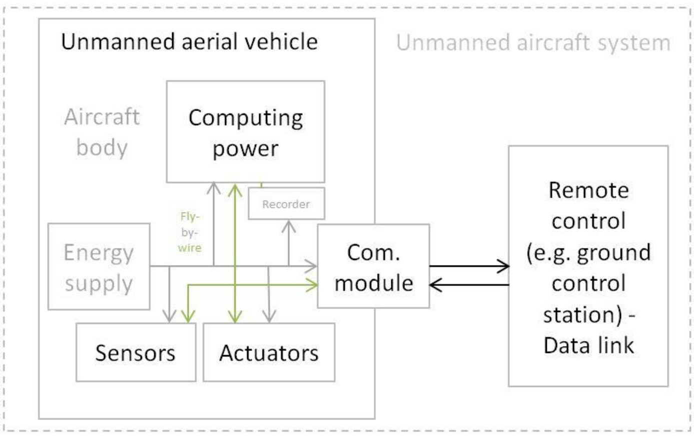

Figure 4.4 Typical configuration of a UAV (Source: Vijayavargiya et al, 2016)

UAV technology, which was originated for military combat purpose, has been developed swiftly in recent years. The current (5th) advanced generation of UAV (Figure 4.5) can provides the long-ranged, incessant data process and transport capability which is one of the most important requirements for vessel detection, tracking and monitoring. Hence, it is ideal for maritime surveillance.

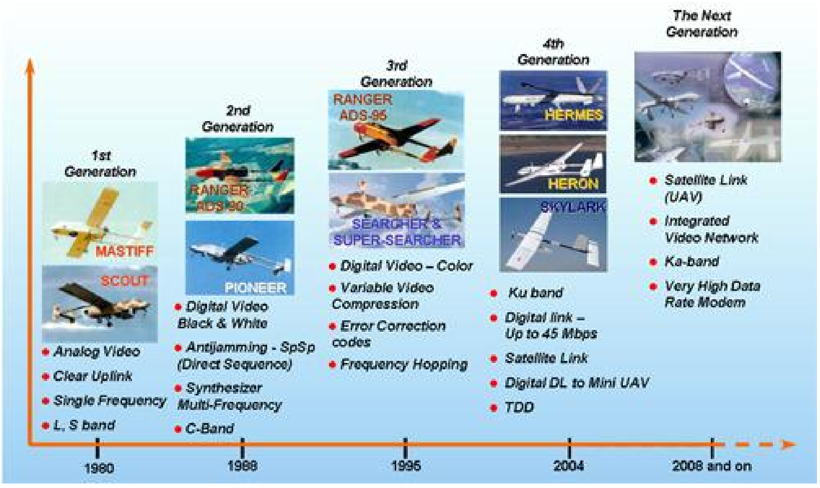

Figure 4.5 Evolution of UAV (source: http://www.tadspec.com/)

During the rapid development, UAV can be broadly categorized according to function and size. Based on Kückelhaus (2014), the functional categories of UAV system can be showed in Table 4.1

Table 4.1 Functional categories of UAV (source: compile by the author)

Number	Category of UAV	Function
1	Target and decoy	providing ground and aerial gunnery a target that simulates an enemy aircraft
2	Reconnaissance	providing battlefield intelligence
3	Combat	providing attack capability
4	Logistics	delivering cargo
5	Research and development	improve UAV technologies
6	Civil and commercial UAVs	aerial photography, data collection

According to Gupta et al (2013), the UAVs can be classified into 6 categories, which illustrated in Table 4.2.

Table 4.2 Category of UAVs (Source: Gupta et al, 2013)

Category	Weight of UAV	Normal Operating Altitude	Radius of Mission	Endurance	Altitude	Normal Employment	Typical Use
MICRO	< 2 kg	Up to 200ft AGL	5 km (LOS)	A few hours	Very Low Altitude	Tactical Platoon(Single operator)	Reconnaissance, inspection, surveillance
MINI	2-20 kg	Up to 3000ft AGL	25 km (LOS)	Up to 2 days	Low Altitude	Tactical Sub-Unit(manual launch)	Surveillance, data gathering
SMALL	20 -150 kg	Up to 5000ft AGL	50 km (LOS)	Up to 2 days	Low Altitude	Tactical Unit(employs launch system)	Surveillance, data gathering
TACTICAL	150-600 kg	Up to 10,000ft AGL	200 km (LOS)	Up to 2 days	Low Altitude	Tactical Formation	Surveillance, data gathering
MALE	> 600 kg	Up to 45,000ft AGL	Unlimited (BLOS)	Days/ weeks	Medium Altitude	Operational/ Theatre	Surveillance, cargo transportation
HALE	> 600 kg	Up to 65,000ft AGL	Unlimited (BLOS)	Days/ weeks	High Altitude	Strategic/ National	Surveillance, data gathering, signal relay

As the focus of this paper, civilian UAV, which the size is between small and tactical size aircraft, is the suitable candidate to complement the Chinese MS system.

However, without supporting systems, a perfect-performance UAV is just another airborne-vehicle, and also meaningless in term of maritime surveillance, which requires sophisticated data acquisition, transportation, processing and analysis. Therefore, a UAV with relevant and necessary sub-systems, like ground control station, remote control network, launch and recovery sub-system and etc, is qualified to be a UAV system which is suitable for multiple missions of maritime surveillance. As Austin (2011) points out, such system "*comprises a number of sub-systems which include the aircraft (often referred to as a UAV or unmanned air vehicle), its payloads, the control station(s) (and, often, other remote stations), aircraft launch and recovery sub-systems where applicable, support sub-systems, communication sub-systems, transport sub-systems, etc*", which is depicted in Figure 4.6.

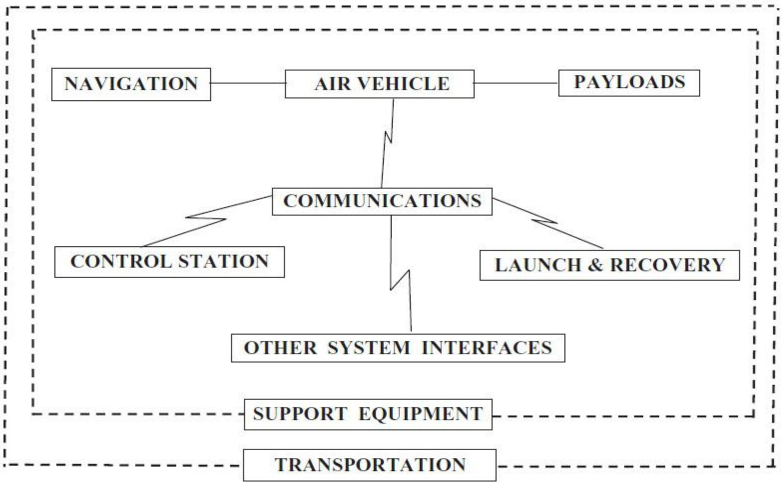

Figure 4.6 UAV systems—a functional Structure (Source: Austin, 2011, p9)

4.2.5.2 Advantages of UAV System

A large number of factors highlighted the technical and practical advantages of UAV system, which were commonly listed included:

a) High surveillance performance capability

According to Liu et al (2014), the overlook characteristic of UAV system provides maritime authorities a much higher (12 times) surveillance range comparing with other non-stationary surveillance systems (i.e., MPV, buoy-mounted system), under the same distance and visibility conditions. Also, with the help of network relay and supplementary systems, UAV system grants the authority the ability to detect, track and monitor a suspected vessel (i.e., maritime accidents, oil spills) at any time in any place (Australian Government, 2015; Vijayavargiya et al, 2016), to effectively eliminate the 'blind zone' of the MS system. Hence, UAV system can overcome the shortcomings of shore-based surveillance systems and MPV which were described in 2.2.1-2.2.3 & 2.2.6.1.

b) High practicability

Due to the characteristics of agility (approximately 60-400 km/h), maneuverability, portability (light weight aircraft body) and readiness (Zhou et al, 2013), UAV system can be competent for multiple tasks of maritime surveillance, like emergency response (Yeong et al, 2015): UAVs can expeditiously reach to the sites in short notice, the low-altitude even-pace flying provides emergency response team the capability of short-range monitoring and shooting high-resolution videos, which are valuable for decision maker(s) to avoid 'information delay' and unnecessary losses. In addition, the UAV system equipped with adequate devices can be utilized in life saving during the search and rescue operations and intelligent information gathering for oil-spill accidents (Liu, 2014). Such high practicability of UAV offers MS system the flexible capability to complement the existing systems, like VTS, AIS, CCTV and SAR.

c) Low associated risks

The other advantage of applying UAV is its low associated risks (Australia Government, 2015), ad hoc, comparing with MPA system (i.e., pilots) during the circumstance of severe weather and high-risked environment. UAV system can effectively cooperate with MPV and MPA system which described in section 2.2.6.1 and 2.2.6.2, timely arriving at scene to carry out high-risked and high-intensity missions (De Cubber, et al, 2013) like monitoring dangerous cargo vessel accidents (i.e., leakage, explosion). Also, this low risked characteristic provides UAV system the ability to execute 24/7 duties even in dangerous areas and heavy weather situations if necessary, (Zhou et al, 2013) which can complement the MS system by adding another effective dynamic maritime surveillance measure

d) Low requirements

Unlike MPV or MPA systems, the requirements for operating and maintaining a UAV system are relatively low (Liu et al, 2014), especially compared with high expenditure for initial cost of aircrafts purchase and pilots recruitment. Moreover, qualification for operators of UAV system is not so restricted, after adequate trainings and assessments, ordinary staff could be qualified to operate a UAV, thus greatly facilitate the deployment of UAV system. On the other hand, UAV (i.e., rotary UAV) can be launched and recovered in a relatively small space (Zhou et al, 2013), which lead to building of special UAV bases and matched garages unnecessary. Hence, low requirements from UAV system could further enhance the flexibility and compatibility of the Chinese MS system which is urgently required.

e) High cost-effectiveness

The final advantage of UAV system application is its superior cost-effectiveness (Lawler, 2010), especially in comparison with other measures (Table 4.3).

Table 4.3 Economic comparison of different maritime surveillance measures

Measure	**Initial Cost**	**Fuel Cost 100km/kg**	**Annual Cost**	**Personnel**	**Auxiliary Facility**	**Remark**
VTS	15 million RMB	N/A	0.5 million RMB	About 5	Radar Tower	1.High initial cost 2.High maintenance 3.Constant renewal
MPV	27million RMB	1100	1 million RMB	10 Crew member +	Maritime Bases	1.High costs 2. Complicated system
Manned Helicopter	50 million RMB	40	5 million RMB	2 pilot+ ground service	Designated Areas	1.High costs 2.High risks 3.High requirements
Manned Fixed-wing	30 million RMB	80	8 million RMB	2 pilot+ ground service	Runway Bases	1.High costs 2.High risks 3.High requirements
UAV	2 million RMB	3	0.3 million RMB	3 people	Almost anywhere	1. Relatively low costs 2. Low risks 3. Low requirements

Source: compiled by the author based on Zhang (2015)

According to Austin's (2011) research, UAVs equipped with surveillance sensors typically are only 3–4% of the weight, require only 2.5% of the engine power (and 3% fuel consumption) and 25% of the size (wing/rotor span) of a light aircraft, therefore the cost of acquisition and operation of UAV system is much lower than the manned platforms (MPV, MPA) including training, components and maintenance. The excellent cost-effectiveness of UAV system can also be augmented by applying UAV system into daily harbor maritime patrol which could significantly lower manpower and fuel cost (Duan, 2015), to detect and eliminate hidden dangers in time, by using autopilot technology (Chao et al, 2010).

4.2.5.3Limitations of UAV System

Although UAV system is filled with advantages and ideal for maritime surveillance missions, the technology and its related application are not without limitations and potential problems:

a) Limited coverage

One of the problems UAV system encounters in maritime application is its limited network coverage (Shenzhen MSA, 2015b), the LOS of typical medium size UAV is usually about 100-200 kilometers of which the fuel (i.e., battery or diesel) and remote signal range (i.e., typical station-UAV communication range is about 180km; (Shenzhen MSA, 2015b)) are taken into consideration. Therefore, single or a few UAVs might be able to cover ports and the adjacent areas, but the waters further offshore are out of the reach of UAV surveillance range, which might restricts the application of UAV system in Chinese MS system.

b) Malfunction risk

The other potential problem is malfunction risk which usually associated with electronic devices. Although reliability of UAV system is championed by many (i.e., Zhou et al, 2013; Liu et al, 2014; and Yeong et al, 2015), the harsh environment (high salinity, high humility and high wind-force) within which UAVs are supposed to work daily would significantly increase the risks of systems' (i.e., navigation, remote control) failures or even break-down, which might ultimately results in total loss of the UAV and collateral loss in case of related accidents. In addition, electronic communication channel might be vulnerable by other radio interference (Zhang, 2015b), which also raise the possibility of losing control of UAVs during operations.

c) Human factors

The third limitation is human factors. As Hopcroft et al (2006) claim, "*despite the aircraft being unmanned, it is important to remember that humans are still heavily involved in the operation of UAVs*". Therefore, for the remotely controlled of automated UAVs to be used safely and effectively, a number of human factors need to be considered and accounted for, like potentials for human errors during the surveillance mission planning, route design, maintenance and operations. Also, the automated UAV systems, which like any other newly introduced technologies (Lützhöft et al, 2002), might generate potential hazards during their operations in ports and busy waterways (Hetherington et al, 2006).

d) Technical and weather limitations

The final limitation in according with the maritime surveillance application of UAV system is the technical limits and uncertainties. For example, the study of Saif et al

(2014) revealed the difficulties of image acquisition of fast moving objects and the problem of transporting large amount of data back to control station stably and reliably. Also, even the deployments of UAVs are considered low-risked, the dispatchment of UAVs are still heavily determined by weather conditions, because of the properties at stake.

4.3 Summary of Potential Solutions

As discussed, a few innovative potential and off-the-shelf alternative options, which have distinct advantages and disadvantages (Table 4.4), are available for improving the current Chinese MS system. After taking criteria detailed in Chapter 3 and section 4.1-4.2, the author proposes the application of UAV system as a suitable solution, which will be detailed in next chapter, to problems and challenges faced by the China MSA. Along with the necessities mentioned, the feasibility of applying UAV technology will also be analyzed in chapter 5.

Table 4.4 Summary of the Potential Solutions (Source: made by the author)

Solution	Advantage	Disadvantage
Ship board VTS	1. Easy to equipped; 2. Flexible for deployment; 3. Enlarge existing VTS monitor areas	1. Easily be blocked; 2. Restricted range; 3. Low cost-effective
Buoy-mounted surveillance system	Enlarge existing MS system monitor areas	1. Limited range; 2. Restricted usage; 3. Maintenance cost
Satellite-based SAR	1. Wide-range areas surveillance; 2. Near real-time surveillance	1. Not real-time; 2. Low resolution 3. Low cost-effective
OTHS radar system	Long-range real time surveillance	1. No civilian usage; 2. Expensive
UAV system	1. High surveillance performance capability; 2. High practicability; 3. Low associated risks; 4. Low requirements; 5. High cost-effectiveness	1. Limited coverage; 2. Malfunction risks; 3. Human factors; 4. Technical limits

4.4 Chapter Summary

In this chapter, the author has searched various kinds of alternative measures to solve the problems and challenges faced by the Chinese MS system, in line with the criteria discussed in previous chapters and the beginning of this chapter. After careful study and comparison, the author deems UAV system, which the details of system will be provided in chapter 5, as an ideal solution for improving the effectiveness and enhancing the overall capability of Chinese MS system. Therefore, UAV system and related applications and constructions should be recommended to the decision maker(s) of China MSA for further research and consideration.

CHAPTER 5

ESTABLISHING OF UNMANNED AERIAL VEHICLE MARITIME SURVEILLANCE SYSTEM

5.1 Introduction

In recent years, UAV plays a more significant role in fields, inter alia, maritime patrol (Zhou et al, 2013; Liu et al, 2014), surveillance (Duan, 2015; Australian government, 2015) and search and rescue (Garratt et al, 2007; De Cubber, et al, 2013; Yeong et al, 2015), range of application of UAV has been expanded drastically, countries like United States (Weatherington, 2005), France and Japan have all implemented UAV system for maritime governance. In fact, with the relaxing control over low-altitude air space and the cancellation of vessels visa system in China (Zhang, 2015b), China MSA has initiated pilot programs of UAV in Guangzhou and Tianjin (Liu et al, 2014), but the way toward a comprehensive UAV maritime surveillance system is still far away, due to the lack of researches and legal hurdles. Also, as an innovative maritime technology, technical and management problems still exist within the UAV system, therefore, this chapter will introduce an appropriate UAV system designated for China MSA, including the system design, application range, limitations and recommendations, a feasibility analysis will be conducted, to further facilitate the establishment of a comprehensive Chinese maritime UAV system.

5.2 Proposed Solution

In addition to problems discussed in Chapter 3, the pending cancellation of vessel visa and rapid development of maritime transport (Shenzhen MSA, 2015b) require additional measures to achieve effective maritime governance for China MSA. Therefore, in order to substantially improve the effectiveness and enhance surveillance capability of the Chinese MS system, this paper proposes the establishment of a comprehensive UAV system, which can complement existing Chinese MS system (Figure 5.1) and facilitate the setting of 'three-dimension' (Liu et al, 2014; Zhang, 2015b) maritime surveillance system , to fully achieve the goal of effective maritime surveillance and expeditious search and rescue proposed by MSA (2011a; 2011b).

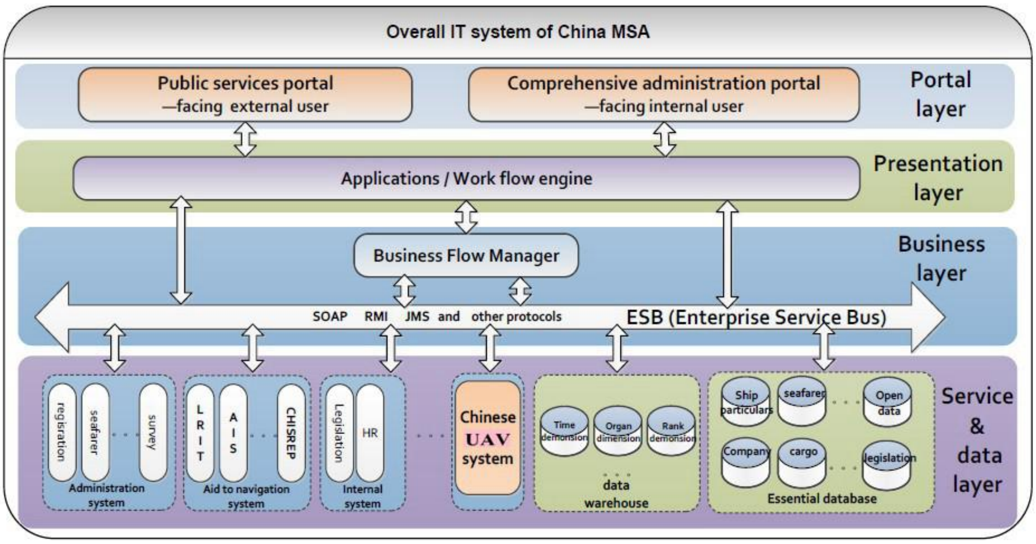

Figure 5.1 Expected overall IT system of China MSA
(Source: edited by author based on China MSA (2011b))

In accordance with criteria discussed and top-down design for the informatization of China MSA, the establishment of UAV should follow certain general principles:

a) Reliability

Due to the harsh environment surrounded by UAVs, UAV system should be as reliable as possible, for instance, reliable communication network and dependable electronic surveillance devices, in order to carry out daily missions.

b) Practicability

The establishment of UAV system should take various types of geographical landscapes and different MSAs conditions into consideration, to satisfy specific needs of maritime surveillance rather than the overall needs.

c) Cost-effectiveness

As an important public domain organization, the cost-effectiveness should be carefully evaluated, which means establishment of UAV system should take advantages of existing system network and be integrated with other MS systems, so as to lower associated cost as much as possible.

d) Easy for maintenance

One of the advantages of UAVs is its flexibility and portability, therefore proposed UAV system should be easy for maintenance and operation for ordinary staff of MSA.

5.2.1 Maritime UAV System Functionality

The proposed UAV system should be consisted of multiple functions which are based on the criteria discussed and the practical situation of MSA, the detailed functions of UAV system are described as follow:

a) Maritime law-enforcement

High-resolution camera and sensors equipped UAVs can be applied for aperiodic aerial maritime patrol, which can be a powerful deterrent for illegal transport, overloading, illegal underwater construction and dumping, to manage and guarantee the maritime safety and protection of environment in the jurisdiction of China MSA.

b) Emergency response

UAVs, which could arrive at scene in time, can provide needed aerial imagery for emergency response mission. Specifically, UAVs can monitor (dangerous) situations from the air and then forward those collected information, which are essential for emergency response, to decision maker(s) at ground/vessel for forming further action plans.

c) Search and rescue

Within UAV system, long range fixed-wing UAV or ship carried rotary-wind UAV (Figure 5.2) can cover large areas in a shorter period of time and provide access to difficult-to-reach areas, for missions like searching of MH370. In addition, life-saving appliance equipped UAV can immediately provide essential supports for victims (Yeong et al, 2015) of maritime accidents (i.e., SEWOL ferry).

Figure 5.2 Example of ship carried UAV (Source: Garratt et al, 2007)

d) Information relay

Beside emergency response, UAVs can act as an “information hub” (Figure 5.3) for various maritime missions, like maritime law enforcement, search and rescue and incessant maritime communication, which can be critically important in the absent of shored-based and satellite provided (i.e., maritime satellite) information network.

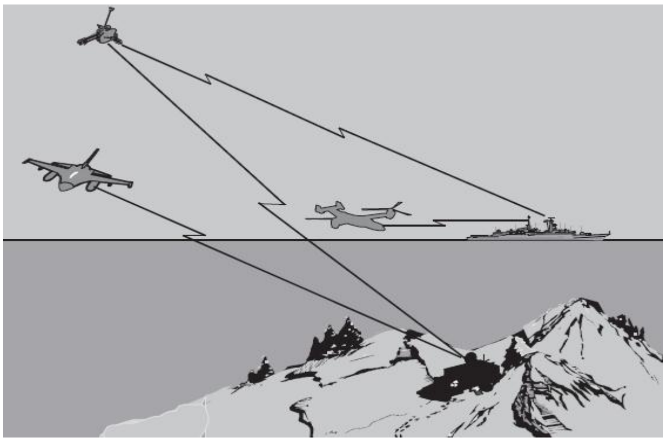

Figure 5.3 UAV Information/Data relay framework (Source: Austin (2011))

e) Oil spills and waste dumping detection

The early hours of oil spills or related accidents are crucial for containment and subsequent clean-up efforts, otherwise without early detection and containment, major oil spills could cause catastrophic disasters (i.e., Prestige). Therefore, UAV system should be able to provide timely first-handed information for emergency response mission. Additionally, UAV system should also provide an effective mean to pinpoint and track those responsible for illegal dumping (i.e., drainage or ballast water).

f) Navigation lantern maintenance

Navigation lanterns, which usually located at isolated islands and remote areas, are difficult for maintenance. In order to lower associated maintenance cost, UAV system can achieve cost-effective patrol and examine navigation lanterns by providing real-time working status and avoid unnecessary manned maintenance.

5.2.2 Requirements for Maritime UAVs

To achieve designated goals of UAV system mentioned, requirements for UAVs are listed as follow:

1) Low requirements for taking-off and landing (TOAL, i.e., rotary-wing UAV) and high reliability (no-failure life should be more than 2,000 hours);

2) Higher speed (Maximum speed should not be less than 70km/hour), adequate cruising radius (i.e., for harbor designated UAV, fully-loaded should not be less than 1.5 hour and 120 kilometers, idle loaded 2.5 hours and 200 kilometers) and sufficient anti-wind capacity (not less than 7 level of Beaufort scale);

3) Maximum cruising altitude should reach at least 2,000 meters;

4) Accurate location (latitude & longitude) identification capability and real-time (image) information transmit capability (two-way between control centers);

5) Autopilot or pre-planning route aerial patrol, automatically return to base or switch manual control in case of emergency;

6) Necessary safety protection procedures, for instance, dangerous zones identification, auto hazards avoidance, malfunction and fuel alarm, auto-return in case of losing control.

5.2.3 Off-the-shelf UAVs

To meet requirements listed above, there are a few advanced off-the-shelf UAVs available (Table 5.1) for the establishment of Chinese maritime UAV system:

Table 5.1 Off-the-shelf UAVs for Chinese maritime UAV system[14]				
UAV Type/ Nationality	**Performance**	**Features**	**Functions**	**Model**
LH-Aviation (France)	**1.**R-wind radius 2.5m **2.**Max speed 90km/h **3.**Max load 1.5 hours **4.**Max wind 8-level **5.**Max altitude 3048m	**1.** Easy to control **2.**Flexible; **3.**Expandbale; **4.**Portable **5.**Cost-effective	**1.** Real-time surveillance **2.** Law enforcement **3.** Traffic control	
NEOs-300 (Switzerland)	**1.**R-wind radius 3 m **2.**Max speed 120km/h **3.**Max load 2 hours **4.**Max wind 8-level **5.**Max altitude 3048m	**1.**High performance **2.**Safe and reliable **3.**Light body **4.**Excellent surveillance ability	**1.**Maritime surveillance **2.** Law enforcement **3.**Support for SAR **4.** Oil detection	
APID-60 (Sweden)	**1.**R-wind radius 3.3 m **2.**Max speed 110km/h **3.**Max load 4.5 hours **4.**Max wind 8-level **5.**Max altitude 3000m	**1.**Easy to control; **2.**Safe and reliable; **3.**Cost-effective; **4.**Adaptable	**1.**Maritime surveillance **2.** Law enforcement **3.** Emergency response **4.**Support for SAR **5.** Oil detection	
TANAN300 (France)	**1.**R-wind radius 4.5m **2.**Max speed 150km/h **3.**Max load 8 hours **4.**Max wind 9-level **5.**Max altitude 4000m	**1.**Easy to TOL; **2.** Easy maintenance **3.**High functionality **4.**Multiple mission capability	**1.**Maritime surveillance **2.** Law enforcement **3.**Emergency response **4.** Search and rescue **5.**Information hub	
U8 (China)	**1.**R-wind radius 3.7m **2.**Max speed 100km/h **3.**Max load 4 hour **4.**Max wind 8-level **5.**Max altitude 3600m	**1.**Easy to control **2.**Cost-effective **3.**Made in China	**1.**Maritime surveillance **2.** Law enforcement **3.**Emegency response	

(Source: compiled by the author based on sources online)

After researches of applicable and available UAVs for the Chinese MS system, it is clear from the table above that the rotary-wind UAVs would be the ideal component for the proposed establishment of Chinese maritime UAV system.

[14] All of the UAVs provided have already been prescreened by the Shenzhen MSA which the author as one of the participating members

5.2.4 Data Fusion System

It is of vital importance to generate real-time wide-area maritime monitoring pictures by UAV system for operators of the maritime surveillance system to carry out multiple missions. Nevertheless, without the cross-check of other real-time intelligence information (i.e., VTS, AIS and COMPASS), such pictures or videos are less reliable and effective for maritime authorities, especially within the ports and coastal regions. Therefore, a data fusion system (Figure 5.4) is required for the proposed UAV system to integrate its data with other intelligence sources from the existing MS system (Table 5.2), so as to maximize the effectiveness of proposed UAV system.

Table 5.2 Integrating maritime surveillance data of China MSA

Data Source	Content/Format	Origin Mean	Reliability	Availability
VTS	Dynamic Encrypted data	VTS MIS system	high	Readily available
AIS	Static/dynamic message standard data	AIS data base	high, except busy water areas	Readily available
CCTV	Dynamic video data	MSA data centers	Depend on weather	Readily available
LRIT	Semi-dynamic standard info data	LRIT data centre	High in Inmarsat-C terminal	Readily available
Sat-AIS	Static/dynamic message standard data	According to the contracts	Lower than AIS	Depend on the contract
SAR	Dynamic Image format	According to the contracts	High in most cases	Depend on the contract
COMPASS	Dynamic Encrypted data	According to the contracts	Medium	Depend on the contract
MPV	Dynamic data	MSA data centers	Relatively High	Relatively High
MPA	Dynamic data	According to the contracts	Depend on weather	Depend on the contract
UAV	Dynamic data	MSA data centers	Relatively High	Readily available

Source: compiled by author inspired by Sun (2015)

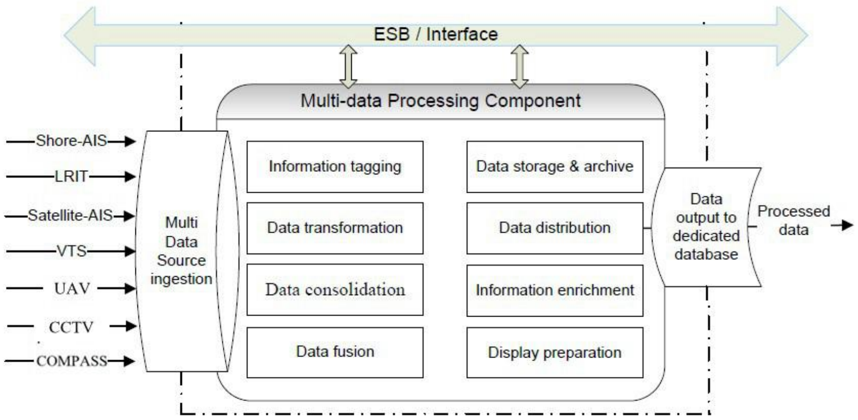

Figure 5.4 Proposed Data fusion system for Chinese maritime surveillance system (Source: edited by author based on Sun (2015))

5.2.5 Proposed UAV System Architecture

After above descriptions, it is clear that proposed maritime UAV system relies on rotary-winds UAV as flying platform which usually equipped with surveillance appliance like high resolution cameras, airborne-VTS, IR sensors and AIS system. To control and support UAVs, supporting ground control system should be consisted of at least two shore-based control centers, one portable control unit and one vessel-based control unit, which can directly or through relay data hub communicate or control UAVs by WIMAX or similar existing information network. The acquired information data can be transmitted back to the command center through these units, after integrating with other intelligence data (i.e., VTS) the information can thus be provided to decision maker(s) for further actions. Hence, UAVs, supporting control unites and data fusion system together can form a comprehensive maritime UAV system[15] (Figure 5.5) which can provide useful support and complement the Chinese MS system.

[15] The model is made by the author based on the pilot maritime UAV project proposed by Shenzhen MSA

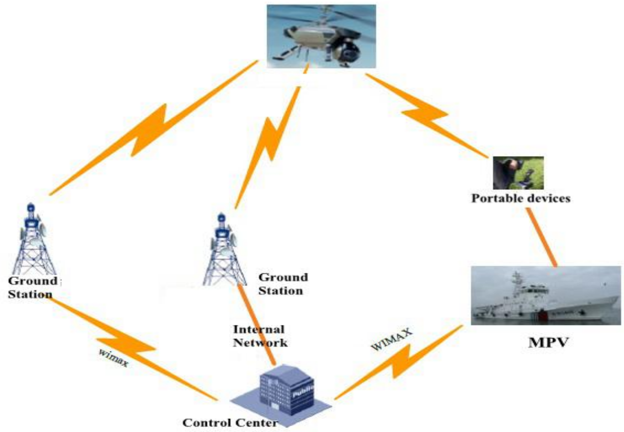

Figure 5.5 Architecture of proposed maritime UAV system (Source: made by author)

In addition, maritime UAV system should be further specified its distribution according to China MSA practical situation, which is similar with sub-systems of Chinese MS system, the UAV system should be comprised of at least one top-level command and control centers, 14 province-level command centers and various numbers of ground and vessel control unites. As of specific mission, each UAV system should be specified (Figure 5.6) in line with maritime zones outlined by UNCLOS (Mukherjee, 2015), areas beyond EEZ are not included[16]:

1) Port and adjacent areas (0-44.448km)

According to UNCLOS, 24 mile (12 miles territorial sea and 12 miles contiguous zones) off-shore areas are considered sovereign or semi-sovereign for the coastal State (China). Therefore, effective and sufficient UAVs (LH-aviation or NEOs-300 equivalent or above) should be deployed to carry out maritime surveillance missions like law enforcement, traffic control, fighting illegal transport and dumping, oil spills, emergency response and etc.

[16] This paper mainly focus on the validated jurisdiction managed by China MSA

2) Medium range areas (44.448-150km)

The areas further offshore (beyond 24nm or 44.448km) are within exclusive economic zone (EEZ) which the rights of the coastal State (China) diminished seaward, but there are still many interests at stake, like oil pollution accidents, search and rescue (Chapter 1), smugglings and potentially terrorist attacks. In order to deal with these risks and challenges, UAVs should be expeditious and powerful, like APID-60 or TANAN-300 equivalent or above.

3) Long range areas (150-370.4km)

The seas further than 150 km but still within the EEZ line are considered long range areas which are often not covered by conventional maritime surveillance measures mentioned, but thus areas are usually accident prone and difficult to monitor due to the distance and sea conditions. Therefore, UAVs designated for these areas should be at least as powerful as TANAN-300 or above.

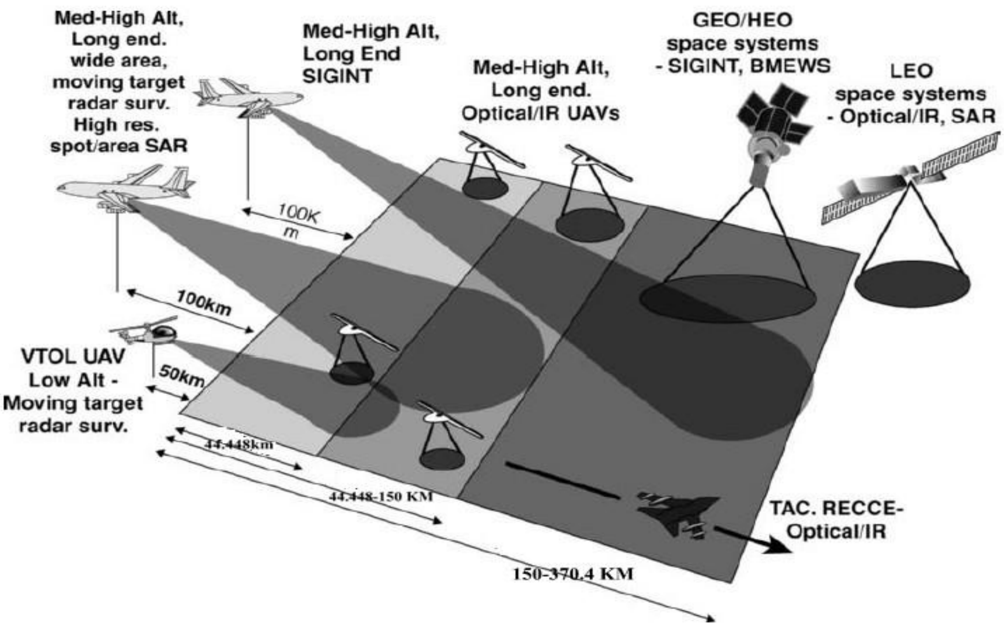

Figure 5.6 Distribution of UAVs
(Source: edited by author based on Austin (2011))

To sum up, maritime UAV system for enhancing the Chinese MS system has generally been introduced. A major advantage of the proposed UAV system is that a more comprehensive and effective MS system can be built by introduction of the real-time situation awareness provided system. Furthermore, the proposed UAV system can also complement the current MS system by filling the “surveillance gap” between shore-based and long-range maritime surveillance measures (Figure 5.7).

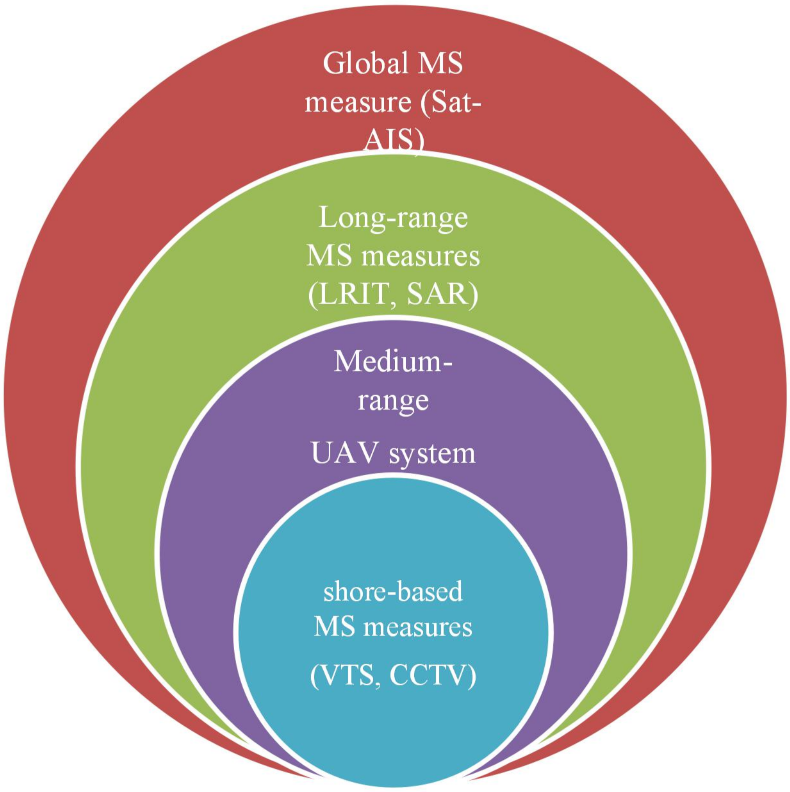

Figure 5.7 Classification of Enhanced Chinese MS System by surveillance range (Source: made by the author)

5.3 Feasibility Analysis of Establishing UAV System for China MSA

However, there is still a long way to go for the meaningful application of proposed maritime UAV system for China MSA, inter alia, administrative and legal problems (Zhou et al, 2013; Huang, 2014) will be difficult hurdles. In this section, this paper will conduct a feasibility analysis to summarize some problems and try to find out feasible solutions.

5.3.1 Administrative Issues

As an innovative measure and new add-in application for MSA, proposed UAV system related administrative problems, like procedures for UAVs missions, administrative integration with other systems, will be unavoidable and tricky. However, report of top-level design for the informatization for China MSA China MSA (2011b) and report 13th 5 years plans for maritime administration (TPRT, 2014) indicate that leadership has determined to fully modernize MSA with the Sensing Ship strategy (Figure 5.8). As crucial part of the overall strategy, author convinces such issues would be overcome by the strong supports from the MSA leadership.

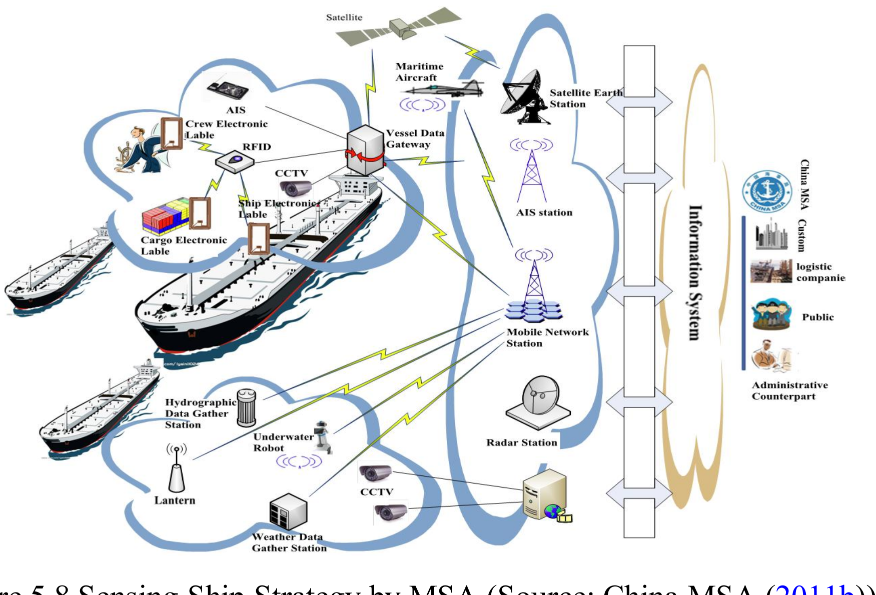

Figure 5.8 Sensing Ship Strategy by MSA (Source: China MSA (2011b))

5.3.2 Regulatory Issues

The single major obstruction for early application of UAV system for MSA in the past is the airspace regulation which imposed by the air force of PLA (Huang and Zhou, 2010). However, as a result of support from the leadership of Chinese government, the controls of low altitude airspaces are due to relax (Shenzhen MSA, 2015b), according to the Regulation for Managing the Usage of Low Altitude Airspace. In fact, from the results of pilot programs of MSA (Liu et al, 2014), thus issues could be resolved. Therefore, from the regulatory prospective, wide-range of applying UAVs for maritime surveillance related missions will be admissible, since most of working-altitudes of the proposed UAVs are well below 1000 meters.

5.3.3 Legal Issues

The other issues might worth concern is legal usage of electronic devices for law enforcement, which might be a problem for maritime authorities to prosecute suspects by using videos or images acquired through UAV system (Huang, 2014), because of the complexity of legal procedures. But maritime authorities can jointly work with other legal authorities to set up a mechanism to validate video or image evidences which can be used in the court, taking reference to the traffic police which law enforcement has heavily depended on CCTV cameras to obtains images or videos to fine traffic rules violators.

5.3.4 Safety Concerns

The final problem which might hinders the application of maritime UAV system is safety concerns, as more accidents (or dangerous situations) emerged alongside the widespread usage of amateur UAVs recently. Yet according to the report of

Australian Government (2015), professional UAVs, which using resilience engineering and fault tolerance techniques, are extremely reliable comparing with other civilian UAVs. Therefore, China MSA should closely cooperate with the UAV manufacturers and airspace regulators to ensure the safe application of maritime UAV system.

On all counts, although meaningful application of maritime UAV system for MSA is still a long way to go and problems ahead are challenging, but with the supports of top-level leadership and technology advancement, the paper deems the wide-range of maritime UAV system application for MSA is feasible and highly practicable.

5.4 Chapter Summary

In this chapter, main principles, functionalities, requirements of proposed UAV system for China MSA have been detailed, according to criteria and requirements reviewed and discussed. Available and applicable UAVs as well as data fusion system and system architecture are also provided subsequently so as to complete the overall picture of Chinese maritime UAV system. To further justify and facilitate the establishment of such system, the author conducted a feasibility analysis of UAV system for MSA under current circumstances, which show that even certain concerns remain, it is not only feasible but also practicable to apply the UAV technology into Chinese MS system, by incorporating a comprehensive maritime UAV system.

CHAPTER 6

CONCLUSIONS

6.1 Summary

The purpose of this research paper is to provide a critical review of the Chinese MS system and offer a viable recommendation for decision maker(s) of China MSA, specifically, establishing a Chinese maritime UAV system:

At the beginning, this paper has carried out a careful review of the Chinese MS system in the Chapter 2, and reached a conclusion that current system is far from perfect and there are problems lie within. **Additionally**, challenges and maritime risks associated with maritime transport in China have been introduced in Chapter 3 by a qualitative analysis to demonstrate the urgent need for enhancing Chinese MS system in order to improve maritime safety. **Subsequently**, the author carried out researches on finding an applicable solution for MSA in Chapter 4, and deemed UAV system will be the viable choice for improving Chinese MS system in a cost-effective and practical manner, by critically analyzing UAV technology and related systems. **Finally,** broad requirements and detailed description of system architecture of the proposed maritime UAV system has been introduced in Chapter 5, and in order to prove the feasibility of applying maritime UAV system, a feasibility analysis has been conducted which the paper concluded that such UAV system is not only feasible but also practical.

6.2 Limitations

Firstly, this research is constrained by various factors, such as a limited time and accessible resource (statistics), when exploring problems and risks faced by China MSA in term of maritime surveillance and governance, the lack of quantitative data restricts the objectivity which the qualitative research cannot fully provide. **In addition**, due to geographical distance covered in the qualitative research, telephone interviews were adopted. But such interviews might result in the loss of certain information, which can be gained via direct observation. **Furthermore**, the proposed model for UAV system is still far from mature for immediate application by China MSA, because of limited knowledge and resources of the author. **Finally**, due to the time and resource restrictions, this research paper does not specify technical details of the comprehensive UAV system which provides room for further research.

6.3 Implications for Further Research

There are some implications for China MSA and related stakeholders (i.e., TPRT and CTTI) to conduct more objective researches and studies to further improve the current Chinese maritime surveillance system:

1) The quantitative research of cost-effectiveness of Chinese MS system should be carefully conducted to further justify the establishment of the maritime UAV system.
2) Top-level design of Chinese maritime UAV system should be thorough conducted by China MSA and related research institutes like CTTI; relevant studies of setting up UAV designated departments in MSA should also be carried out.
3) Experimental program should be carried out to test the validity and effectiveness of proposed maritime UAV system which is supposed to combine with other sub-systems of Chinese MS system and meet the needs of local MSA.

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APPENDIX: A Satellite Status of BEIDOU Navigation system

Satellite	Launch date	Launch site	Carrier rocket	PRN	Orbit	Status	Remark
BeiDou-1A	2000-10-30 16:02	XichangLC-2	Chang Zheng 3A	N/A	GEO 140°E	*Retired* December 2011	1st generation experimental satellite
BeiDou-1B	2000-12-20 16:20	Xichang LC-2	Chang Zheng 3A	N/A	GEO 80°E		
BeiDou-1C	2003-05-24 16:34	Xichang LC-2	Chang Zheng 3A	N/A	GEO 110.5°E	*Retired* December 2012	
BeiDou-1D	2007-02-02 16:28	Xichang LC-2	Chang Zheng 3A	N/A	GEO 86°E	*Retired* February 2009	
Compass-M1	2007-04-13 20:11	Xichang LC-2	Chang Zheng 3A	C30	MEO ~21,500 km	*Retired*	In-orbit validation
Compass-G2	2009-04-14 16:16	Xichang LC-2	Chang Zheng 3C	N/A	GEO drifting		
Compass-G1	2010-01-16 16:12	Xichang LC-2	Chang Zheng 3C	C01	GEO 140.0°E	*Operational*	

Satellite	Launch date	Launch site	Carrier rocket	PRN	Orbit	Status	Remark
Compass-G3	2010-06-02 15:53	Xichang LC-2	Chang Zheng 3C	C03	GEO 110.5°E		
Compass-IG SO1	2010-07-31 21:30	Xichang LC-3	Chang Zheng 3A	C06	55° inclination IGSO118°E		
Compass-G4	2010-10-31 16:26	Xichang LC-2	Chang Zheng 3C	C04	GEO 160.0°E		
Compass-IG SO2	2010-12-17 20:20	Xichang LC-3	Chang Zheng 3A	C07	55° inclination IGSO 118°E		
Compass-IG SO3	2011-04-09 20:47	Xichang LC-3	Chang Zheng 3A	C08	55° inclination IGSO 118°E		
Compass-IG SO4	2011-07-26 21:44	Xichang LC-3	Chang Zheng 3A	C09	55° inclination IGSO 95°E		
Compass-IG SO5	2011-12-01 21:07	Xichang LC-3	Chang Zheng 3A	C10	55° inclination IGSO 95°E	*Operational*	

Satellite	Launch date	Launch site	Carrier rocket	PRN	Orbit	Status	Remark
Compass-G5	2012-02-24 16:12	Xichang LC-2	Chang Zheng 3C	C05	GEO 58.75°E		
Compass-M3	2012-04-29 20:50	Xichang LC-2	Chang Zheng 3B	C11	MEO ~21,500 km		
Compass-M4	2012-04-29 20:50	Xichang LC-2	Chang Zheng 3B	C12	MEO ~21,500 km		
Compass-M5	2012-09-18 19:10	Xichang LC-2	Chang Zheng 3B	C13	MEO ~21,500 km		
Compass-M2	2012-09-18 19:10	Xichang LC-2	Chang Zheng 3B	C14	MEO ~21,500 km		
Compass-G6	2012-10-25 15:33	Xichang LC-2	Chang Zheng 3C	C02	GEO 80°E		
BDS I1-S	2015-03-30 13:52	Xichang LC-2	Chang Zheng 3C/YZ-1	C31	55° inclination IGSO		
BDS M1-S	2015-07-25 12:29	Xichang LC-2	Chang Zheng 3B/YZ-1	C34	MEO ~21,500 km		

Satellite	Launch date	Launch site	Carrier rocket	PRN	Orbit	Status	Remark
BDS M2-S	2015-07-25 12:29	Xichang LC-2	Chang Zheng 3B/YZ-1	C33	MEO ~21,500 km		
BDS I2-S	2015-09-29 23:13	Xichang LC-3	Chang Zheng 3B	C32	55° inclination IGSO		
BDS M3-S	2016-02-01 07:29	Xichang LC-2	Chang Zheng 3C/YZ-1		MEO ~21,500 km	*In commissioning*	
Compass-IG SO6	2016-03-29 20:11	Xichang LC-2	Chang Zheng 3A	C15	55° inclination IGSO 95°E		

APPENDIX: B Interviewees Information

Interviewees	Job Title	Job Description	Experience
A	Infrastructure Planning Manager	MSA infrastructure planning and implementation	23 years
B	Senior VTS Operator	VTS duty and operation	27 years
C	Senior Search and Rescue Coordinator	Trans-department search and rescue coordination	18 years
D	Senior Anti-pollution Expert	Anti-pollution policy and implementation consultancy	23 years
E	Search and Rescue Coordinator	Maritime search and rescue coordination	12 years
F	VTS Manager	VTS management	20 years
G	Senior Frontline Staff of Law Enforcement	Maritime law enforcement	19 years
H	Frontline Staff of Law Enforcement	Maritime law enforcement	10 years
I	Frontline Staff of Law Enforcement	Maritime law enforcement	7 years
J	Frontline Staff of Law Enforcement	Maritime law enforcement	6 years
K	Frontline Staff of Law Enforcement	Maritime law enforcement	6 years
L	Frontline Staff of Law Enforcement	Maritime law enforcement	6 years

APPENDIX: C List of Questions

Number	Question Content
1	What is your job title?
2	Can you briefly describe the duty of yours?
3	How long have you been working in China MSA?
4	Do you know the Chinese maritime surveillance system and its component sub-systems?
5	Please describe your knowledge of the Chinese maritime surveillance system and the relevance with your job duty.
6	How do you evaluate the current Chinese maritime surveillance system?
7	Please give a few (at least one) examples to support your view.
8	Can you describe the shortcoming(s) of the Chinese maritime surveillance system?
9	Can you provide some recommendation to (further) improve the current Chinese maritime surveillance system?

APPENDIX: D Interview Transcripts Sample

Interviewer: I'm glad that you have the time to share your opinions, should we start?
Interviewee F: Ok, let's do it.

Interviewer: Could you briefly tell me about your job title, description of your job and your relevant experience of your duty?
Interviewee F: Well, as you know I have been in the MSA for almost 20 years and been in a lot of position during the time, now I currently working at the branch-level MSA as a VTS manager to oversee the daily operation of the VTS center, my main duty is in charge of the VTS center management, VTS related-policy consultancy, and emergency response (i.e., research and rescue, oil spills and collision accidents) coordination which is also the main duty of the VTS of China MSA, to enhance maritime safety and environmental protection.

Interviewer: As a senior MSA veteran, you must know clearly about the Chinese maritime surveillance system and its component sub-systems, like Sat-AIS and LRIT
Interviewee F: I cannot say I know clearly about the system because I am just a manager of VTS and know mostly about the VTS and related systems like AIS and CCTV, but I have to admit that over the past years, the maritime surveillance system has been improving greatly and provide us means that we cannot dream of at the time I first joined the MSA in the last century. Today, we can sit in the VTS room to monitor the real-time situation of the ports which can significantly improve the safety at sea, for instance, if one suspicious activity of a vehicle has been caught by our VTS operators, we can pinpoint the vehicle by AIS and using VHF to make contact with the vessel, otherwise we can deploy our maritime patrol vehicle to make further investigation and adjustment, but of course most vessels will obey and follow our instructions. Talking about the systems you mentioned, I know a little bit about them but never use them.

Interviewer: So I assume you think the current Chinese maritime surveillance system is superb if not perfect?
Interviewee F: I did not say so, even I am proud of the development progress of the maritime surveillance system during the past decades, but that does not mean I am greatly satisfied by the current situation and performance of the maritime surveillance system.

Interviewer: Then how do you evaluate the current maritime surveillance system, if possible please give me an example.
Interviewee F: The current maritime surveillance system of course can satisfy many of our needs in terms of guaranteeing maritime safety and marine environmental protection, otherwise it will be overhauled and readjusted then. But it still has many of disadvantages, and shortcoming which might not fit into the development of maritime industry. Take the VTS surveillance as an instance, in VTS center, we can only rely on what we have here, if something (accident) happens

beyond the reach of the system, for example AIS, we can do nothing about it. LRIT and Sat-AIS are just too distant (and expensive) for us to use. Also, the VTS false alarm is concern, because the (MS) system is not really reliable, for instance the currents or small floating objects might easily be recognized as vessels by the VTS radar, sometimes is difficult for us to discern especially in busy water, like in Shanghai or Shenzhen port.

Interviewer: Okay, since you mostly talk about maritime safety, can you tell me more of the shortcomings of the MS system, in realm like marine environmental protection?
Interviewee F: The maritime surveillance system has been improving the performance of maritime marine environmental protection, especially in the port areas, to greatly reduce the pollution (i.e., lower the chance of oil spills and dangerous cargo leakage or explosion). However, the system is without drawbacks, for example, there are problems for us to prosecute those offenders in terms of vessel-source pollutions, and the problem bothers me the most is the evidence gathering for illegal discharge of vessel-source pollutants, the existing means are either no use or too slow, many times we can only watch pollutions happening without arresting those responsible. Therefore, the system lacks of an effective and expeditious mean in this regard.

Interviewer: So do you have any suggestions on how the Chinese maritime surveillance system should be improved or adjusted?
Interviewee F: As I have mentioned, the characteristics of the limited distance of maritime surveillance system should be improved, by adding more effective long-distance surveillance measures, the ready-to-use systems like LRIT are just too ineffective and too remote for us. Secondly, in order to tackle the false alarm issue, a more accurate real-time surveillance measure should be incorporated into the current maritime surveillance system, because none of the current maritime surveillance measures can satisfy this demand. At last, the works of vessel-source pollution prevention should be better supported by a more expeditious surveillance method.

Interviewer: It seems you have all respond to the problems you raised previously, do you have any other more recommendations? How about the maritime unmanned aerial vehicle?
Interviewee F: The only thing I want to emphasize is that we cannot only focus on the current situation and forget the big-picture, we as an implementation department should jointly work with related institution to further assess and improve the MS system. Maritime UAV is a big hit recently, and I know that in Tianjin and Guangzhou the pilot programs is processing, let's see the result before any comments made by the outsiders like me, but truth to be told, I like the idea.

Interviewer: Do you have any other suggestions to say?
Interviewee F: Well, I'm pretty sure that would be more than enough for you, isn't it?

Interviewer: Ha ha**,** thank you for participating in my interview!
Interviewee F: You are welcome.