THE AIS OPERATION FOR EFFECTIVE BRIDGE LOOKOUT

by

HUA-ZHI HSU

A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

School of Earth, Ocean and Environmental Science
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ABSTRACT

The shipborne Automatic Identification System (AIS) supports its end-users with independent traffic information that is in addition to the information available from RADAR and visual lookout. AIS is able to provide similar traffic information to RADAR, however, RADAR is a standalone device whereas AIS relies on the data contributed by other AIS equipped targets.

AIS has been mandatory bridge equipment onboard SOLAS ships since July 2004 and as a relatively new bridge system, a consensus among deck officers as to its effectiveness has yet to be reached. The potential of AIS to be a significant aid to bridge lookout necessitated the undertaking of this investigation. The research examined the performance of AIS in bridge lookout including case studies of AIS-assisted collision, a survey of users' perspectives and finally, a simulator trial was run to test the performance of AIS assisted bridge lookout.

Current attitudes and expectations toward the use of AIS were obtained from deep sea deck officers based in Taiwanese shipping companies. As the mandatory AIS implementation schedule was changed recently, an additional study was made to investigate how this influenced opinions deck officers.

To be able to determine the real effect of AIS enhanced bridge lookout operation, two groups of simulator experiments were proposed. The summarised results from the two surveys were used to inform the design of simulator trials. The first group of participants had AIS information available on RADAR and ECDIS. With the same scenario, the second group did not have any information coming from the AIS.

From the AIS-assisted collision case studies and survey results, it was apparent that there was a strong link between AIS target identification and VHF/collision avoidance calling. In terms of simulator trials, significant results were found in reading privileged status (Rule 18 COLREGs) from AIS's navigational status. The time spent on avoiding collision risk by means of off-track distance with AIS proved significantly quicker than the ordinary bridge operation. Furthermore, an earlier collision avoidance action was found with AIS target detection. However the use of AIS did not impact on the ability of the mariner detect Rate of Turn and vessel speed change when compared to a non AIS equipped bridge. The results support the theory of AIS-assisted collision avoidance where AIS is still under development towards a potential full scale onboard carriage.

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GLOSSARY

AB	Able seaman
AIS	Automatic Identification System
ARPA	Automatic RADAR Plotting Aid
AtoN	Aids to Navigation
BIIT	Built-In Integrity Test
BRM	Bridge Resource Management
BTM	Bridge Team Management
CAAS	Collision Avoidance Advice System
COG	Course over the Ground
COLREGs	Collision Regulations
CPA	Closest Point of Approach
CPU	Central Processing Unit
CQS	Close Quarter Situation
CSMA	Carrier Sense Multiple Access
CTW	Course through the Water
DR	Dead Reckoning
DSC	Digital Selective Calling
DWR	Deep Water Route
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ENC	Electronic Navigation Chart
EPIRB	Emergency Position Indicating Radio Beacon
ETA	Estimated Time of Arrival
GIS	Geographical Information System
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
grt	gross registered tonnage
HARP	Harbor Advisory Radar Project
HSC	High Speed Craft
IALA	International Association of Lighthouse Authorities
IBS	Integrated Bridge System
IEC	International Electro-technical Commission
IFSMA	International Federation of Shipmasters' Associations
IHO	International Hydrographic Organisation
IMO	International Maritime Organisation
INS	Integrated Navigation System
IRPCS	International Regulations for Preventing Collisions at Sea
ISPS	International Ship and Port Facility Security
ITU	International Telecommunication Union
KW	Kruskal Wallis
MAIB	Marine Accident Investigation Branch

MCA	Maritime and Coast Guard Agency
MGN	Marine Guidance Note
MKD	Minimum Keyboard and Display
MMSI	Maritime Mobile Service Identity
MSC	Maritime Security Committee
MTP	Marine Training, Plymouth
MW	Mann Whitney
NCOR	National Centre for Ocean Research
NI	Nautical Institute
nm	nautical mile
NOA	Notice of Arrival
NTSB	National Transportation Safety Board
NUC	Not Under Command
OECD	Organisation for Economic Co-operation and Development
OOW	Officer of the Watch
PC	Personal Computer
RACON	RADAR Transponder Beacon
RADAR	Radio Detection and Ranging
RCDS	Raster Chart Display System
RCS	RADAR Cross-Section
RNC	Raster Navigation Chart
ROT	Rate of Turn
SA	Situation Awareness
SAR	Search and Rescue
SART	Search and Rescue Transponder
SOG	Speed over the Ground
SOLAS	Safety of Life at Sea Convention
SOTDMA	Self-Organised Time Division Multiple Access
STCW	Standards of Training, Certification and Watchkeeping for Seafarers
STW	Speed through the Water
TCAS	Traffic-alert and Collision Avoidance System
TCPA	Time to Closest Point of Approach
TDMA	Time Division Multiple Access
TEU	Twenty-foot Equivalent Unit
THD	Transmitting Heading Device
TSS	Traffic Separation Scheme
UAIS	Universal Automatic Identification System
UNCTAD	United Nations Conference on Trade and Development
UOP	University of Plymouth
US	United States
USCG	US Coast Guard
UTC	Co-ordinated Universal Time
VHF	Very High Frequency
VLCC	Very Large Crude Carrier
VTC	Vessel Traffic Control
VTS	Vessel Traffic System
WGS84	World Geodetic System 1984
WRC	World Radio Committee

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DECLARATION

No part of this thesis has been submitted for any award of degree at any institute.

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other university award without prior agreement of the Graduate Committee. Publications by the author, in connection with this research are included at the end of the thesis in Appendix M.

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Maritime Automatic Identification System (AIS 03), Church House, London, Royal Institute of Navigation and The Nautical Institute. 24-25 November 2003.

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Chapter 1

Introduction

1.1 Background

Marine navigation concerns the best methods for sailing a vessel from its point of departure to its destination safely and efficiently. During the voyage, an effective lookout is essential for the safety of cargo, passengers and vessel. Lookout is a marine navigational practice that ensures an awareness of the status of elements affecting the vessel. Geographical aspects, weather conditions and the traffic situation are all relevant to lookout. Traditionally, 'a lookout' could mean a person who is on duty in a crow's nest reporting any developing phenomena at sea. Although it is still possible to see a bridge full of ratings who fulfill the mission of a lookout in some naval ships, it is a luxury for a merchant ship-owner to put extra personnel on bridge specifically for the purpose of lookout. Over time, bridge equipment has evolved and modernised the merchant shipping industry. The introduction of advanced navigation equipment has led to a reduction of ratings on the bridge (Sonnenberg 1988). An Officer of the Watch (OOW) will no longer have a group of ratings to report any situation developing at sea, but will instead have access to a range of electronic navigational aids providing the necessary information. The impact of this technology results in the OOW having a new role, that of information manager; as a representative of the master, the OOW has to ensure that an efficient lookout is maintained at all times (Meurn 1990). The

International Regulations for Preventing Collisions at Sea (IRPCS), known as Collision Regulations (COLREGs), determined the term 'lookout' (IMO 2003b) as:

> Every vessel shall at all times maintain a proper lookout by sight and hearing as well as all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

It is the responsibility of the OOW to use all available, valuable means to achieve a proper lookout. Hence, the handling of all data from both ordinary means (e.g. visual and hearing) and electronic aids to navigation has resulted in the OOW having to develop strategies to ensure best performance in lookout.

1.2 Bridge lookout

Maintaining an effective lookout is one of the most important tasks for every OOW during their duty on the bridge. The development of advanced electronic navigational aids has shown a benefit to bridge operations where serious manning can be saved. Nevertheless, these will never challenge the position of the watch keeper until a fully automated bridge has been accepted by the maritime industry. It is clear that electronic navigational equipment is aimed at assisting the person who is in charge of the bridge lookout.

The OOW can obtain information from the electronic aids to navigation in addition to the ordinary means (sighting and/or hearing). COLREGs clearly indicate that it is the OOW who has to take any information into account in their decision-making. Nowadays, electronic aids to navigation are heavily relied on, and sometimes over-reliance on these aids may occur. As both system errors and human errors in man-machine interfacing in the operation of electronic aids cannot be ruled out entirely, conventional lookout methods and other independent systems may be applied to check system redundancy. The job of an OOW today in bridge lookout is to seek a balance between conventional methods and the advanced electronic aids.

1.3 Shipborne AIS

The shipborne Automatic Identification System (AIS) is a comparatively new system on Safety of Life at Sea Convention (SOLAS) ships. The function of the identification can range from simply acquiring a target's identity to the creation of situation awareness. Therefore, there is additional AIS information coming onto the bridge and this can be used by the OOW. In associated with COLREGs, the information can be taken into account in lookout, as 'every available means' are essential for making decisions on the bridge.

AIS is recommended for use in collision avoidance in the guidelines for onboard operational use of shipborne AIS, Resolution A917 (22) (IMO 2002c). The guidelines also suggest AIS should be used to assist the Radio Detection and Ranging (RADAR) operation. As a supplement to RADAR (Berntsen 2004), a similar contribution to this in overall bridge lookout operation should be achieved. To consider the use of AIS as an aid to bridge lookout alongside RADAR, the unique contribution provided by AIS should be investigated. With shipborne AIS, OOWs can experience a similar working environment to that of a general VTS controller. AIS end users are able to obtain additional information on each of the AIS equipped targets that are at sea. Moreover, the person who acquires these VTS-like traffic images is the same person who actually controls the ship from the bridge. Awareness of the overall traffic situation should thus be measured to determine whether traffic safety can be improved through the use of AIS.

AIS is in the relatively early stages of system development and thus consensus, training requirements and formal operation for bridge lookout have yet to be finalised. Through its innovations and capability in target detection, tracking and classification (Winbow 2003), AIS is expected to provide the OOW with independent situation images by offering additional traffic data resources. By connecting AIS to a Global Navigation Satellite System (GNSS) receiver, it is also possible to provide real-time, precise data, which can be used in conjunction with other advanced systems on the bridge. As an independent information source, it is for the end user to decide whether they should apply the benefit of this additional information to achieve the greatest effectiveness of lookout.

As a newly introduced device, AIS will have to prove itself to be competitive in its contribution with other bridge systems in order to be considered for the overall bridge lookout. The question thus raised for this research will be, 'can AIS be useful in bridge lookout operation?'

1.4 Aim and objectives

The aim of the research is to evaluate the effectiveness of AIS operation in the application of collision avoidance procedures in bridge lookout. The following objectives were created to achieve this aim:

1. To investigate the current status of shipborne AIS;
2. To investigate the issues related to bridge lookout;
3. And to evaluate OOWs' behaviours when using RADAR and AIS for bridge lookout.

1.5 Methodology

Based on the findings of a literature review and a study of relevant collision cases, the methodology has been developed to investigate the advantages and disadvantages of AIS operation in collision avoidance. Two quantitative methods are adopted: a survey study and an experimental project. The survey study investigates the viewpoints of mariners. The experimental project is designed to examine the proposed trials by means of simulator evaluations.

Figure 1-1 shows the strategy for evaluating AIS bridge operation.

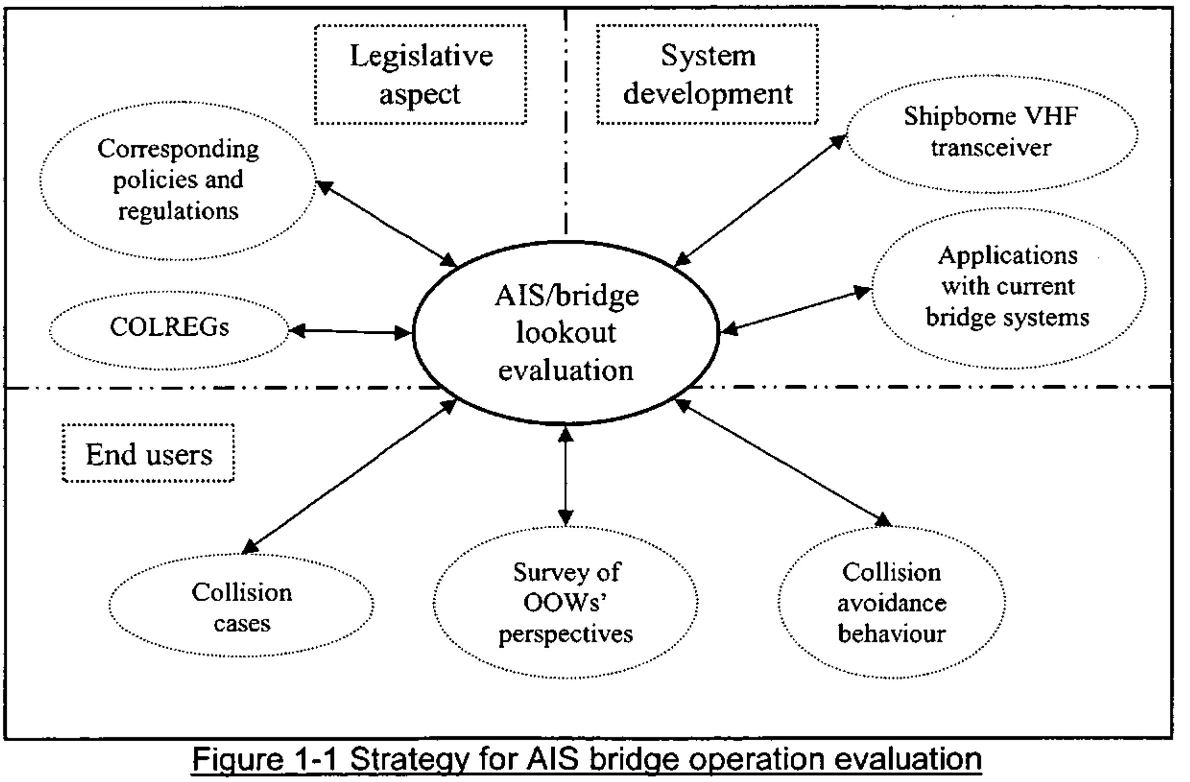

Figure 1-1 Strategy for AIS bridge operation evaluation

The research strategy can be divided into three parts: the legislation aspect, the system development and the study on potential end users. This research aims to investigate the three corresponding groups which are the law makers, the systems industry (design and manufacturers) and the mariners.

Firstly, the legal position of shipborne AIS will be investigated with relation to rules concerning carriage requirement, timeline of implementation, and legislation in bridge lookout (SOLAS and COLREGs). Secondly, with reference to system development, methods of data transmission and associated bridge lookout usage between shipborne AIS and other bridge equipment will be investigated. Finally, the attitudes and opinions of end users will be studied to develop an understanding of the use of AIS-assisted collision avoidance.

To investigate the current situation of AIS and collision avoidance, a number of collision cases will be analysed to reveal current errors related to the use of bridge lookout. To obtain real-world data, users' opinions will be collected by means of questionnaire surveys. The surveys will investigate views and expectations of shipborne AIS before and after the SOLAS carriage requirement came in to force. The final phase of this research will be to investigate users' behaviour in a simulated bridge lookout operation involving AIS-added bridge information.

1.6 The structure of the thesis

There are eight chapters in this thesis. Following the introductory chapter, the research is divided into five areas:

1. A review of shipborne AIS, its application in navigation and associated case studies are presented in Chapters 2, 3 and 4.
2. The design of the research methodology allows investigation of the possible applications of AIS in lookout operation, which are presented in Chapter 5.
3. A survey investigation of AIS end users is reported in Chapter 6.
4. The experimental trials of shipborne AIS in collision avoidance applications are outlined in Chapter 7.
5. The conclusions of the thesis are presented.

- **Chapter 2: AIS Overview**

An overview of shipborne AIS, including device characteristics, technical development and associated regulations, is undertaken.

- **Chapter 3: Application of AIS in Navigation**

AIS display can be integrated with other existing bridge systems in bridge operation. The co-operation of AIS with other electronic devices, RADAR, Electronic Chart Display and Information System (ECDIS) and Very High Frequency (VHF), will be discussed. In terms of legitimate roles, the COLREGs are discussed as they affect AIS potentials in ship manoeuvring.

- **Chapter 4: Collision Cases**

A number of collision cases involving the operation of shipborne AIS will be analysed. Collision cases involving RADAR, VHF and Vessel Traffic System (VTS) are studied. The findings will be considered in the development of the Research Methodology, as shown in Chapter 5.

- **Chapter 5: Research Methodology**

This describes the research methodology that was created and established to plan for further studies in users' experiences. There are two parts to Chapter 5: the first part concerns the methodology for the research survey; the second part deals with the methodology for the simulator trials.

- **Chapter 6: Survey Findings**

A pilot study and two surveys to investigate user' opinions in shipborne AIS operations are described in Chapter 6.

- **Chapter 7: Ship Simulation and Evaluations**

From the contributions of the literature review, collision cases and users' opinions, simulator scenarios were created to investigate users' behaviours when using AIS information in ship manoeuvring. Chapter 7 analyses the results collected from the simulation trials undertaken by a number of qualified mariners. This research investigated seafarers' behaviours in relation to bridge lookout.

- **Chapter 8: Conclusions**

This chapter draws conclusions from the work presented in this thesis and proposes areas for further development.

Chapter 2

AIS Overview

2.1 Introduction

The AIS is a broadcast communication system that is able to transmit and receive data via its two designated marine VHF radio channels. The AIS functions are: a tool within VTS, a security measure and a navigational aid (Pettersson 1995; Oltmann and Bober 1998; Leclair 2002; Mitropoulos 2002; Tepper 2002; Komrakov 2003). In brief, VTS operation benefits from prompt identity and automatic ship reporting via AIS between ship and shore. Secondly, every AIS-fitted ship will broadcast a detailed identity, which can then be applied to a ship's database in order to maintain marine security awareness. Thirdly, GNSS ground stabilised movement and manoeuvring data (heading and turning rate) are obtainable from the AIS target, which means that additional data resources are available to the current bridge system.

This research will concentrate on the identifying effects occurring from the implementation of AIS in bridge operations and investigate the relationship between AIS and OOW. The aim in considering AIS data in navigation and manoeuvring is to achieve navigational safety. This chapter will discuss the AIS system, technical developments and corresponding regulations.

2.2 Basic features

The International Maritime Organisation (IMO) defined the features of AIS, which has become one of the mandatory shipborne carriage requirements, by the revision of SOLAS (Regulation 19, Chapter V), which is under the supervision of the IMO (2002a). AIS allows automatic communication between ships using the VHF radio transmission network. The characteristics of AIS transmission are the same as ordinary radio transmissions, where the theory of transmitting range, line-of-sight, applies. The transmitted distance in nautical miles (nm) between an AIS station and an AIS equipped ship can be estimated as (Cairns 2004):

$$\text{Estimated transmission range} = \sqrt{2}(\text{height in feet}_{\text{station}} + \text{height in feet}_{\text{ship}})$$

Compared with traditional radio verbal communication on VHF, where only one user occupies the selected channel at any time, the advanced transmission technology used by AIS allow a vast number of users to share the radio band at the same time. Therefore, using two designated VHF channels, more ships are able to communicate with ships and other potential users simultaneously. In Figure 2-1, a simplified diagram is provided to show the information provided by AIS.

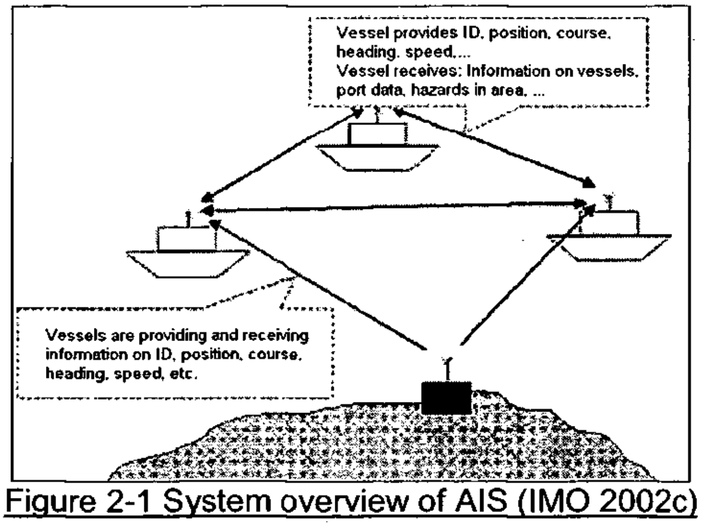

Figure 2-1 System overview of AIS (IMO 2002c)

2.2.1 History of AIS development

The invention of AIS has its roots in the enhancement of RADAR identification in the late 1980's. Although marine RADAR has been operated for more than fifty years, discovering a target's identity was not an option (Harre 2000). RADAR can only recognise targets through a distress mode (e.g. by Search and Rescue Transponder (SART)), or through beaconage signals (e.g. RADAR Transponder Beacon (RACON)). In order to add ship identity, an upgrade to a RADAR transponder operating in the 9GHz band was initially considered (Fisher 2000). Nevertheless, the trial did not prove to be successful. One of the reasons for this was that the existing shipborne RADAR system would need a costly modification. Because of the limited transmission range by RADAR, putting shore stations with these RADAR transponders to accomplish shore surveillance would raise costs for both installation and maintenance. Therefore, a different approach with an extra transponder system was considered. A new VHF radio transceiver was introduced to the maritime industry whose installation and maintenance costs were considerably lower than the RADAR upgrading scheme.

In the early 1990's, traffic management and collision avoidance were seen as the major tasks for AIS (Parker 2004). Lord Donaldson's Report published in 1994 raised need to reduce environmental pollution from the merchant shipping (Donaldson and HMSO 1994). The report suggested that higher standards of ship design, maintenance and operation were needed in order to fulfil the goal of 'Safer Ships, Cleaner Sea'. Among the suggested measures, 'ship identification' was discussed to improve vessels' presence, position, etc. Furthermore, the Donaldson's Report preferred the radio transponder to RADAR because of cheaper costs and reliability. The ability to monitor other ships' dynamic positions would give the traffic controller and other seafarers a great advantage, improving their awareness of the traffic. The discussion on AIS began in 1990 during the 36th session of the Sub-Committee on the Safety of Navigation (NAV 36) at IMO. The use of a transponder system which would permit ships to be identified and tracked when approaching, entering or sailing within a VTS area was studied thoroughly and presented by the International Association of Lighthouse Authorities (IALA). In September 1991 at NAV 37, IALA illustrated VHF transponder systems with operational and technical characteristics for radio transponders for VTS purposes. However, the IMO was not ready to implement this type of system through SOLAS or COLREGs at NAV 38 in 1992. The reasons that were stated by Leclair (2002) were:

- The system was shown as a VTS tool and not, as it is now, as equipment to be used primarily by ships to avoid collision;
- VTSs were not yet 'recognised' by the SOLAS Convention (they were introduced by SOLAS in July 1999);
- Transponders need to be interfaced with a position fixing system, but no such system was required on ships by SOLAS, except for a RDF and a RADAR;
- The use of the VHF (channel 70) for transponders could be harmful for the distress alerting system and the Global Maritime Distress and Safety System (GMDSS); and
- The maritime industry was not ready to abandon the principle of anonymity when sailing along, but not being bound for, a coastal State, particularly when not in its territorial waters.

The expanded Maritime Security Committee (MSC) adopted an amendment to SOLAS Chapter V in May 1994. This required that a ship reporting system, when adopted and implemented in accordance with the guidelines and criteria developed by the Organisation, shall be used by all ships, or certain categories of ships or ships carrying certain cargoes, in accordance with the provisions of each system so adopted. Later, this amendment came into force on the 1st of January

1996. It became clear that the transponder system for ship identification would be a mandatory carriage requirement after the year of 1994. With the potential that more ships would take part in accessing the transponder system in one area, a multi-access technique was required to fulfil the user demand. Hence, a Swedish engineer Hakan Lans created a technical solution (Pettersson 1995), the Self-Organised Time Division Multiple Access (SOTDMA), for the new shipborne transponder system. The details of SOTDMA will be discussed in detail in Section 2.3.1.1.2.

Sweden and Finland introduced SOTDMA together for an AIS based message packaging system at NAV 45 (Sandford 2004). This appeared in a recommended draft for ship-to-ship and ship-to-shore transponder systems. Meanwhile, VHF/Digital Selective Calling (DSC) was considered as a potential option for a transponder standard at NAV 42 (in 1996). As an existing system under the GMDSS, VHF/DSC was discussed by IMO as an alternative method to data transmission. However, VHF/DSC already had another major application with GMDSS at the time and it was not able to extend its function to fulfil the needs of ship identification. Eventually, SOTDMA was favoured and accepted as the AIS performance standard at NAV 47 by IMO in 1997. IMO defined a Universal Automatic Identification System (UAIS), which was also adopted into the newly revised Chapter V of SOLAS and was planned to come into force from 1st July 2002.

2.2.2 Implementation of shipborne AIS

In December 2000, a timeline for the installation of AIS was written into Chapter V SOLAS that detailed a schedule between 1st July 2002 and 1st July 2008, according to ship type, tonnage and serving voyages. The six-year long implementation plan was aimed at installing AIS onboard step by step, giving enough time for mariners to adopt AIS in the bridge operation. In fact, the original time schedule was soon changed and moved forward, requiring all SOLAS ships to install AIS onboard no later than December 2004. The sudden change of plan was related to the terrorist concerns resulting from the 9/11 event (Sandford 2004). The events of September 11th 2001 caused the United States (US) to adopt a heightened sense of urgency. The US successfully persuaded the world maritime community to shorten the timeframe for AIS installation at an IMO emergency meeting in order to tackle the great concern of an unknown terror attack from the open sea. IMO agreed to an accelerated fitting schedule of AIS in February 2002, which required all SOLAS ships to be equipped with AIS onboard within 24 months. The US Department of Homeland Security pamphlet 'Secure Seas-Open Ports', published in June 2004, describes AIS as an awareness tool increasing both security and safety (Parker 2004), where the use in littoral nations' security measures starts to be considered as one of the recognised applications of AIS.

The shortened time schedule caused concerns for implementation on a vast number of ships (IMO and IALA 2002), as an estimated 100,000 vessels in the US alone required AIS installation in a limited time (Sandford 2003). From December 2004, all SOLAS ships over 300 gross registered tonnage (grt) serving international voyages, and ships over 500 grt with national voyages, would have to install a VHF/AIS radio transceiver. All existing SOLAS ships would have to install a basic display device, known as the AIS Minimum Keyboard and Display (MKD). MKD is an alpha numeric display which was seen as an interim measure to fulfil the AIS carriage requirements onboard SOLAS ships.

Under the rules and requirements of IMO, the use of AIS for anti-terrorist security was not part of the original reasons for fitting AIS on ships. Nevertheless, it became the main driver for bringing AIS into the marine industry at an earlier date. As AIS was at an early developmental stage, the trials for operating AIS in several usages would be shortened. The result of this was that users would have less time to familiarise themselves with the AIS onboard. Whether AIS operation has an impact on the current bridge operation will need a thorough study.

2.2.3 Target identification

The ability to identify targets at sea has been an interest recognised by a number of groups, such as littoral nations, VTS controller and seafarers. In short, the users who can benefit from identification can be divided into inshore authorities and offshore mariners. Traditionally, targets detected by means of VTS surveillance RADAR or visual sighting need verbal communication to accomplish ship reporting between ship and Vessel Traffic Control (VTC) (Koburger 1986). A reply-on-request via VHF makes vessels more likely to be anonymous when passing VTC monitored areas. The prompt identification of AIS targets at sea can provide filtered information, which allows the authorities more time to concentrate on suspicious AIS targets or targets without an AIS identity. In the interests of traffic management, the ship reporting process to the VTC can be simplified by a reduction in verbal conversation. Furthermore, target swap and blind sector derived from RADAR detection can be backed up by AIS target detection. The same function can be of benefit onboard in identifying ships and Aids to Navigation (AtoN) fitted with an AIS transponder. In fact, there are certain types of vessels and floating objects not identified by AIS.[1] A reading from an AIS display should always be treated with caution since the coverage of target detection is not perfectly complete.

AIS can create a platform of information exchange whereby a target's identity, Rate of Turn (ROT) data, heading (from gyro) and speed (from log) are obtainable. In addition, voyage data such as a target's destination, Estimated Time of Arrival (ETA), etc., can also be shared among the users. If the vessel is within broadcasting range from land, real time meteorological and hydrographical information can be acquired from a regional broadcast station via the onshore AIS antenna.

Furthermore, AIS can be fitted onto AtoN, such as buoys and lightships. An AtoN with AIS identity can support the OOW in cross-checking with observed buoys by providing its position and working condition. The same idea can also be applied to temporary or permanent hazardous objects, such as a wreck, by showing an AIS identity to transiting vessels. By ordering a virtual AIS identity onto a wreck or a buoy, the AIS transceiver does not necessarily need to be physically installed.

[1] Under the current Chapter V, SOLAS, non-SOLAS vessels, mostly leisure boats, fishing vessels and military crafts, are not required to fit AIS.

The automatic and autonomous information exchange via AIS, based on the ship-to-ship mode, can reduce/save manpower from both ends of verbal communication (Pettersson 2002). In building up a network for target surveillance, RADAR surveillance stations with high power transmission can also be saved by establishing lower transmission power AIS/VHF stations onshore. In general, AIS target identification can be seen as a link in the information chain, allowing users to share data. A greater number of users participating create a better structure for the AIS network.

2.3 Technical developments

Shipborne AIS has its own method for broadcasting ship's data via designated VHF channels. Moreover, a number of ship's sensors, such as heading, ROT and GNSS, can contribute more data input via the AIS network transmission. Generally, shipborne AIS should include (IMO 2002c):

- Antennas;
- One VHF transmitter;
- Two VHF receivers;
- A VHF/DSC;
- A Central Processing Unit (CPU);
- A GNSS receiver;
- An interface of heading, log and other navigational equipment;
- A connection capability to RADAR/Automatic RADAR Plotting Aid (ARPA), ECDIS and Integrated Navigation System (INS);
- Built-In Integrity Test (BIIT); and
- An MKD.

The corresponding diagram for an AIS base station is shown in Figure 2-2.

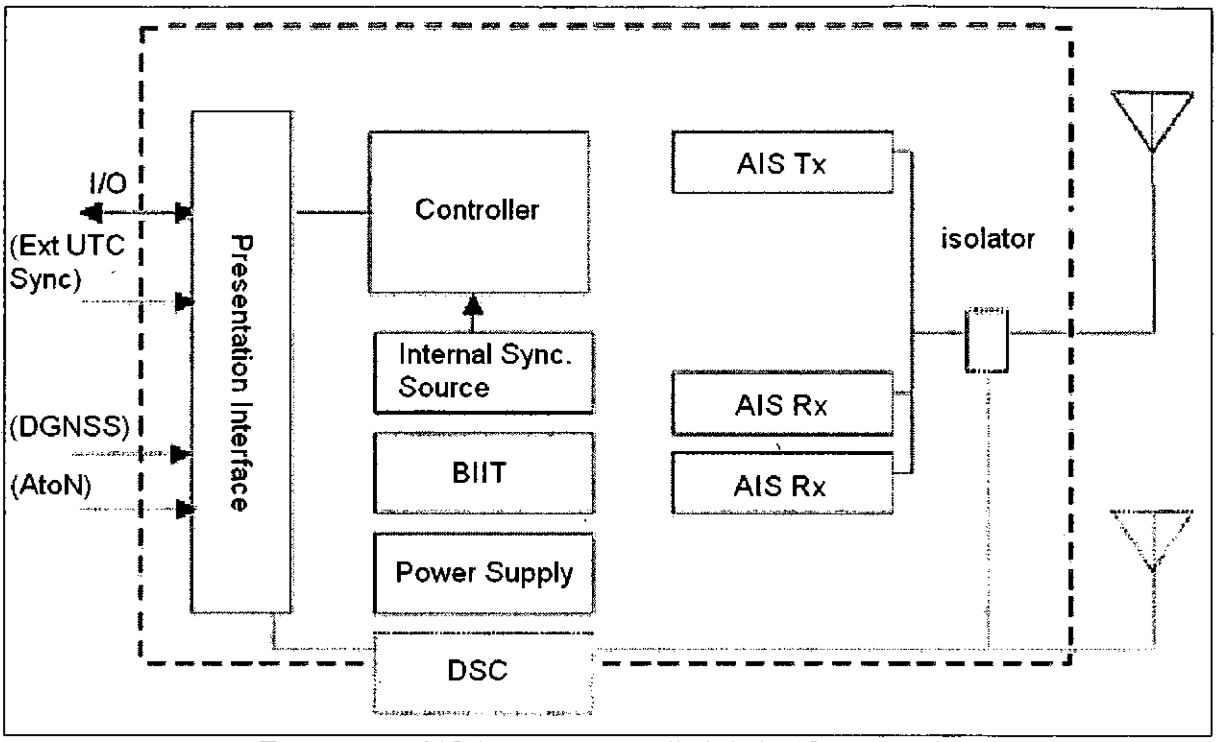

Figure 2-2 AIS base station (IALA / AISM 2002)

The technical developments will be discussed in detail concerning the way AIS manages its data (data transmission, channel management and time synchronisation), the connection to the other sensors and the presentation of AIS information.

2.3.1 Data transmission

AIS data transmission operates in the maritime VHF radio bands, which are capable of communicating with other users in a 'line of sight' distance (McGeoch 1998). The range of AIS/VHF radio transmission has been estimated at 20~30 nm. Currently, two simplex channel bandwidths, 25 kHz and 12.5 kHz, are available (IALA / AISM 2002). In general, AIS data transmission via VHF suffers less from issues such as weather attenuation and detection behind a landmass obstacle.[2] Nevertheless, the close proximity of buildings and bridges could cause interference to AIS transponders. The so-called 'urban canyon' effect could make data transmission vulnerable, especially in a heavily built-up area. In comparison with a RADAR transponder, the characteristics of VHF radio transmission can provide AIS users with larger transmission coverage.

The current technology for AIS data transmission is called SOTDMA. It was invented in Sweden in the mid 1980's and the aim was to enlarge the transmission capacity over a standard period of time (Basker, Parkinson et al. 2003). Sandford (2004) described SOTDMA as a special message packaging system that allows multi-users communicating on its network simultaneously. The details of AIS data transmission will be discussed separately as message packaging systems, VHF channel management and system synchronisation.

2.3.1.1 Message packaging methods

There are three message packaging methods that represent the development of data transmission. DSC was developed first, followed by the currently-used SOTDMA and a potential future method known as Carrier Sense Multiple Access (CSMA). SOTDMA will have most discussion as this technology is currently used by AIS.

[2] Atmospheric ducting can also affect VHF radio transmissions, as radio waves can travel further (see Section 3.3.2.1).

2.3.1.1.1 DSC

In the mid 1970's, DSC was introduced under the umbrella of the GMDSS (Tepper 2002). The concept of DSC was first proposed to improve the alerting of rescue and stand-by forces in cases of maritime distress. The use of a DSC transponder was first applied by the International Telecommunication Union (ITU) according to M.825 within the operation of GMDSS. Fundamentally, DSC under GMDSS transmits enquiry information automatically. A connection to GNSS improves target vessels' identities with an accurate position in the same timeframe. Hence, DSC became a well-established technology in the early concepts of a message packaging system for AIS. During the development for DSC/AIS, the technique used to transmit data worried the developers. As ship-to-ship data transmission by DSC would need an information relay (Pettersson 1997), a message would have to be sent from the ship to a nearby shore station which would then relay the message to a calling ship. As a result, adopting the DSC message packaging system would inevitably raise costs in the need to build more inshore stations to maintain the throughput of data transmission. Eventually, the capability of DSC was not sufficient to fulfil the AIS tasks due to the lack of transmission capacity and inadequate techniques for data processing. Although this method of DSC/AIS was not selected due to data transmission issues, the built-in DSC is used to initiate a DSC call to another ship (See Appendix A).

2.3.1.1.2 SOTDMA

The technology of SOTDMA was initially invented by the University of Stockholm and the Swedish Defence Research Institute in the mid 1980's (Figure 2-3). The aim in adopting SOTDMA was to provide integrated communications, navigation and surveillance for traffic management when it was under development by both the aviation and maritime industries (Basker, Parkinson et al. 2003).

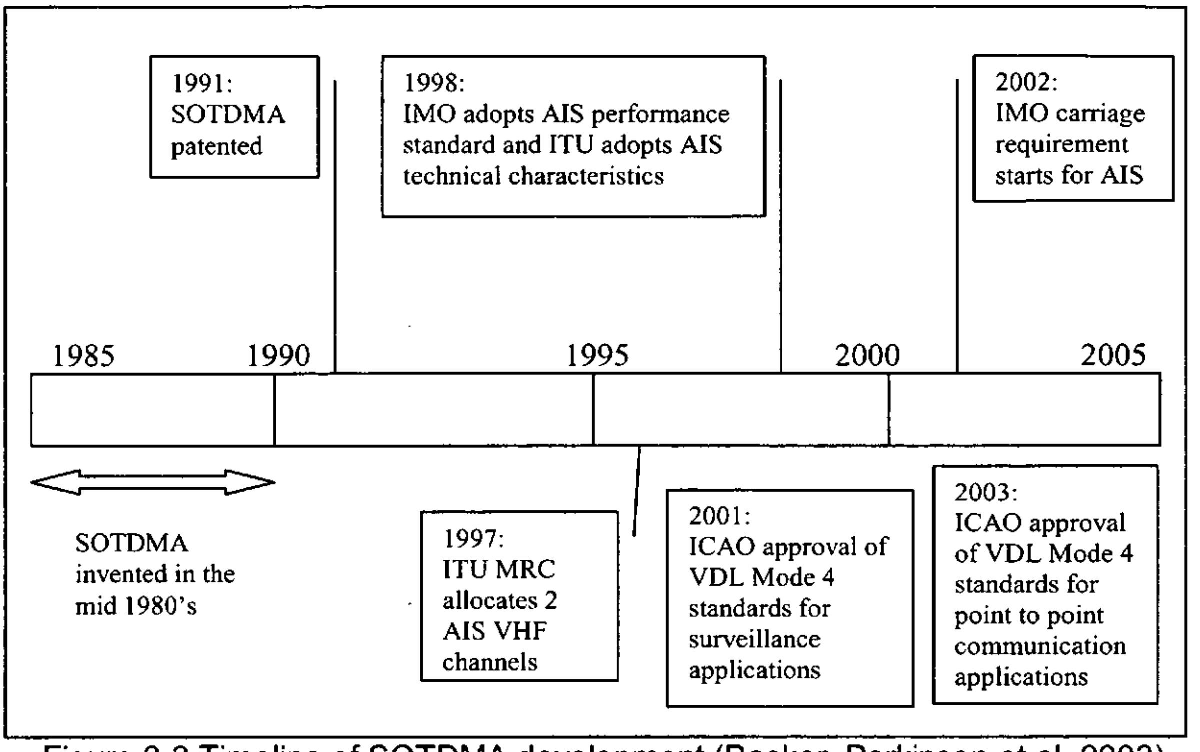

Figure 2-3 Timeline of SOTDMA development (Basker, Parkinson et al. 2003)

The SOTDMA user begins by listening to the channel for one minute prior to making its first transmission. This will build up a picture of planned channel activity to help identify slots that appear to be available. The user randomly selects one of these free slots to transmit their own data and includes slot reservation information. The ITU Technical Standard for the AIS determines 4500 time slots in a one-minute timeframe for its two channels. The transmitting speed is 9600 bits per second, 1 frame for 1 minute (or 2250 time slots). The 2250 time slots in each channel start from 00 second to 60 second, making every time slot equals to 26.7 milliseconds (Figure 2-4).

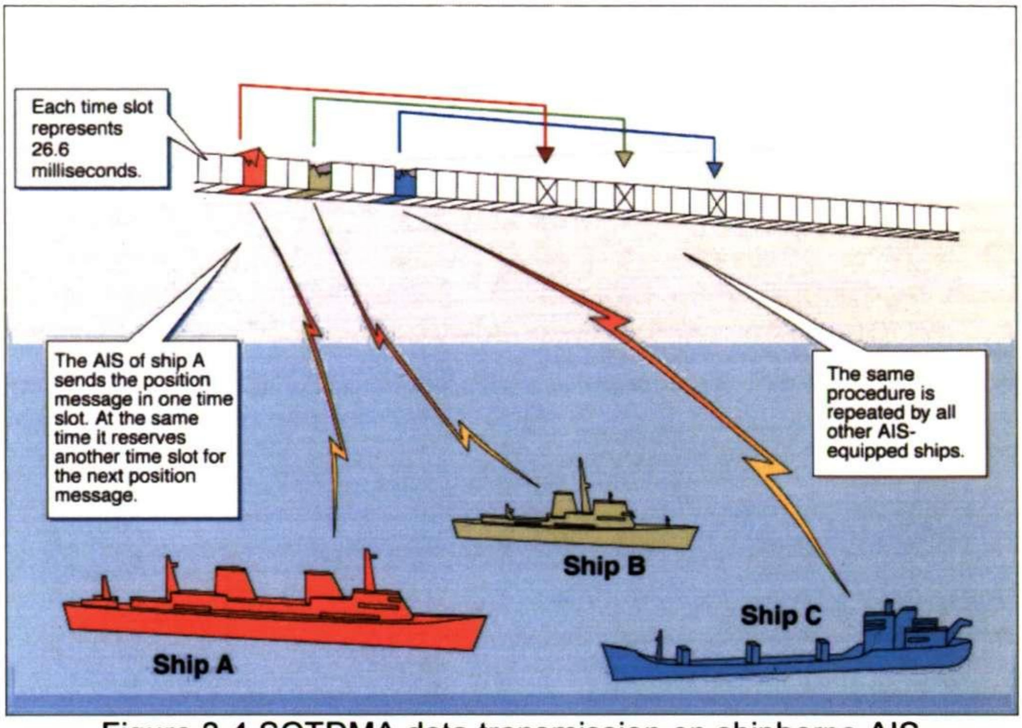

Figure 2-4 SOTDMA data transmission on shipborne AIS (IALA / AISM 2002; USCG 2002)

A conventional Time Division Multiple Access (TDMA) has to have a master station in order to support synchronised signals and to maintain multiple access (Shao 2002). However, SOTDMA does not require a dedicated/extra authority to manage data transmission (Zhang and Chen 2002). Hence, a ship-to-ship communication by SOTDMA will not necessarily need an onshore infrastructure. The possibility of a communication connection without constructing relay stations and the derived operation costs is foreseeable. Through the contribution of GNSS based positioning and synchronised timing data, the stations (users) can organise themselves to operate a network that is not under the control or boundary of a master/slave station. The advantages of this are greater than using DSC, where a relay to a shore station was required for a ship-to-ship communication.

Generally, AIS users will have to request a first calling time slot in order to log into the regional networking. When a user is already on the AIS network, it will need to reserve a time slot before the next transmission is due. In order to make sure that every user is operating at the same time, a synchronised timing unit is required. To help this system, a standardised Co-ordinated Universal Time (UTC) was adopted into the SOTDMA. Furthermore, the connection to the GNSS was recognised as supporting the UTC standard (Hofmann-Wellenhof, Lichtenegger et al. 1997). As a result, every AIS user is able to establish its own identity automatically in the network, and users are able to receive the broadcasting data based on the standardised timeframe.

In order to keep track of future transmissions, each AIS transponder has a slot-map that contains at least one minute, i.e. one timeframe. In general, a vessel could transmit data up to 30 times a minute (1 time frame). There are two ways to select time slots: one is to select unreserved slots, and the other is to select slots that were reserved by another user at a remote distance (Bole, Dineley et al. 2005). In Figure 2-5 and Figure 2-6, two users (ship A and ship B) are not in line-of-sight of each other and both ships could therefore reserve the same slot, although interference (garbled slot) would occur onboard ship C.

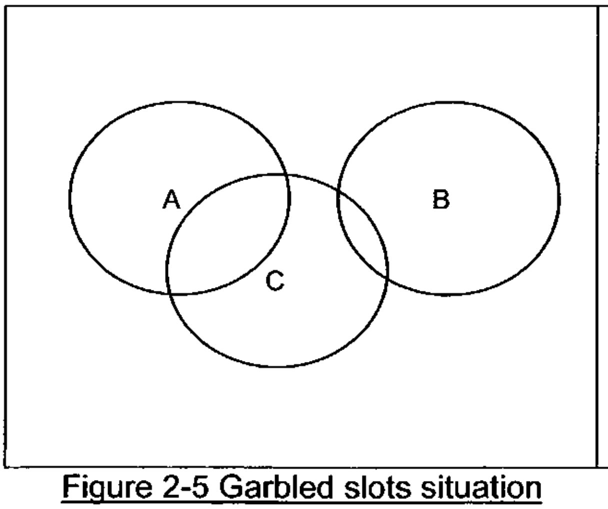

Figure 2-5 Garbled slots situation

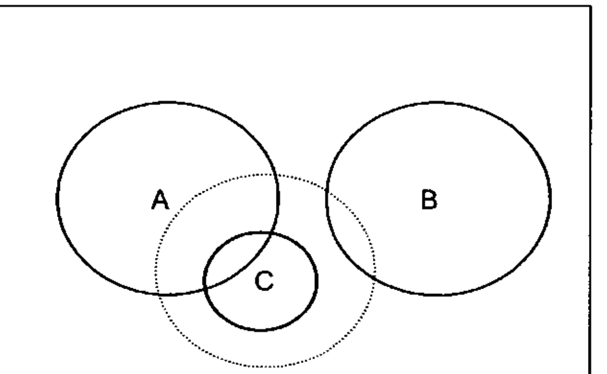

Figure 2-6 Discriminated reception

The risk of running out of slots is inevitable (Saab 2004). This issue could be solved through a method of intentional slot reuse. This method would ensure that the system has a graceful degradation in case of overload. The idea is to "steal" slots from transponders far away and leave transmissions that are close, hence creating a dynamic radio range based on the link load. This degradation under overloading ensures that users will always hear vessels closer to them ahead of ships that are further away.

The output power of the AIS transmitter can be reduced as a consequence of data overload (Koehler 2003). The transmitting range then reduces to half of its original power. The main goal is to achieve 100% throughput of data transmission within the new established/reduced range. If a free slot still cannot be found, a previously reserved slot (based on selecting reservations from users furthest away) may be used again.

Overall, the AIS user's transmissions are organised with respect to other users within AIS cells. In general, each user's picture of the channel is different unless they are very close together. The transmission concept is to pre-announce a future transmission plan at the current transmission. All surrounding AIS transponders will then notice this slot reservation from other ships to avoid garbling other users' transmissions.

2.3.1.1.3 CSMA

CSMA has been established as an application to AIS and a future alternative to SOTDMA (Stewart 2004). The CSMA transmitter was designed to listen for a carrier wave before initiating a message transmission (Lin 2003). The 'carrier sense' tries to detect the presence of an encoded signal from another station before attempting to transmit. This results in each AIS station determining its own transmission schedule or slot allocation, based on the history of data link traffic and knowledge of future actions from other stations (as opposed to SOTDMA, where users jump into the data transmission channel and reserve the next transmission by the availability of free slots). The chance of garbling can then be reduced.

2.3.1.2 Channel management

In order to facilitate the full use of the frequency band, and to enable automatic frequency channel switching for ships and shore stations, the AIS standard utilises DSC. The standard refers to this as channel management. The new AIS standard also provides TDMA channel management via DSC and limited polling via DSC (IALA / AISM 2002). Normally, ships use the designated AIS channels (ch-87B and ch-88B). In reality, these two channels could be occupied for other uses in some areas. The AIS internal DSC can establish a connection to the onshore AIS station and re-arrange a new channel for the AIS network transmission.

2.3.1.3 Time synchronisation

A GNSS supplied position has been input into a number of systems such as GMDSS, ECDIS and, lately, AIS (Ward 2003). According to the SN/Circ.227 Guidelines for the installation of a shipborne AIS (IMO 2002a), all SOLAS ships with AIS onboard (as known as a Class A AIS) should connect to a GNSS antenna. Not only will the GNSS based navigational data be fed into the AIS, but the UTC data regarding time synchronisation will also be important in maintaining the working pattern of AIS. Fundamentally, GNSS is able to provide time with respect to UTC to better than 100 nanoseconds (Sandford 2004). In Figure 2-7, a SOTDMA frame length is divided into 2,250 time slots with 256 bits (45-55 characters or numbers in one bit) per slot. Each slot only lasts 0.026 seconds.

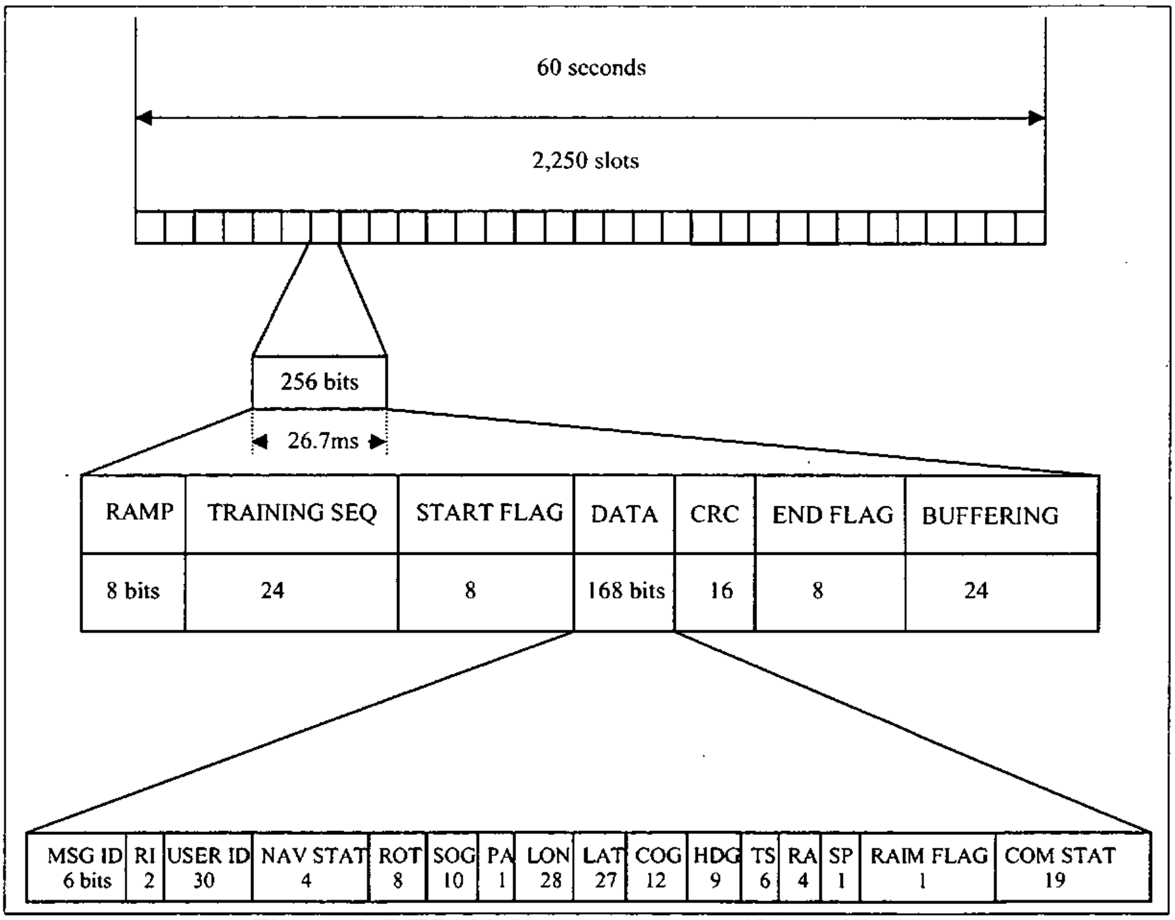

Figure 2-7 TDMA frame structure (Shao 2002)

To allow for such a large data exchange in its two designated VHF channels, synchronised time among users became standard to determine each user's allocation when occupying the slots (Buckens 2002). GNSS based UTC data will be extensively used by AIS in this respect and, furthermore, the time supported by GNSS will be able to fulfil the timing precision in milliseconds.

2.3.2 Sensors and transmission rate

Sensors installed in compliance with other carriage requirements of SOLAS Chapter V should be connected to the AIS (IMO 2002b). The creation of a ship's data is based on the sensors connecting to the AIS itself. A GNSS receiver provides synchronised time, position fixing and Course over the Ground (COG) and Speed over the Ground (SOG) data. The gyro compass provides a ship's heading and the log provides the speed, which all contribute to the ship's dynamic information. In addition, the AIS interface can also make a ship's turning rate data available if the ship carries an ROT device.

Every AIS-equipped ship is able to provide more navigation-related details to other AIS users. In addition, the AIS uses the sensors' information to decide the frequency of information refreshing. The result can be effective in controlling the throughput of AIS data transmission. In fact, every ship's data could be transmitted via AIS at different/variable rates (IALA / AISM 2002). The variance of transmission rates depends on the necessity and urgency of movement the ship is undergoing. The reporting intervals determined by situation of ships are shown in Table 2-1.

Situation of ship	Reporting Interval
Ship at anchor	3 min
Ship 0-14 knots	10 sec
Ship 0-14 knots and changing course	3⅓ sec
Ship 14-23 knots	6 sec
Ship 14-23 knots and changing course	2 sec
Ship >23 knots	2 sec
Ship >23 knots and changing course	2 sec

Table 2-1 Update intervals for Class A AIS (IALA / AISM 2002)

A case study in shore-based AIS by Lin (2003) took a trial of over 100 visits of merchant vessels a day to the Port of Kaohsiung, Taiwan (Formosa). The model of AIS capacity calculation is based on 118 wharves according to the demand of Port of Kaohsiung. The scenario used 59 sleeping targets (anchor ships or berthing ships), 59 slow moving targets (0-14 knots and changing course) and 110 fast moving targets (over 14 knots and changing course). With the availability of 4,500 time slots in a minute, 97.38% of transmission capacity (4,382 slots) would be occupied. As this scenario did not include non-SOLAS vessels, a concern was raised whether current AIS transmission could work if all vessels within the Harbour's VTS join the AIS network. Merchant mariners will have to consider this if all maritime users (offshore/inshore) are going to participate in the AIS network in the future. Put simply, overloads of transmission throughput in the two designated VHF channels are imminent. Recent solutions for this are to reduce transmitting coverage (see Section 2.3.1.1.2) or to limit the channel to designated users (e.g. SOLAS ships). The solutions also raised concerns for vessels that are not asked to install AIS but are willing to carry AIS-like (a sub-AIS system). The non-SOLAS vessel can operate under a system called Class B AIS. Being a sub-class AIS receiver, it receives the AIS information but does not send any data at all. Another alternative that would enable Class B AIS/vessels to send data to the AIS network would be to send data over a much longer period (Table 2-2).

Platform's condition	Reporting Interval
Class B Ship < 2 knots	3 min
Class B Ship 2-14 knots	30 sec
Class B Ship 14-23 knots	15 sec
Class B Ship > 23 knots	5 sec
Search and Rescue (SAR) aircraft	10 sec
Aids to Navigation	3 min
AIS base station	10 sec

Table 2-2 Update intervals for Class B shipborne mobile equipment (IALA / AISM 2002)

2.3.3 Display of AIS targets

AIS target information can be integrated into one of the graphical displays, such as RADAR, ECDIS or Integrated Bridge System (IBS) on the bridge (IMO 2002b). The interim guidelines deal with the graphical presentation and display of AIS target data in either standalone or IBS, and are considered as interim performance guidelines (IALA / AISM 2002).[3] While the general principles of AIS need to be imparted, the primary effort must be for a clear understanding of the MKD (or the associated Electronic Chart System (ECS)/ECDIS operating system, if present) and the effective interpretation of all AIS information provided (Davidson 2002). Recently, four possible types of Class A AIS display have been proposed: an independent alphanumerical MKD; an independent graphical MKD; an AIS integrated ECDIS/ECS; and an AIS integrated ARPA/RADAR.

One of the most cost-effective ways to display the AIS is to have a RADAR-like display on a Personal Computer (PC) presenting only the AIS targets and their information (Pettersson 1997). The bearing and distances to the targets could also be compared and identified on the RADAR. At first, data fusion or data association as recognised by IMO should be achieved to generate a single vector of target vessels (Hughes and Sowdon 2006). The accuracy of a target's vector relies on AIS navigation data resources, such as GNSS, gyro and log sensors. For example, the input or transmission of Speed through the Water (STW) protocol is not required under the existing regulations. Furthermore, the connection of a conventional log or/and additional converter is not required to convert log pause into a serial protocol (according to IEC 61162) (Koehler 2003). Therefore, the

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[3] The guidelines were set by the Sub-Committee on Safety of Navigation - 47th session: 2-6 July 2001, IMO.

AIS/ARPA target fusion is only related to the display of information in order to avoid clutter on the RADAR screen. If the result of vector calculation differs from AIS and ARPA, the target should be presented respectively in an AIS identity and a RADAR echo.

The upcoming schedule for AIS/ARPA data fusion will be effective from 1st July 2008 (Hughes and Sowdon 2006; Norris 2007). In the case of a RADAR display, RADAR signals should not be masked, obscured or degraded by AIS. Moreover, the equipment should be capable of appropriately stabilising the radar image and AIS information. Target data derived from RADAR and AIS should be clearly distinguishable by source. Generally, the vectors of COG and SOG should be displayed as dashed lines starting at the centroid of the triangle (Figure 2-8). The heading should be displayed as a solid line of fixed length starting at the apex of the triangle. A flag on the heading indicates a turn and its direction in order to detect a target manoeuvre without delay.

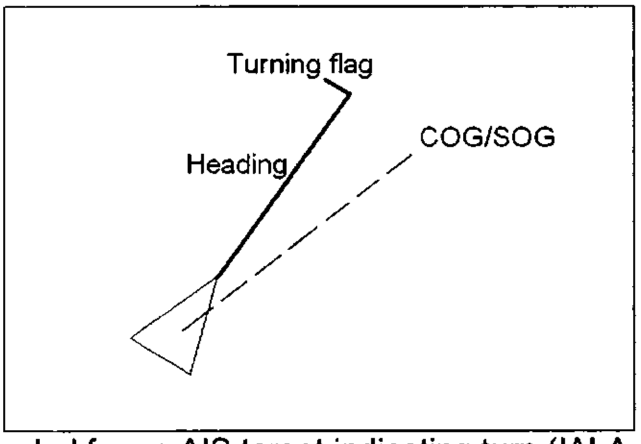


Figure 2-8 Symbol for an AIS target indicating turn (IALA / AISM 2002)

2.4 Legislation and regulations

There are several regulations and rules covering and related to AIS (IMO and IALA 2002), which are:

- IMO Performance Standard for AIS MSC.74 (69) Annex3;
- IMO Carriage requirements for AIS, Regulation 19 Chapter V SOLAS;
- ITU-R M.1371-1 Technical Recommendations on AIS;[4]
- IALA Technical clarification on ITU-R M. 1371-1;
- IALA Technical Guidelines for AIS;
- International Electro-technical Commission (IEC) 61993-2 Test Standard for Class A AIS Transponders;
- IEC 62287 Test Standard for Class B AIS Transponders;
- More details ITU-R M. 1084-4 (radio performance), IEC 61162-1 and 61162-2 (interfacing).

The legislation for the carriage of navigation equipment, including AIS, is derived from the conventions of the IMO, and particularly the SOLAS Convention (Fisher 2000). The standards for AIS consist of Resolution MSC.74 (69) for AIS performance standards by IMO 1998, Recommendation M.1371-1 for AIS technical characteristics by ITU 2001 and AIS methods of testing by IEC 61993-2 2001. The guidance for operating AIS includes Resolution A.917 (22) Guidelines on onboard operational use [5] and SN/Circ. 227 Guidelines for installation. Furthermore, the IALA has close cooperation in the set-up of AIS, including in its AIS Guidelines considerations for shore stations, AtoN stations and technical clarifications.

[4] ITU – R M. is the Recommendation of Mobile, radiodetermination, amateur and related satellite services, Radiocommunication sector, ITU.
[5] The guidelines can also be found at annex 17 of MSC Safety of Navigation.

In terms of functional requirements, AIS is seen by IMO (1998) as:

- a ship-to-ship mode for collision avoidance;
- means for littoral States to obtain information about a ship and its cargo; and
- ship-to-shore traffic management as a VTS tool.

In order to describe the corresponding regulations and legislation that concern AIS, four international organisations will be discussed. Overall, the IMO defines the operational requirements for the AIS performance standard. The ITU defines and sets the telecommunication protocol for the radio specification of AIS and the VHF radio frequency standards for the AIS on a worldwide scale. The IEC is in charge of the operational and performance requirements, methods of testing and required test results for AIS. And finally, the IALA is concerned with the application of AIS in relation to AtoN and onshore installation.

2.4.1 IMO guidelines

The Class A AIS is defined by IMO (2002a) and has been made a carriage requirement by the latest revision of SOLAS Chapter V. Apart from the mandatory requirements in the Chapter V SOLAS Conventions, three guidelines were established by IMO for AIS standards and instructions.

2.4.1.1 Regulation 19 Chapter V SOLAS

The ships that are required to fit AIS onboard with a time schedule were approved by IMO and included in *Regulation 19, carriage requirements for shipborne navigational systems and equipment, Chapter V Safety of Navigation, SOLAS Convention*. Basically, all ships over 300 grt engaged on international voyages and all ships over 500 grt not engaged on international voyages were to fit AIS onboard from July 2002 and no later than December 2004. The SOLAS Convention further indicates that AIS shall:

- provide automatically to appropriately equipped shore stations, other ships and aircraft information, including ship's identity, type, position, course, speed, navigational status and other safety related information;
- receive automatically such information from similarly fitted ships;
- monitor and track ships; and
- exchange data with shore based facilities.

2.4.1.2 SN/Circular 227

SN/Circular 227, *Guidelines for the installation of a shipborne AIS*, was decided in 2002 by the Sub-committee on the Safety of Navigation (NAV 48) (IMO 2002a). The annex of the Guidelines describes AIS installation, bridge arrangement, data input and long-range function. Firstly, there are antenna issues, interface connections and input data illustrated as installation matters of shipborne AIS. The form of digital communication could make AIS VHF communication vulnerable as a result of radio interference. For the connection of VHF antenna, the location should be carefully chosen to avoid interference with other radio-transmitting antenna, such as a ship's VHF radiotelephone or a ship's GNSS antenna. Due to time synchronisation and positioning data input, there must be an internal connection to a GNSS receiver as one of the units of AIS equipment. The location and cabling of its GNSS antenna should also be chosen carefully to prevent signal attenuation and radio interference.

With regards to bridge arrangement, the Guidelines recommended MKD as an interim solution for ships already built before the mandatory carriage requirement of AIS. The MKD has to be a three-line display of a target's data. A graphical display is also available and optional in the market (Figure 2-9). In addition, the

AIS can be connected to the other navigational devices in terms of graphical display. The IEC 61162-2 requirement for AIS system presentation interface should be met to fulfil the demands of system integration.

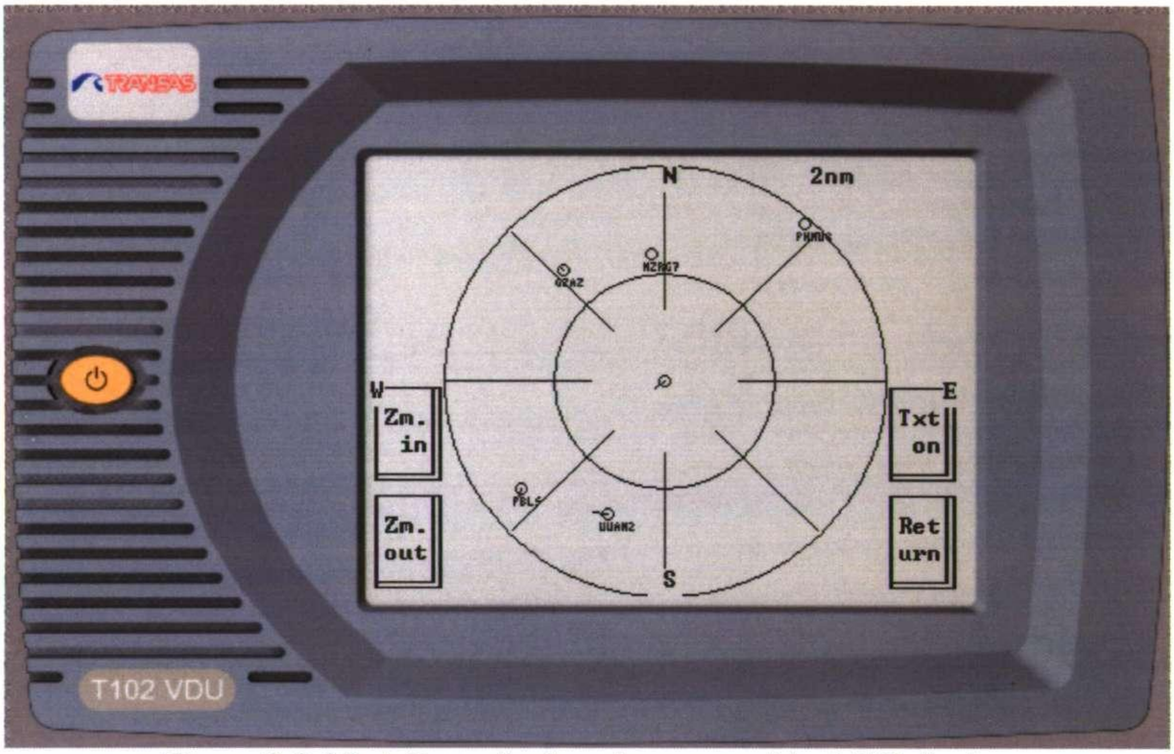


Figure 2-9 All stations displayed on a graphical AIS display

In terms of dynamic data input, the AIS should be able to provide position (including COG and SOG), heading, ROT and navigational status. Interfaces configurable as IEC 61162-1 or IEC 61162-2 enable connection to GNSS, gyro or Transmitting Heading Device (THD) and ROT-indicator sensors (IMO 2002c). As above, the data input is achieved without interference from the users. Next, the Guideline suggests the manual input to set up a ship's own navigational status should be simplified. OOWs will have to make sure the displayed navigational status via AIS is consistent with the signals/shapes being applied. In terms of static information input, data is maintained manually. Most static information is established initially to broadcast the details of the host ship. The name of the ship, type of ship, Maritime Mobile Service Identity (MMSI) number, IMO vessel number, etc. are therefore available to all users. Finally, detailed information about the GNSS position with the ship's dimensions enhances broadcasting accuracy of a ship's dynamic positioning data.

2.4.1.3 Resolution A.917 (22)

Resolution A.917 (22), *Guidelines for the onboard operational use of shipborne AIS*, is intended to inform a mariner about the operational use, limits and potential use of AIS as it is intended to enhance safety of life at sea, the safety and efficiency of navigation and the protection of the marine environment (IMO 2002a). The Resolution described AIS data transmission as continuous and automatic by ship-to-ship and ship-to-shore modes. If an appropriate graphical display is available, targets' positional information can be obtained and shown graphically. The Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA) are also available via AIS. The potential of AIS as an anti-collision device is recognised in the Resolution in ship-to-ship mode (IMO 2002a). The Resolution also warns about the possibilities of misusing AIS in collision avoidance:

- AIS is an additional source of navigational information. It does not replace, but supports, navigational systems such as RADAR target-tracking and VTS; and
- The use of AIS does not negate the responsibility of the OOW to comply at all times with the COLREGs.

In reality, the possibilities of floating objects and ships without AIS identity exist. Apart from the floating objects, there are two reasons why vessels may not have available AIS identity (The Nautical Institute 2007). One is that the vessel is below the SOLAS standard and does not need to carry AIS. The other is an incident that occurs causing the ship master decides to switch AIS transmission off (e.g. a fear of piracy). Vessels in these situations would not be shown on the AIS monitor.

2.4.1.4 Annex 3, Resolution MSC. 74(69)

The performance standards for universal shipborne AIS were recommended in Annex 3, Resolution MSC.74 (69). The official recognition of AIS occurred when the IMO MSC adopted Resolution 74(69) in May 1998 (Leclair 2002). There are three functional requirements (IMO 1998; Oltmann and Bober 1998) mentioned by the Resolution:

1. AIS is an onboard and autonomous means of improving collision avoidance;
2. AIS is a means for VTS to gain a traffic image independent from RADAR; and
3. AIS is a means for ship reporting schemes.

In terms of AIS functionality, the system was recommended as three operational modes: autonomous and continuous, assign and poll.

Firstly, the autonomous and continuous mode will be the general operational mode. Secondly, the assigned mode will be used in a traffic monitoring area where an authority can set the data transmission interval and time slots for interested targets to use. Thirdly, the polling mode will be used to interrogate a selected target from either a ship or an onshore station (authority).

2.4.2 ITU-R M.1371-1

The ITU was invited by IMO to develop and approve technical standards for AIS. Prior to the ITU-R M. 1371-1, the ITU-R M. 825-1, '*Characteristics of a transponder system using digital selective calling techniques for use with vessel* *traffic services and ship-to-ship identification*', applied DSC techniques in the use of vessel identification for VTS. In 1997, there were two VHF channels allocated for AIS internationally in the World Radio Committee (WRC). Later, in 1998, TDMA techniques replaced DSC techniques with the advance of multi-data access simultaneously (see Section 2.3.1.1.2).

Officially, ITU approved the *Technical Characteristics for a Ship-borne AIS Using TDMA in the Maritime Mobile Band*, ITU-R M. 1371-1, November 1998 (IALA / AISM 2002). In response to a request from the IMO seeking global frequencies for AIS, the 1997 ITU WRC-97 allocated two worldwide channels from the VHF maritime mobile band. The two channels are AIS I-87B (161.975MHz) and AIS II-88B (162.025MHz). The frequencies may be varied if the two channels have been occupied already in a given area (see Section 2.3.1.2). In the case that Channels 87B and 88B have been occupied by other uses, the built-in DSC will act as a channels manager to switch the default channel to a new one.

2.4.3 IEC Standard 61993 Part 2

IEC provides operation standards and performance for AIS according to IMO's requirements. The Commission is responsible for the international equipment standards which will provide type approval of the equipment (Clandillon-Baker 2000). The IEC Standards include test specifications, data transfer standards, compatibility connections with bridge equipment and display recommendations. IEC 61993 Part 2 by IEC Technical Committee 80 Working Group 8 includes *Shipborne AIS Operational and Performance Requirements, Methods of Testing and Required Test Results* (IALA / AISM 2002). Manufacturers of AIS equipment will have to follow the IEC standards in order to obtain a certificate for international approval. In addition, the IEC 61993 Part 2 also regulates data input and display. The least requirements for interfacing with other input and display devices are also illustrated.

2.4.4 IALA Guidelines on AIS

IALA has been the primary organisation sponsoring and coordinating the development of the AIS transponder (Prime 2001). In the early development of an identification system, two different systems, a RADAR AIS and a radio AIS, were presented to IMO (see Section 2.2.1). IALA initially proposed identifying ships and the ship's position in VTS areas of coverage and in areas of restricted waters using the proposed maritime VHF channel 70 that had been designated for DSC (Basker, Parkinson et al. 2003). The idea was mainly aimed at assisting a VTS operator in identifying traffic (Pettersson 1997). Due to IALA presenting the RADAR AIS proposal to IMO, issues related to mariners with AIS were not examined. IALA was not concerned with aids to navigation, but wanted to put identification equipment onboard that could be seen from the shore.[6] As a VTS tool IALA (2001a) recognised several benefits by operating AIS:

- Automatic vessel identification;
- Improved vessel tracking;
- Electronic transfer of sailing plan information;
- Electronic transfer of safety messages;
- Automatic indication of voyage related information;
- Impact on VHF communication;
- Achieving data;
- System redundancy;
- Potential for interaction within regional AIS network; and
- Improved SAR management.

[6] The basic concept for a shipborne transponder that could be used for ship-to-ship and ship-to-shore communication was not introduced by IALA until the 1990's.

The limitations associated with the use of AIS were also analysed by IALA (2001a): over-reliance on AIS data may affect VTS operators in detecting other non-AIS vessels/objects; AIS transmission could be affected in certain situations (e.g. urban canyon effect) due to its characteristic form as a VHF radio signal; and finally, AIS coverage could be adjusted automatically when overloading occurs. The VTS will need more base stations to overcome this last issue.

2.4.5 The legal position of AIS on the bridge

The SOLAS Convention indicates that only SOLAS vessels have to compulsorily carry AIS (Class A). It is highly likely that vessels outside the scope of SOLAS will not need to comply with this carriage requirement. Therefore, with no requirement for non-SOLAS vessels to carry AIS further amendments would be required to include a wider range of vessel types.

The above mentioned inter-governmental organisations (Sections 2.4.1-2.4.4) developed these guidelines and rules associated with shipborne AIS operation. Thus, there will be guidance for the system manufacturers, ship owners and, most importantly, the end users, i.e. deck officers. There are three applications where AIS can be operated: VTS, coastal surveillance and collision avoidance. In order to reach a world-wide deployment of shipborne AIS network, these four inter-governmental organisations have developed usage, applications, carriage and network protocols.

In terms of hardware and software issues, AIS based on a VHF radio transmission has been regulated to enable communication between users. The idea of sharing information is derived from the functional network. The most essential function mentioned by the associated rules is that AIS will enable access to a number of bridge systems. In brief, the access/connection to GNSS, rudder indicator, gyro compass and log allows information sharing of navigational data such as position, ROT, heading and speed. The information obtained from AIS is different to that obtained from RADAR or other electronic aids as AIS is able to provide an extra information-sharing platform to the users with a VTS-like information for bridge lookout operation.

2.5 Conclusions

The identification of targets at sea has attracted a number of groups who will benefit from the installation of shipborne AIS. The VTS controller will reduce the time used in verbal communication of ship reporting and also maintain continuous and real-time traffic in his region. For a nation with concerns about the security of its sea boundary, any intruder acting suspiciously can also be monitored quickly. For mariners, to be able to obtain information related to other ships will allow early awareness of any approaching risk of collision. In summary, AIS provides an independent platform of data exchange. This chapter has illustrated the AIS characteristic in terms of basic feature illustration, technical developments and associated regulations. The application of AIS in navigation will be discussed next.

Chapter 3

Application of AIS in Navigation

3.1 Introduction

AIS should improve the safety of navigation by assisting in the efficient navigation of a ship by satisfying a ship-to-ship mode for collision avoidance (see Section 2.4). IMO Resolution A917 (22) further describes AIS as a potential aid in collision avoidance. The Resolution also illustrates AIS as an additional navigation system (see Section 2.4.1.3). AIS does not replace, but rather supports, the existing navigational system. The use of AIS does not negate the responsibility of the OOW to comply at all times with the COLREGs.

The aim of shipborne AIS is to help identify vessels, assist in target tracking, simplify information exchange and provide additional information to assist in situation awareness (IMO 2002c). The applications of AIS on the bridge will be discussed in coastal navigation and collision avoidance. The application in coastal navigation will be discussed with the ECDIS. The application in collision avoidance will be discussed in relation to RADAR and VHF, and in comparison with COLREGs.

3.2 AIS information on ECDIS

IMO and the International Hydrographic Organisation (IHO) together specified the ECDIS as being connected to the GNSS sensor, to the RADAR and to the gyro as an onboard navigational device (Borgmann and Buttgenbach 1999). Originally, ECDIS was designed to replace the paper chart (Hanekamp 2000). As an electronic form of the paper chart, ECDIS has the capability to integrate with a number of bridge systems. For example, the input from GNSS provides the ship's own position in a continuous graphical display (Norris 2005). The situation and intention of the traffic can be compared in a geographical sense by reading the ECDIS.

3.2.1 Marine electronic chart

The marine electronic chart should reduce the workload when compared to the use of a paper chart, and its primary function is to contribute to safe navigation (IMO 1998). The formats available from the marine electronic chart are raster and vector charts. A raster chart is a visual scan of a paper chart (Conley 2000). A vector chart contains data that geographically references each element or feature of the navigational chart data with its own specific attributes.

In terms of data storage, data from a raster chart is stored as a grid of pixels (cells) where each pixel carries an assigned code and correlates to a geographic position. As the image is formed by a group of pixels, a raster chart could be scaled with a loss of clarity. Data from a vector chart is stored in the form of points, lines or areas. The data items have their own feature codes, associated attributes and geographical positions. As opposed to the attributes of a raster chart, vector-based images can be scaled indefinitely without image degradation.

In order to make a marine electronic chart in vector formats, every detail in the chart has to be well-referenced and an identity given. This will then allow the information to be used in a more sophisticated way. In fact, each point on the vector chart is digitally mapped and all the details of the feature can be displayed by clicking on that feature. Compared to a scanned raster chart, it takes longer to produce a chart in vector format. In some cases, the unwillingness to share chart data between countries reduces the process of data exchange. In comparison to the situation of vector chart production, a scan of the chart can be simply turned into a digitalised raster format ready to be used.

The Electronic Navigation Chart (ENC) is the chart database supplied with the authority of a national hydrographic office for the ECDIS. The Raster Navigation Chart (RNC) is the raster database for the Raster Chart Display System (RCDS). To be qualified for ENC data, the IMO Resolution A.817 (19), IHO S57 Edition 3 and IEC 61174 are the standards for fitting and operating ECDIS on board. For instance, data in vector format approved by official hydrographic offices and displayed on the ECDIS is ENC data. With up-to-date charts as a back-up on board (see Regulation 20, Chapter V, SOLAS), the ECDIS can be used for route planning and route monitoring (Norris 2001). Due to the lack of availability of the vector format in charting, ECDIS approved by IMO have not reached complete worldwide coverage. As an alternative, the modification from IMO MSC 70, December 1998, approved RCDS as a mode of operation on ECDIS if the ENC data is not available. This solution should be supported by an appropriate up-to-date paper chart as a backup measure.

A less manpower intensive requirement for the automatic corrections system can be an advantage in adopting an electronic chart system, as errors from the manual chart corrections will be eradicated (IMO 1998). The workload for an ordinary chart correction can be removed where OOWs still have the most up-to-date chart information and corrections.

3.2.2 ECDIS in route planning and monitoring

The connection of navigation sensors to ECDIS can assist the OOW in route planning, monitoring and positioning (IMO 1998; Norris 2001). For instance, a ship's own GNSS can be connected to ECDIS. Because it shares the same geodetic format World Geodetic System 1984 (WGS 84), the ship's track and Dead Reckoning (DR) from its latest fix can be displayed. The continuous positioning on the ECDIS (Figure 3-1) gives mariners a great advantage in fixing position, accomplished with visual confirmation. The near real-time positioning on ECDIS not only prevents latency and saves the workload of an ordinary fixing at the same time, but it also reduces the probability of human errors occurring when fixing onto a paper chart. For ship route planning, planning with GNSS positioning can achieve a saving in fuel costs and awareness of safe navigation.

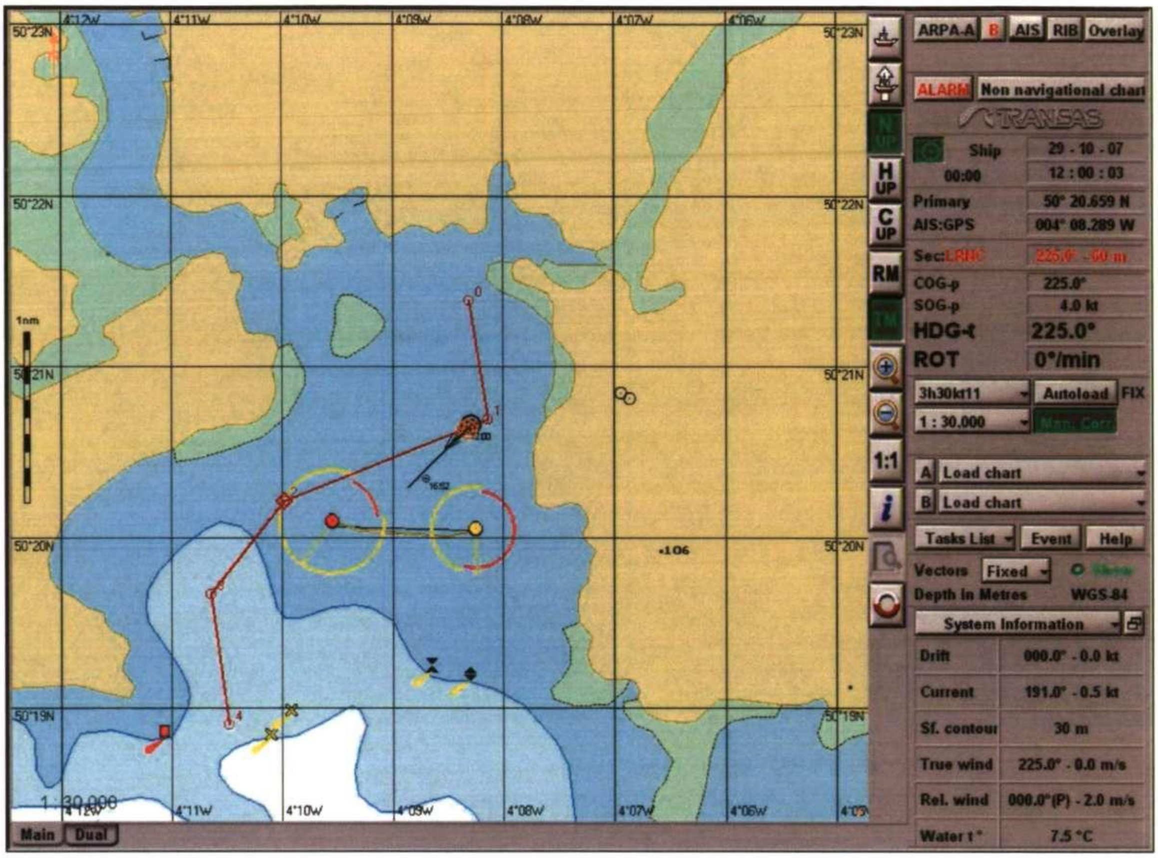


Figure 3-1 Own ship's track on ECDIS

A connection to a GNSS can provide a ship's own position displayed on the ECDIS. As both GNSS and ECDIS use the same geodetic datum, a claimed horizontal fix accuracy of less than 30 metres (See Section 3.3.4) can be expected on the ECDIS navigation. Furthermore, RADAR images can also be added to the ECDIS display (IMO 1998). As an addition to a GNSS/ECDIS display, a RADAR-integrated ECDIS can also show RADAR detected targets (Figure 3-2). Therefore, a better understanding of the intentions of surrounding vessels can thus be achieved when compared with charted information (Hecht, Berking et al. 2002). Moreover, the system redundancy can be improved by operating a RADAR/ECDIS integrated display. The shoreline displayed by RADAR can be applied to check the integrity of the chart presentation during a coastal navigation.

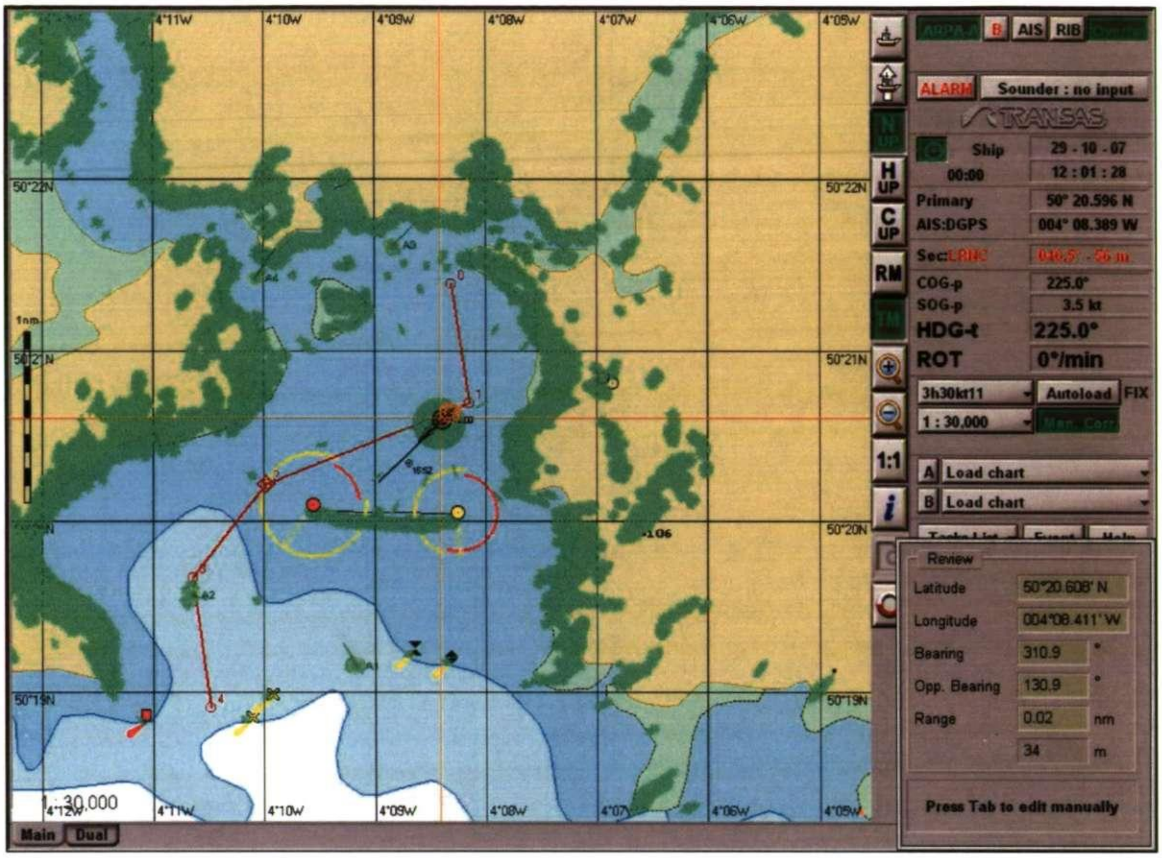


Figure 3-2 RADAR image overlays on ECDIS

With AIS data made available to an ECDIS, ground-stabilised (GNSS supported target information) and near real-time traffic can form a third layer to the chart and its RADAR images (Figure 3-3). In short, ECDIS is a form of Geographical Information System (GIS), where layers of information can be added to the chart display (Kao, Lee et al. 2007). The overall navigating situation can be studied upon these three main sources feeding to a single ECDIS monitoring. Furthermore, the level of integrity can be increased by three information sources in terms of system redundancy.

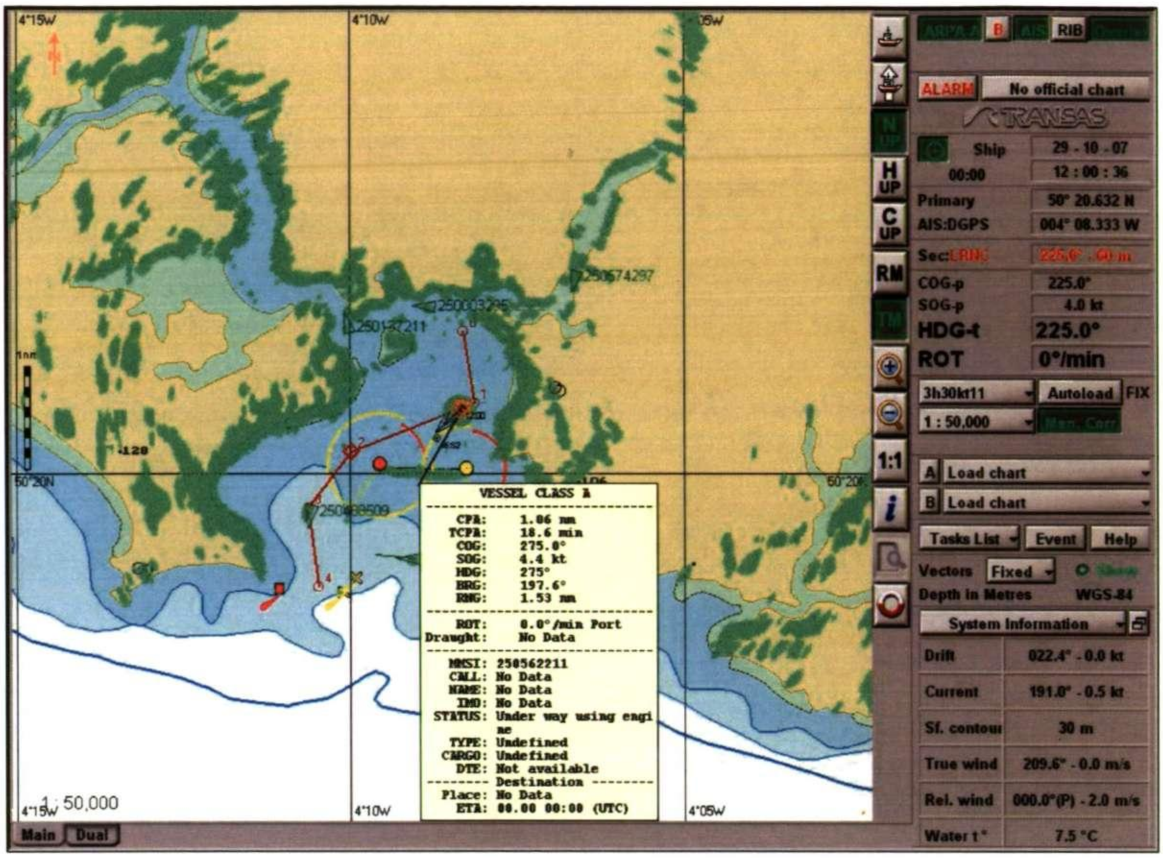


Figure 3-3 Overlaid data on ECDIS

3.2.3 Summary

The applications of route planning, monitoring and position fixing from ECDIS can be enhanced by a number of navigational aids on the bridge. The integration of onboard systems can be obtained, where layers of information can be added into the ECDIS display. In particular, the integration of RADAR images onto ECDIS can assist OOW awareness of traffic aspect, as well as giving integrity checks. The AIS added ECDIS supports all AIS targets with prompt identification and GNSS navigational data. With multi-layer information displayed on the ECDIS, it is the OOW's responsibility to make the best result of operation in costal navigation. Despite the display of AIS on ECDIS, advanced ARPA/RADAR can also display AIS data. The operation of RADAR and AIS will be discussed next.

3.3 AIS information on RADAR

RADAR is the main anti-collision tool on the bridge (McGeoch 1998; Pettersson 2002). RADAR is practical for offshore navigation, such as position fixing and parallel indexing, and as a reference for collision avoidance (Berking and Pettersson 2003). However, target detection is not perfectly guaranteed by RADAR as there are a few drawbacks in its operational function. Firstly, limitations such as a blind sector occur, which can decrease the area of RADAR coverage. The weather and sea conditions may also affect the performance of RADAR causing signal attenuations. Thirdly, the effect of target-swap is likely to occur if two detected targets are close to each other.

When compared with AIS, RADAR does not provide a detailed identity of the detected target.[7] With pressure from growing traffic and growing tonnage of ships at sea, a mutual exchange of ship's details may be required to assist OOW. AIS is not only able to give the identity of the targets, but also additional information with regard to navigational and manoeuvring data. The capability of RADAR on the bridge will be discussed first, followed by RADAR operation limitations, enhancement from AIS and issues of integrated display.

3.3.1 RADAR function

RADAR is capable of handling multi-targets, which makes it the primary detection and tracking system (Davidson 2002). Initially, RADAR was developed for military purposes during World War II. Since 1945, civil RADAR has been available (in the X Band) onboard ship, and since then marine RADAR has been able to assist

[7] Only distress signals via Emergency Position Indicating Radio Beacon (EPIRB) and RACON can be displayed on RADAR.

OOWs with target detection and target tracking. The modern ARPA/RADAR is able to calculate a target's motion and is presented in vectors where information of a target's course, speed and a simulated trial for collision avoidance are available (Lin 2003). In terms of performance, ARPA/RADAR is able to provide continuous, accurate and rapid situation evaluation by enabling OOWs to obtain information automatically, which can save on workload (McGeoch 2002). At present, RADAR is required for all voyages, while for ships from 3,000 grt and above it is also compulsory to install a second RADAR. The carriage of an ARPA/RADAR is required for ships from 10,000 grt upwards.

As RADAR is a system with the characteristic of 'line of sight' detection, objects seen visually on a clear day will also be seen on the RADAR (Smith 2001). By means of the pulse echo principle, the radio electro-magnetic wave travels at the speed of light in space and it will reflect if it hits an object. Generally, targets detected by RADAR will be shown if they are giving a sound echo within the displayed RADAR range (Appleyard, Linford et al. 1988). However, there are certain types of vessels, e.g. small size crafts, various hull materials (glass fibre, stealth material, etc.), that may not be able to give a strong return signal to the ship's RADAR receiver. In case of range selection, targets that are out of the display range will not be shown on RADAR unless a change of range is made. There are possibilities that RADAR will miss detection of targets at sea. As a solution, RADAR observers can adjust the displayed range or have an additional RADAR display with a different range. Overall, the possibilities of omission by RADAR detection can always be checked through traditional means for lookout, as well as using aid from other electronic devices.

Marine RADAR has two designated radio bands: one S Band known as 10 cm and the other X Band known as 3 cm, both working as a means of surface detection. A narrow beam width in the horizontal plane and a wide beam width in the vertical plane are designed in order to give the best results of the targets at sea (Hoy 2000). The wider design of vertical beam width allows for a ship's roll and pitch. In Table 3-1, the frequency, wavelength and maximum peak power are listed for the two main RADAR bands. The higher frequency (i.e. X band) gives good bearing discrimination and long range at reasonable power, whereas the moderately lower frequency (i.e. S band) gives better performance in rain and sea clutter. A bridge could have two RADARs with two different bands or a bridge could have a RADAR with the two bands as optional.

Band	Transmitting Frequency	Wavelength	Radiated power
S	2.9-3.1 Giga Hertz	10 cm	20-75 kW
X	9.2-9.5 Giga Hertz	3 cm	3-25 kW

Table 3-1 Marine RADAR transmitting frequency (IALA / AISM 2001b; IMO 2004)

As with visual bearing in collision avoidance, the echoes gathered from RADAR can be drawn in the form of vectors. In displaying these echoes, the observing target can be displayed in different motions and under different stabilisation (Figure 3-4 and Figure 3-5). The true ground-stabilised vector of a ship unambiguously indicates its actual movement over ground. The true sea-stabilised vector does not necessarily indicate the actual movement through the water, but it might yield the heading (Berking and Pfeiffer 1995). Relative motion is the apparent motion of target ship to host ship.

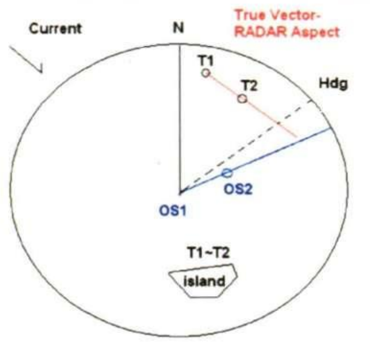
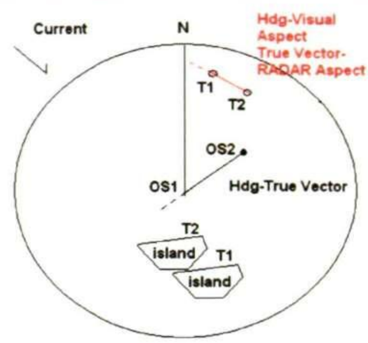
Stabilisation Motion (Vector)	Ground	Water (Sea)
True (Aspect)		
Key	N: North Up; Hdg: Own ship's heading; OS1: own ship at time T1; OS2 Own ship at time T2; T1: 1st observation time; T2: 2nd observation time;	

Figure 3-4 True vectors on ARPA/RADAR display

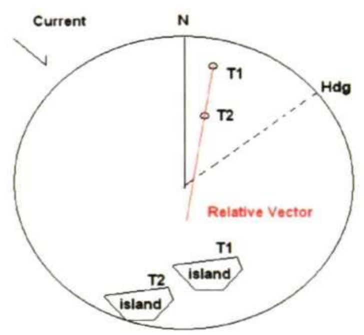
Stabilisation Motion (Vector)	Vessel
Relative (Risk determination)	
Key	N: North Up; Hdg: Own ship's heading; T1: 1st observation time; T2: 2nd observation time;

Figure 3-5 Relative vectors on ARPA/RADAR display

In terms of application, true motion gives the aspect of the target ship but the ability to pick up a collision risk by observing a constant bearing scenario disappears (Barfoot 2005). On the other hand, relative motion gives information regarding the determination of potential collision risk. A speed input from an electro-magnetic log reflects STW and therefore the display is based on water/sea stabilisation. The shown vector from a fixed object reflects the status of current and the vector of moving targets will not involve element of the current. For ground stabilisation, a manual input (e.g. from a GNSS speed data) or Doppler log data reflects the motion of the host ship against the seabed. The vector of moving targets is based on the movement over the ground where the stationary object will not have a vector on the display screen.

For an ordinary (prototype) RADAR, the observer had to calculate each vector of the targets from the monitor display by hand. Later, an automatic system that was able to perform plotting and collision assessment risks was developed, commonly known as ARPA. In Figure 3-6, the functional diagram of ARPA with three input sensors (radio bands, gyro and log) is displayed.

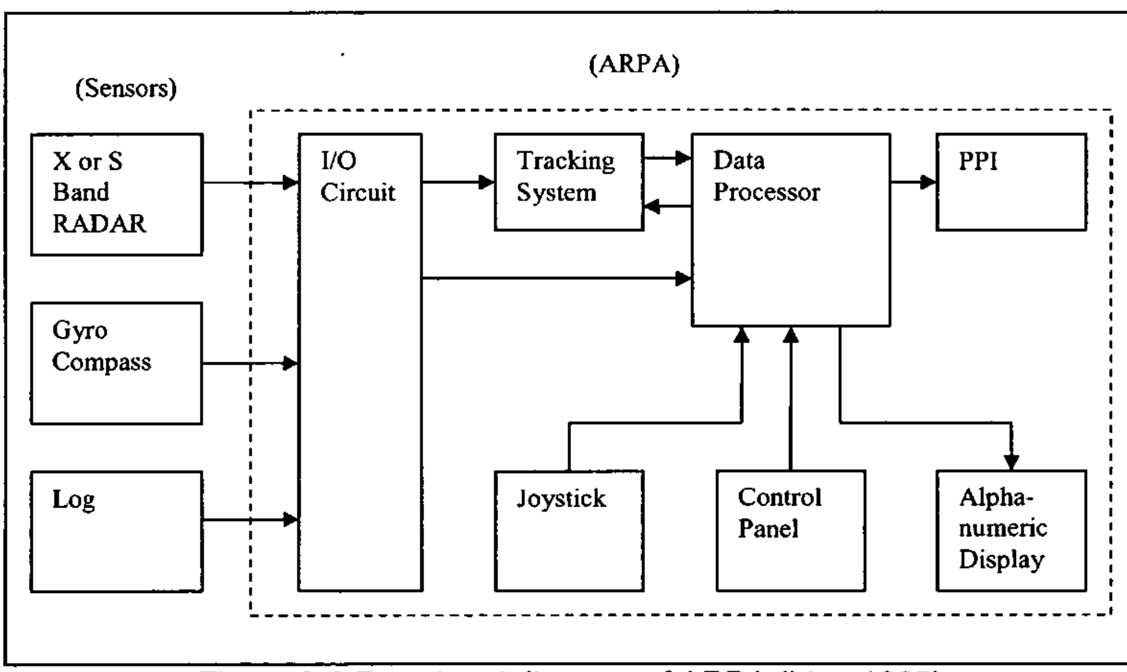


Figure 3-6 Functional diagram of ARPA (Liao 1995)

Generally, multiple targets can be acquired and assessed by means of bearing, range, CPA and TCPA in a certain period after the first request of target acquisition. ARPA plotting for an acquired target could take 1 to 3 minutes in terms of store, process and estimate target data (MAIB 2005). The target acquisition could be manual or automatic. In practice, manual target acquisition is a more common operation than the automatic mode as the latter may end up with too many unnecessary targets' data on the display. The capability of handling more than one encounter in a short period makes ARPA powerful in terms of continuous and prompt determination of situations at sea.

3.3.2 Working limitations of ARPA/RADAR

Observers of ARPA/RADAR are normally advised not to rely on the device alone because there is a chance that ARPA/RADAR may not detect all the targets at sea. There are weather effects, operational shortages and external threats, which may limit the working function of ARPA/RADAR.

3.3.2.1 Weather effects

Attenuated signals on RADAR can occur resulting in a clutter effect due to some worsening weather conditions. In practice, clutter effect (mostly caused by rain, snow and sea) can be suppressed by the anti-clutter control. However, a small target that is hidden in the sea/rain clutter might also be suppressed after the anti-clutter adjustment (Buckens 2002). Despite the weather effect, the material of a small target usually does not give a strong echo to be detected under RADAR. As a result, small targets are more likely to be missed by RADAR's target detection.

The characteristics of transmission of the RADAR electromagnetic wave can be defined as polarisation and refraction (Borje 1991). In general, the electrical field is at a right angle to the proceeding direction. The RADAR electrical field is based on a form of linear polarisation, which weather conditions can interfere with. The proceeding path of the RADAR wave can bend or refract when travelling in a different density of atmosphere. Under the standard atmosphere, the RADAR horizon range is defined as 1.23√h nm, where 'h' is the height of the RADAR antenna above sea level measured in feet. As the weather changes, different sea and weather conditions may cause different results of refraction. As is shown in Figure 3-7, a super refraction can reach further when a temperature inversion or a hydro lapse is present (Hoy 2000).

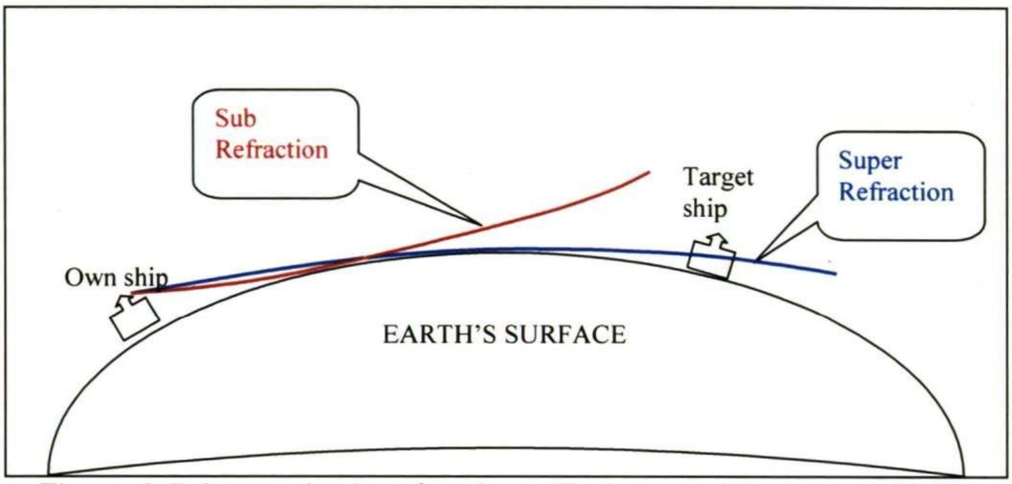


Figure 3-7 Atmospheric refractions (Emberson, Nash et al. 1947)

In other conditions, the RADAR wave can be bent upward and decrease its detection range (known as sub refraction). This sub refraction could take place when the visibility is unusually further than the RADAR contact range. The ducting effect also belongs to a type of radio wave refractions. A ducting effect could happen to a RADAR's wave in the case of an inversion of the temperature layer (an increase in temperature with height, or to the layer within which such an increase occurs). An inversion layer causes weather conditions to thin rapidly. The result is that a target further away can be detected from the RADAR receiver as the waves are guided around the curvature of the earth at a constant altitude; however, this is a rare case.

3.3.2.2 Operation limitations

Due to the working function of RADAR itself, there are a few limitations that may cause OOWs concern when using RADAR information in navigation and ship manoeuvring. Firstly, a target swap could occur if a ship is close to land, beacons, bridges and other ships (Pettersson 1997). This makes ARPA/RADAR functions very restricted in narrow and congested waters. When two target ships pass close enough to one another, RADAR tracking can be interrupted with the result that the RADAR tracking of one contact is confused by the proximity of the other.

Secondly, the characteristics of X or S Band wavelength in a target's detection (see Section 3.3.1), the accuracy of the host ship's heading (from gyro) and the speed (from log) can have an impact on the quality of input data to ARPA/RADAR. The dependence of ARPA/RADAR operation on these sensors is inevitable in seeking targets' acquisition, orientation and consequential vectors.

Thirdly, the ARPA data is delayed because of RADAR's echo-based position, and velocities have to be smoothed for tracking purposes (Berking and Pettersson 2003). Smoothing is also known as damping or filtering, and is carried out in order to obtain the motion vector by averaging a series of positions, fixing them into a straight line. For example, it may need 5 to 10 antenna rotations to determine the movement of a target in the case of a course alteration (IALA / AISM 2002).[8] Alternatively, the host ship changing its course may have to wait until it is on a steady course in order to produce a reliable target vector on RADAR.

[8] A steady movement may take ARPA/RADAR 1 to 3 minutes to work out according to the IMO performance standard for navigational equipment.

Fourthly, the detection of large ships by ARPA/RADAR may have difficulties in operation. The complexities in detecting a large ship may result in the distortion of RADAR detection and delayed ARPA/RADAR motion calculation (IALA / AISM 2002). In terms of RADAR detection, the high superstructure of the aft section of a tanker, for example, may give a stronger echo to the ship's own RADAR. Hence, the likely RADAR target could reflect as an echo from the tanker's aft structure instead of its central part. As a result, a big ship could have an opposite motion to the predicted heading (Pettersson 1997). When a ship is turning starboard around the pivot point (Figure 3-8), the heading of the ship shown on the ship RADAR may turn in the opposite direction as the superstructure aft swings to port. Moreover, the turning ability of a tanker can also confuse ARPA/RADAR detection. It is believed that ARPA/RADAR could take up to five minutes to detect a bigger ship when turning (Berking and Pettersson 2003). In the meantime, an alteration of course made by the big ship could reach 40 to 50 degrees. Overall, the automatic tracking represents a history of the target's movement. A fast manoeuvre by target vessels might not be detected promptly.

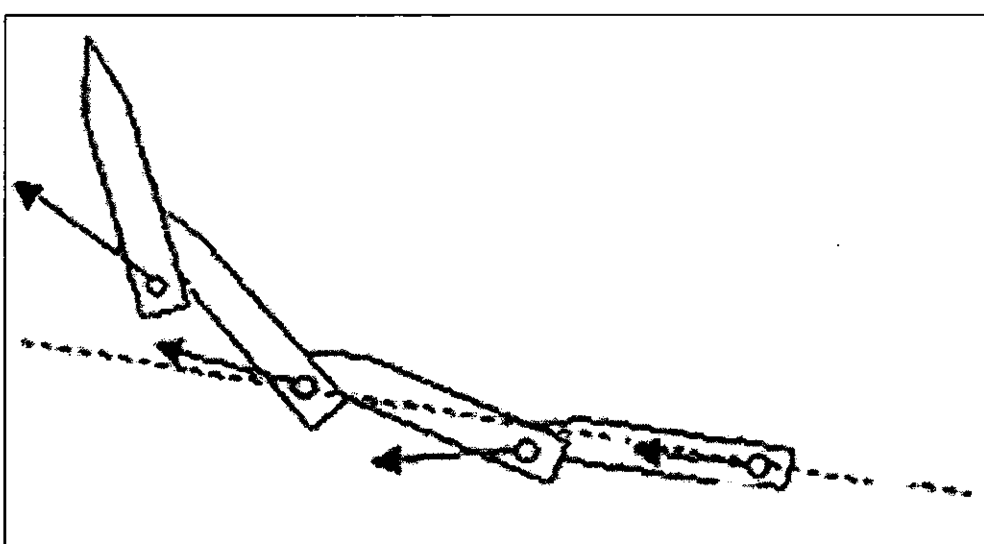


Figure 3-8 ARPA detection of a large ship when turning (IALA / AISM 2002)

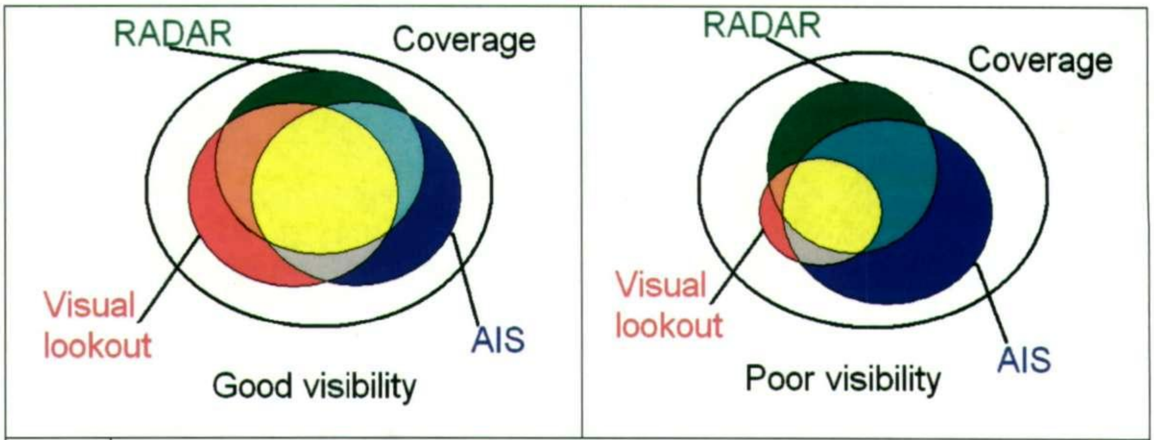
3.3.2.3 External threats

Finally, changes in RADAR development may affect the operation of RADAR itself. There have been proposals to share bands (particularly 3GHz band), which are likely to change RADAR technology (Pope 2002). Threats to the radio spectrum occupied by RADAR can be found from other users, such as a mobile phone spectrum. Even if marine RADAR is not going to lose one of its radio bands, competition from other operators may cause a narrower RADAR operating band width and signal interference is foreseeable. Hence, target identification improvement from either AIS or a solid-state RADAR technology could be necessary as a solution to these threats. However, the current detection of RACON, SART and RADAR reflectors would not be available to these two methods for detection.

3.3.3 Aid from AIS

RADAR is the one of the main tools dealing with collision avoidance; nevertheless, the problems of RADAR operation should be under scrutiny when using RADAR on the bridge. In terms of coverage (target detection), there are certain areas and targets that might not be detected by RADAR: firstly, a shadow sector in the form of sea/rain clutter could happen on RADAR; secondly, targets at a close range or a small target vessel behind a larger ship might not be shown on RADAR. The danger in relying solely on RADAR in order to gauge the overall situation is apparent. To maintain a proper lookout, conventional and modern manners should be adopted at the same time.

Taking a visual lookout, RADAR and AIS into an evaluation of the target detection onboard a SOLAS vessel, each individual method has a contribution to make in bridge lookout. In good visibility (Figure 3-9), most targets can be confirmed by the three methods together (the yellow area). In poor visibility, coverage from both visual lookout and RADAR detection can be reduced. Thus, there is a greater chance that a target might not be covered in poor visibility than good. The introduction of AIS can improve awareness of ships if both RADAR and visual lookout are badly affected. Ships with AIS onboard will automatically identify themselves via the AIS network. With regards to the blind sector where a target is hidden behind the landscape, AIS targets will not be affected due to the propagation characteristic of a VHF radio signal being different to RADAR's electromagnetic radio wave. Next, the range scale setting on the RADAR could accidentally eliminate a target with collision probability if the target is out of the display range. A Close Quarter Situation (CQS) might not be spotted at an early stage if the target is outside the range scale. As ships with AIS can see each other on the AIS display up to 30 nm so that a development of a CQS can easily be acquired using AIS.



Key	Red area: targets in visual contact without AIS identity nor RADAR echoes; Green area: non AIS targets detected by RADAR beyond visual contact range; Purple area: AIS targets without RADAR echoes beyond visual contact range; Yellow area: targets confirmed by visual contact, RADAR and AIS altoghter; Blue area: targets confrimed by RADAR and AIS, yet beyond visual contact range; Orange area: non AIS targets confirmed by RADAR and visual contact; Grey area: AIS targets with visual contact confirmation that did not show on RADAR.

Figure 3-9 Lookout coverage in good and poor visibilities
(Hsu, Witt et al. 2005)

The characteristics of ARPA/RADAR plotting for target tracking are delayed, smoothed and historical results (see Section 3.3.2.2). In the case of fast moving targets, course changing targets and speed changing targets ARPA/RADAR could take 3 to 5 minutes to provide real data of a target's movement (Harre and Meine 2004). Ship manoeuvres can be indicated with less delay because AIS data is determined at a shorter interval than that derived from the RADAR. As a target ship's gyro data (ROT optional) is transmitted via AIS, the change in a target ship's heading (and course alteration) can be confirmed positively and quickly.

AIS can operate in all visibility conditions and any traffic density, and the RADAR's problem of positively identifying a target is uniquely solved by means of transponder interrogation (Norris 2007). In comparison, RADAR is an active and independent target tracking device, whereas AIS is highly reliant on the information received from other ship. If data transmitted via AIS can be properly maintained by all users, the received data will be more trustworthy and more likely to be adopted and shared among the users. Despite the uncertainty of data sent by nearby ships, there are also objects and vessels which do not have AIS onboard and will not be shown on the AIS display. At present, the role of AIS in relation to the RADAR should be seen as an assistant as AIS can be useful when there are concerns about inadequate RADAR detection and tracking. Next, the operations of both RADAR and AIS will be discussed.

3.3.4 RADAR and AIS operation

Both RADAR and AIS are able to support OOWs in terms of target detection and tracking (Davidson 2002). However, different propagation methods are applied by the two systems. OOWs will have to compensate the differences that occur between the two systems if AIS and RADAR are both considered in an anti-collision decision.

Fundamentally, the pattern for a RADAR target is water based from the perspective of the host ship. The pattern for an AIS target is ground based as a perspective from a satellite (GNSS position fixing). In theory, a target acquired from RADAR and AIS should show at the exact location on the display regardless of any current taking place. For example, targets acquired by RADAR could be shown as ground based movement as long as the RADAR scanner is located ashore. In reality, the current does have an effect in navigation.[9] Displaying vectors from ARPA/RADAR and AIS upon a target will inevitably show two

[9] The elements related to current include ocean current, tidal current, wind, windage on the ship, heavy seas, inaccurate steering, undetermined compass error, error in engine calibration, error in log calibration, excessively fouled bottom and unusual condition of trim.

different headings and proceeding distances, even when no other errors are present.

In terms of data refreshing, RADAR is able to maintain a constant though slower transmission rate due to the antenna's rotation speed. Therefore, the target's heading as acquired by RADAR can have a time lag when the ship's heading changes (see Section 3.3.2.2). Generally, AIS provides transmission with a variable rate regarding the target's speed and ROT (see Section 2.3.2). The limited capacity of transmission channels does not allow equally frequent updating from a less important target at sea. The most frequent transmission rate is two seconds intervals, where a maximum error of +/- 2 degrees could be expected from the AIS indicated heading provided by the gyro. On the other hand, only Class A AIS targets at anchor will have to wait for 3 minutes to refresh its data.

With limited channel capacity, the purpose of variable transmission rates is to give more priority to the vessels at higher speeds and/or in course alteration. By this effort, AIS course alteration can be shown from the moment that the wheel was put over, whereas one could expect an average of 5 minutes between wheel-over and recognition of the fact on ARPA (Buckens 2002). ROT and speed data from AIS can assist ARPA/RADAR when a vector calculation is delayed from a turning vessel. Finally, the setup of the correct range scale is also essential to RADAR observers, where targets will not be seen if it is out of display range. An independent display of AIS next to a RADAR display can support a consistent AIS targets within its VHF transmitted range.

In comparing the performing accuracy of RADAR and AIS, the errors derived from positioning will be illustrated. To determine a target's position, RADAR detection is based on the range and azimuth to the object's echo, whereas AIS target positions are presented in latitude and longitude. In terms of absolute positioning, up to 100 metres accuracy could be expected from RADAR, which is worse than the performance from AIS (Holland Institute of Traffic Technology 2004).[10] Because of the errors derived from RADAR and AIS, resulting in the creation of a target with two tracks (two separate returns, two headings and two vectors), the coordinates derived from RADAR and AIS need integration. As RADAR is not referenced to the coordinates in WGS-84 datum, to fuse a RADAR echo with an AIS return may need further information about the raw RADAR echo. Normally, RADAR accuracy performs better when a target is close to the RADAR site.[11]

Currently, operating RADAR and AIS together can be implemented on a RADAR monitor overlaid with AIS or using a standalone AIS. Apart from the standalone display, data fusion is required if AIS targets are available on RADAR. In a study undertaken by Hughes and Sowdon, a trial was carried out onboard Washington State Ferries using AIS enhanced RADAR display in their daily work. Criteria to fuse AIS and ARPA targets into one symbol were made available on their displays. A number of criteria were made to validate the fused target (Hughes and Sowdon 2006):

- the positioning gap between AIS and RADAR displaying resources;
- the adopted range scale;
- the difference of bearing/course; and
- the calculated speed.

[10] RADAR range accuracy 3.75 metres, radial accuracy 0.2°, AIS accuracy 3m-30m (GNSS positioning accuracy)
[11] A 0.05° deviation is approximately 16 metres at 10 nm, and 3 metres at 2 nm.

These were the major elements used to decide whether the merged targets based on two different sources are valid. In a case where one target vessel representing two targets on the RADAR screen, one of the criteria mentioned above was subject to be breached. It is a cautionary condition either one of the systems, RADAR or AIS, is under tracking errors.

3.3.5 Summary

There are advantages and disadvantages when observing data from ARPA/RADAR and AIS respectively. In both aspects of navigation and ship manoeuvring, RADAR and AIS are able to provide OOWs with targets' movement data and position. In seeking the targets' information (Table 3-2), RADAR is working as a stand alone device whereas AIS is relies on the data contributed by other AIS equipped targets.

RADAR target data	Shipborne AIS data
STW from log	GNSS based SOG
Course through the Water (CTW) from log	GNSS based COG
Past and relative heading	Near real-time heading
Position fixing based on bearing (angle) and range (distance)	GNSS based position provided in latitude and longitude
Target detection by its own electromagnetic scan	Target detection via the transmission network (every users' cooperation)
Constant transmission rate (3 seconds consistently)	Variable transmission rate is dependent on target's speed (2 seconds – 3 minutes)
Manual range setup	Maximum range 20-30 nm

Table 3-2 Comparison between RADAR and AIS in navigation and manoeuvre

In a number of ways, AIS has the potential to assist and improve RADAR functions in target detection, identification and tracking. However, the complex integration between AIS and RADAR may need thorough study to work functionally and be more user-friendly. The setup of criteria for detecting unreliable information produced by using both RADAR and AIS needs to be checked frequently.

3.4 VHF radio communication

The use of VHF radio communication can often be seen in ship reporting as well as intention clearance. However, there are no regulations for the use of VHF radio in ship collision avoidance in SOLAS Convention (Cockcroft 2003), so that different countries might have different guidance in VHF assisted ship manoeuvring. Opposing opinions can be found between the US Coast Guard (USCG) Radio Watchkeeping Regulations and the UK Maritime and Coast Guard Agency (MCA) Marine Guidance Note (MGN) 324 (M+F) (See Appendix A). The use of VHF can cause some difficulties in verbal exchanges, manner of radio communication and length of communication. The application of VHF in ship reporting and ship manoeuvring will now be discussed.

3.4.1 Ship reporting system

Ship reporting is generally required when entering VTS waters or approaching ports (Koburger 1986). The most common procedure is to report the presence of the ship when entering/leaving an area by means of the VHF radio telephone. As a result, verbal communication is a routine procedure with international and national languages used in different harbours/countries. Problems may occur in understanding the languages being used when communication has been established between ships and shore stations (Pettersson 1997). A misunderstanding derived from a VHF communication in ship reporting may lead to some concerns, such as a delay in a ship's passage, running into danger and infringement of the region's regulations. In fact, ship reporting normally is needed in busy and restricted waters for transiting or approaching an area under coastal surveillance. A prolonged conversation between a ship and shore station could cost precious time and reduce the quality of lookout consequently.

3.4.2 Ship manoeuvring with VHF

VHF radio communication can be used in intention confirmation when two ships are approaching each other. This was first found to be useful for pilots who are travelling in the Great Lakes in the US (Deseck 1981). The recommendation in the US was to encourage OOWs to deploy VHF communication with another ship if a potential collision risk exists. By understanding the intention of the other ship, the OOW can evaluate the situation with the surrounding traffic and navigable water. Because of the danger and consequences derived from VHF communication, verbal communication in collision avoidance applications should be kept as short and clear as possible, and take place at a greater distance. Later, the usage was extended from US waters to international water where a problem appears in terms of a language barrier and distraction from duties (Chhabra and Stevzhantov 2006). The language barrier could lead to further misunderstanding or misinterpretation of the other vessel/shore station's instructions. The time that is spent on ship identification via VHF could consume the time for taking bold action against a collision.

It is rarely possible to initiate a conversation with a vessel without an identity (Hadnett 2003). A prolonged attempt to establish the VHF conversation frequently causes confusion due to reliance on the cooperation of the other ship. Hence, to discuss action through VHF between two or more vessels is fraught with danger. Since misunderstandings can still arise where the language of communication is not a problem, VHF should only be used with caution (MCA 2006). Most importantly, an agreement by two ships in collision avoidance should not contravene the spirit of COLREGs.

3.4.3 AIS assisted VHF calling

When vessels enter a ship reporting system, the prompt and unambiguous identification of all AIS equipped vessels will enhance the overall effectiveness of the system with further confirmation by voice or RADAR contact (Davidson 2002). In ship reporting, a shore station with an AIS transceiver can obtain the required information from the broadcast in a regular interval. The content that AIS can send and receive in its network includes static, dynamic, voyage related and navigational information. A VHF conversation assisted by AIS can reduce the length of verbal communication ship-to-ship and ship-to-shore (IALA / AISM 2002). Ambiguous conversations can be improved by a positive identification between the two parties. The time saving and reduction in routing ship reporting can leave the VHF channels and Channel 16 in particular, to users with more urgent needs.

AIS can facilitate rapid radio communication by means of automatic and immediate provision of vessel identity (IALA / AISM 2002). A ship's call sign and MMSI are easily obtainable. This can mean that VHF calling with an unknown vessel could become a rare incidence. The prompt identification and following information from AIS can provide the OOW with the details of the target ship. With increasing confidence in ship identification, the use of VHF calling in collision avoidance between two ships might give an OOW advantages for obtaining more information from the other ship via a further VHF communication.

There is no provision for VHF conversations in the existing COLREGs; however, they do not prohibit mariners from using VHF in collision avoidance (Clandillon-Baker 2000). The AIS ship identity function shortens the time needed to establish a VHF conversation with a target vessel, and so more VHF calling for collision avoidance might be expected (Pettersson 1997; Berking and Pettersson 2003; Hadnett 2003; Chhabra and Stevzhantov 2006). Although identification difficulties in original VHF communication can be overcome by AIS, the dangers of VHF communication between ships in terms of misunderstanding and misinterpretation do not disappear simply with positive target identification. As a result, the research will investigate the current status of AIS VHF usage especially for the use of collision avoidance (See Section 4.2, Section 6.3.3.5 and Section 6.4.3.6).

3.4.4 Summary

VHF verbal communication can be reduced by AIS message broadcast because the language barrier and misunderstanding among ships and with shore stations can be minimised by the use of AIS (Sollosi 2002). AIS constantly feeds information to ships and shore without manual interference. Moreover, prompt identification from AIS could actually boost VHF communication as the target identity is easier to obtain. VHF communication with AIS assistance between two ships can clear doubt and obtain intentions from each other, but this will not erase the danger of misunderstanding. In fact, the convenience brought by AIS could tempt an OOW to use VHF more often to assist with the difficulties of manoeuvring to the extent that the responsibility to comply the COLREGs could be sacrificed. The use of VHF may prove efficient in some areas where experienced mariners, e.g. pilots, share the same language and same procedure in transit of familiar water. VHF assisted collision avoidance will be more complicated in high seas or international water where diverse nationalities of watchkeepers can be expected.

3.5 The impact of operating AIS under the Steering and Sailing Rules

When measuring the risk of collision at sea, the COLREGs are the only authority for vessels (Hinchliffe 2002). In the Steering and Sailing Rules (Part B, COLREGs), three sections deal with the definition of visibility: the conduct of vessels in any condition of visibility, the conduct of vessels in sight of one another, and the conduct of vessels in restricted visibility. According to the revised Chapter V SOLAS the International Ship and Port Facility Security (ISPS) Code[12], most sea-going ships will have to carry AIS. Nevertheless, the compulsory AIS carriage requirement for SOLAS ships came into force after a number of the amendments to the 1972's version of COLREGs. As AIS is capable of giving traffic data, which is in a similar form of RADAR targets (see Section 3.3.3), the impact of operating AIS under COLREGs will be compared with COLREGs involving RADAR operation. Next, the rules for vessels when in sight of one another will be discussed separately in terms of the vessels' conduct and related to the privileged situation.

3.5.1 RADAR referred Rules

COLREGs consider RADAR as an important element in maintaining safe speed, determining the risk of collision and actions to avoid it, and detecting target in restricted visibility (Cockcroft and Lameijer 2003). RADAR has proved itself to be

[12] The ISPS Code is implemented through chapter XI-2 in the SOLAS Conventions.

essential under COLREGs. In seeking the possibility of AIS operation with COLREGs, the Rules considering the operation of RADAR will be discussed.

3.5.1.1 Rule 5 Lookout

"Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision." is required by Rule 5 COLREGs (IMO 2008). In order to identify the traffic nearby, OOWs are advised to take every possible source of information on the bridge into their decision-making processes. The definition of the Rule 5 gave an indication that 'all available means could include RADAR and other potential electronic aids, such as AIS, to evaluate the situation to assist with sight, hearing and other methods of bridge lookout. With a number of advanced electronic aids on the bridge, the balance of lookout might move away from the conventional visual lookout (Pyke 2004; Beer 2006). The advantages and disadvantages of both visual lookout and electronic aids can be appreciated by seeking a balance in operating them at the same time.

3.5.1.2 Rule 6 Safe Speed

Rule 6 of the COLREGs requires every vessel to keep a 'safe speed' at all times, although the Rules do not emphasise a degree of speed in order to seek safe passage with another vessel. A different term, 'moderate speed', was used in the 1960 version of COLREGs. The Rule 16 (a) in the 1960's COLREGs determined the speed by enabling a vessel to stop within half the range of a restricted visibility (General Council of British Shipping 1975). In an attempt to define exact speed for ships, IMO (the Convention on the International Regulations for Preventing Collisions at Sea, 1972) tried to determine levels in different ranges of visibility, but was not successful due to the visibility not being the only concern for ship's speed (Institute of Navigation 1959; George 1966; Dickson 1969; Institute of Navigation 1972; Kemp 1972). In 1972, 'moderate speed' was replaced by 'safe speed' in the latest version of COLREGs and safe speed is used more generally in all conditions of visibility (IMO 2003b). The concern to modify a vessel's speed in order to avoid foreseeable risks of collision is the essence of the Rules. A relatively slower speed in relation to oncoming traffic will gain more time to alter course or speed if necessary. In short, it would be irresponsible and unacceptable if an OOW decides to go full speed when the visibility is restricted and the volume of traffic is high. Yet, the rules do not state that slow speed is safe speed. Slowing down to a certain speed can render difficulties in a vessel's manoeuvrability or even create another CQS with another vessel.

RADAR operation is included in the second part of the Rule 6. With proper use of RADAR information, a higher speed could be justified than for a vessel without RADAR (Cockcroft and Lameijer 2003). The factors related to RADAR operation are in Rule 6 (b), (i)~(vi) (IMO 2003b):

1. the characteristics, efficiency and limitations of the RADAR equipment;
2. any constraints imposed by the RADAR range scale in use;
3. the effect on RADAR detection of the sea state, weather and other sources of interference;
4. the possibility that small vessels, ice and other floating objects may not be detected by RADAR at an adequate range;
5. the number, location and movement of vessels detected by RADAR;
6. the more exact assessment of the visibility that may be possible when RADAR is used to determine the range of vessels or other objects in the vicinity.

If AIS is considered and compared with the factors above, there are some advantages and disadvantages that could contribute to the determination of a safe speed. AIS is able to provide prompt data with a higher updating rate and longer range detection than RADAR. The weather and landmass presence have less effect in disturbing AIS/VHF signal transmission than RADAR. Furthermore, an extra AIS display provides RADAR with additional target display and the possibility of a different display with a different range setup. An AIS-fitted small ship with the potential to be miss detection by RADAR can also be traced, even when the characteristics of RADAR Cross-Section (RCS) are poor. Ideally, operational AIS could improve RADAR operation and overcome some of its drawbacks. Hence, a safe speed determined by a comprehensive reading of RADAR along with AIS could have a positive impact on an OOW's anti-collision decision.

3.5.1.3 Rule 7 Risk of Collision

Rule 7 of COLREGs requires vessels to apply all available means to detect the danger of collision and to take appropriate preventive measures. In particular, the use of RADAR is recognised for long-range scanning for early warning of a collision risk. However, the possibility that scanty information appears on RADAR is also raised in Rule 7. In general, the proper operation of RADAR shall be maintained to seek a better awareness of any collision risk.

Rule 7 has a different purpose in stating the requirement of 'all available means appropriate' to the same phrase used in Rule 5 (Cockcroft and Lameijer 2003), where it emphasises the use of RADAR (ARPA included) in evaluating collision risks. Here, operational RADAR is deemed to be providing long-range scanning in terms of early warning of risk of collision. Moreover, RADAR with a plotting function (i.e. ARPA/RADAR) can calculate the vector of targets. Similar recommendations to the use of RADAR can also be obtained via the AIS network. A target with an AIS transponder can be seen by a ship from a distance of up to 30 nm. Targets' vectors can also be calculated by AIS. On the one hand, RADAR observation of targets at sea could be improved and confirmed with help from AIS identification and dynamic information. On the other hand, scanty information could come via the AIS network, but this can also be observed in relation to a RADAR monitor. As a result, systems redundancy and situation awareness can be improved by cross observation of RADAR and AIS results.

3.5.1.4 Rule 8 Action to avoid collision

Action to avoid collision is described in Rule 8 as bold, made in ample time and with due regard to the observance of good seamanship (IMO 2003b). Rule 8 (b) goes further in stating that the action shall be apparent in a vessel's course alteration and/or speed change. Small course alterations and speed changes may not be monitored by means of visual sighting and RADAR. A vessel (either as give way or stand on vessel) taking manoeuvring action should also send other vessels a clear message that she is activating anti-collision.

To avoid confusion and misunderstanding by sighting and RADAR, bold action in ample time becomes a clear indication for vessels taking action to avoid collision. From the opponent's point of view, detecting vessels taking action is also crucial for subsequent observation of existing risks or determination of new action. Apart from visual lookout and RADAR, information obtained from AIS can also assist an

OOW in risk evaluation. As opposed to RADAR observation of a situation's development, AIS does not need both ships to be stabilised yet still gives near real-time changes of course and speed. Therefore, AIS provides consolidated data that can be applied in anti-collision decision-making.

Understanding what the other vessel is doing is vitally important to OOWs so that misunderstanding and misinterpretation of a developing situation can be avoided (Mosenthal 1996). In assisting both visual and RADAR detection, AIS can be applied to give extra information support to decision-making in collision avoidance.

3.5.1.5 Rule 19 Conduct of vessels in restricted visibility

The conduct of a vessel under Rule 19 is different to the rules in Section II, which deals with conduct regarding vessels in sight. The term 'In Sight' becomes a criterion to differentiate these two sections (Hooper 1995). Rule 19, Section III is for action taken when vessels cannot see each other. In this case, the use of RADAR is recommended to determine any developing CQS and/or existing collision risks. Regardless of the relative position of the target vessel, the observing vessel is required to take avoiding action once it has been determined that risk of collision or a CQS is developing. Course alteration to avoid collision is further specified when RADAR observation is carried out.

When the approaching vessel is ahead of the observing vessel (excluding an overtaking vessel), the vessel is asked not to alter course to port; when the approaching vessel abaft or abeam, a vessel is asked not to alter course toward the encounter vessel. Compared to RADAR's electro-magnetic wave, the AIS VHF radio wave has less attenuation due to various weather conditions. The assistance from AIS is thus able to provide OOWs with extra target coverage and movement information. Any developing CQS could be avoided by taking early action using AIS information.

3.5.2 Section II: Conduct of vessels in sight of each other

Head-on, overtaking and crossing are the three types of situation described in Section II when vessels are in sight of one another (see Rule 11, COLREGs). Two vessels in sight will have clear responsibilities as either a stand-on vessel or give way vessel. [13] As a result, the range of visibility becomes an element in determining the situation according to the COLREGs. The use of RADAR and AIS can give supplementary knowledge of the range of visibility when a vessel is first sighted. However, a target vessel identified by electronic aids only shall not be applied under Section II. These rules shall be applied to vessels in sight and electronic aids should not be used as an excuse to infringe COLREGs.

The rules of good seamanship should always be kept by a prudent OOW. In general, OOWs should follow the rules of Section II when a vessel is within the range of visual lookout and Rule 19 when not in sight.

3.5.3 Rule 18 Responsibilities between vessels

Rule 18 of the COLREGs explains the responsibilities of vessels apart from those required under Rule 9 Narrow channels, Rule 10 TSS and Rule 13 Overtaking (IMO 2003b). A group of vessel's categories are listed to indicate which have less

[13] Two vessels are both deemed as give way vessels in a head-on situation.

difficulty in manoeuvring to keep clear of vessels with privilege. The first priority of the privileged type of ships is that a vessel Not under Command (NUC) is followed by a vessel restricted in her ability to manoeuvre, a vessel constrained by her draught, a vessel engaged in fishing and a sailing vessel. As the Rule is included in the Section II, the burden falls upon vessels when in sight of a privileged vessel. As a privileged vessel, proper signals should be displayed by associated lights and/or shapes.

An early warning of a vessel with a privileged status can be obtained via AIS 'Navigational status' well before the relevant lights or shapes can be expected to be seen visually (Stitt 2004). In addition, voyage-related information showing a ship's draught can also indicate whether the ship has a limited area to run in shallow waterway. In an ordinary situation, vessels with privileged status will need to lift corresponding shapes in the day-time and turn on corresponding light signals at night in order to exhibit their difficult status. The vessels with privileges mentioned in Rule 18 are required to have shapes and lights according to Part C Lights and Shapes, COLREGs. The minimum visibilities of lights are shown in Table 3-3. The privileged condition of any AIS identified vessel can be noticed by the OOW miles in advance.

Sizes of vessel / Navigational lights	Vessels > 50 metres	Vessels between 12~50 metres	Vessels < 12 metres
Masthead	6 nm	5 nm	2 nm
Sidelight	3 nm	2 nm	1 nm
Stern	3 nm	2 nm	2 nm
White, red, or green all-round light	3 nm	2 nm	2 nm

Table 3-3 Minimum ranges of navigational lights (IMO 2003b)

Any decision can be influenced by the information acquired from AIS. Whether the OOW will decide to give way to the privileged vessel at an earlier time is dependent on the situation. In general, the signals of lights and shapes displaying vessels under privileged condition can certainly be improved. Earlier awareness of a privileged vessel will provide an OOW with more time to take a decision, even when the vessel is not within visual sight.

3.5.4 Summary

The role of AIS is as one of the navigational aids on the bridge (Stitt 2004). The real-time mutual exchange of information such as course, speed, etc. can assist the decision making in collision avoidance (Komrakov 2003). From the influence of RADAR to the revision of COLREGs in 1972, AIS will have to prove essential in collision avoidance if it is to be specifically considered in the COLREGs.

3.6 Conclusions

There are a number of applications in AIS associated with the current operations; in RADAR observation, ECDIS route planning and monitoring, and VHF's ship reporting and communication. AIS has shown that it has the capabilities to enhance situation awareness by adding extra information as well as cooperating with other navigational systems. However, several interim consequences may affect use during the early stages of development, such as inadequate display on the bridge, incompetent data fusion or lack of training consensus. As one of the latest navigation aids on the bridge, AIS might require a thorough study to ensure effective operation for lookout.

Although AIS has the potential to assist and support shipborne navigational systems, the functions of AIS for navigation, ship manoeuvring and communication can be studied along with a human operator. It is the OOWs who make decisions based on all the navigation aids they adopt. Hence, man-machine-interfacing must be thoroughly considered in order to bring out the best performance of bridge operation. AIS will have to demonstrate its compatibility with the existing navigational devices as well as being able to work with the operators.

Chapter 4

Collision Cases

4.1 Introduction

The legitimate position and functional performance of AIS have been illustrated in the previous chapters. Next, an investigation from the perspective of AIS end-users will begin by examining AIS-assisted collisions. This case study on collision cases is aimed to build up knowledge by learning from others' mistakes. Although AIS was only introduced to the marine industry in 2002, there have been a few incidents involving the use of AIS. So far, all the cases involving AIS operation have direct or indirect connections to VHF calling in an anti-collision manoeuvre.

Resolution A.917 (22) listed the purposes for onboard operational use of AIS (IMO 2002c): AIS is intended to help identify vessels; to assist in target tracking; to simplify information exchange; and to provide additional information to assist situation awareness. Resolution A.917 (22) acknowledged that AIS may assist in collision avoidance when AIS is seen as an additional source of navigational information. To be able to consider AIS in decision making on collision avoidance, other collision cases involving navigational systems (mainly RADAR and VHF) and traffic management (VTS) will be discussed.

4.2 Collisions cases involving AIS operation

The first collision involving the use of AIS took place in 2004. Until this point, collision and near miss cases were all linked to the subsequent use of VHF calling for ship manoeuvring. Despite the differing views between the US and the UK in VHF assisted ship manoeuvring (see Section 3.4), the function of prompt identification by AIS could simplify a VHF conversation with another ship. This raises concerns about whether AIS-assisted VHF calling affects the execution of the COLREGs.

4.2.1 Hyundai Dominion/Sky Hope

On 21 June 2004, the UK registered Hyundai Dominion collided with Hong Kong registered Sky Hope in the East China Sea (MAIB and HKMD 2005). The incident represents the first collision case involving the operation of AIS. Both OOWs were chief mates, and were both found responsible for the incident. Firstly, fairly good weather with good visibility was reported. Both ships did have each other on visual bearing and RADAR/ARPA at a reasonably early stage (Figure 4-1). The OOW onboard Sky Hope was found to have mistakenly interpreted an overtaking situation with Hyundai Dominion. Seeing his own ship as an overtaken ship, Sky Hope decided to carry on her course and speed at an early stage. The OOW onboard Hyundai Dominion assessed a crossing situation with Sky Hope and therefore also kept course and speed (as a stand-on vessel) in the early stages. Neither OOW altered course nor changed speed, even though a small CPA (about 0.3 nm CPA at range of 5nm) was acknowledged. Instead of ship manoeuvring, the two ships undertook a VHF conversation before it was too late to alter course from collision.

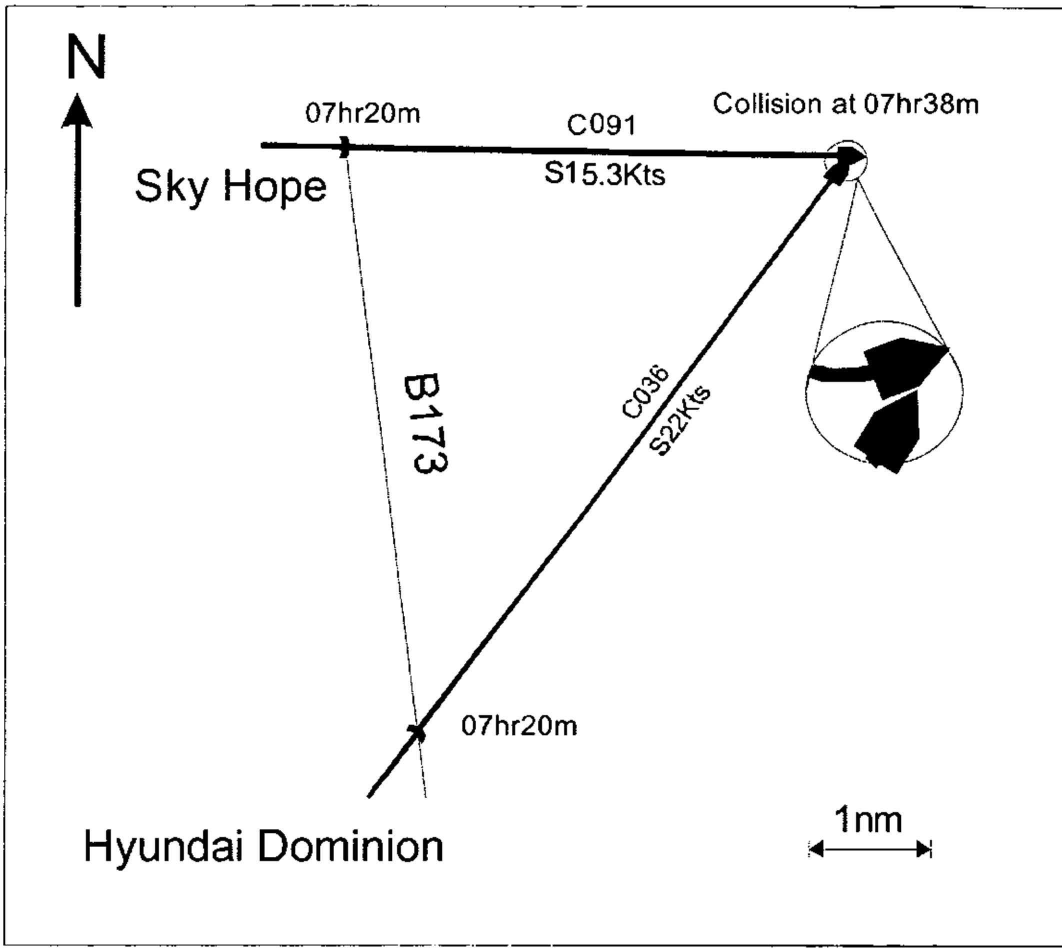


Figure 4-1 Collision incident from Hyundai Dominion and Sky Hope (MAIB and HKMD 2005)

Both Hyundai Dominion and Sky Hope construed the situation differently and thought that the other one should give way. The Hyundai Dominion's chief officer claimed he had sent a text message to the Sky Hope via AIS in order to solve the situation. Nevertheless, the OOW on Sky Hope did not use AIS throughout the incident nor did he notice any incoming message from AIS. The arrival of text messages with an audible alarm is not available for AIS systems. Hence, it is unsuitable for passing urgent safety related messages and this clearly made the system vulnerable in this case (MAIB and HKMD 2005). The exact wording of message sent via AIS was 'PLS KEEP CLEAR', which indicates that Hyundai Dominion would like Sky Hope to give way. During the crucial moment of collision avoidance, this became unrealistic and irresponsible as the Hyundai Dominion did not confirm whether or not Sky Hope actually acknowledged the message. Hence, sending a text message via AIS did not provide the chief officer of the Hyundai Dominion with confirmation that he had communicated with the Sky Hope. Today, there is no regulatory provision from IMO carriage requirements or COLREGs that approves navigational operation through this kind of AIS transmission.

Apart from text messaging to Sky Hope, Hyundai Dominion also spent some time 'texting' a 3rd ship nearby. The Hyundai Dominion's OOW was not sure if other ships had received his message and there was no response to confirm the reception of the message by the other ships. As a result, the bold action to alter course was not taken until both OOWs realised that the situation had deteriorated. The AIS text message sent from Hyundai Dominion was inadequate and irresponsible, but AIS identification was also involved in the establishment of VHF conversation. The time spent on VHF by both ships and the AIS messaging of Hyundai Dominion prevented the OOWs from taking early action. In short, if the COLREGs were followed by both OOWs, none of the VHF conversation and AIS communication would have been necessary and the accident could have been prevented.

4.2.2 Two Gas Tankers AIS near miss collision

The Marine Accident Investigation Branch (MAIB) studied a near-miss case that also involved AIS operation in 2004. Two unnamed gas tankers found each other on a crossing situation and had a near-miss experience in the English Channel. The two gas tankers actually belonged to the same company. In Figure 4-2, one gas tanker was a stand-on vessel in the Southwest bound Traffic Separation Scheme (TSS) channel and the other was a give-way vessel crossing the English Channel. Both gas tankers had detected each other on their ARPA/RADAR and further identities were also obtained using AIS. Instead of manoeuvring, the Southwest bound vessel (stand-on vessel) called on VHF to inquire about the crossing sister ship's (give-way one) intentions when both vessels were only a little over 4 nm apart.

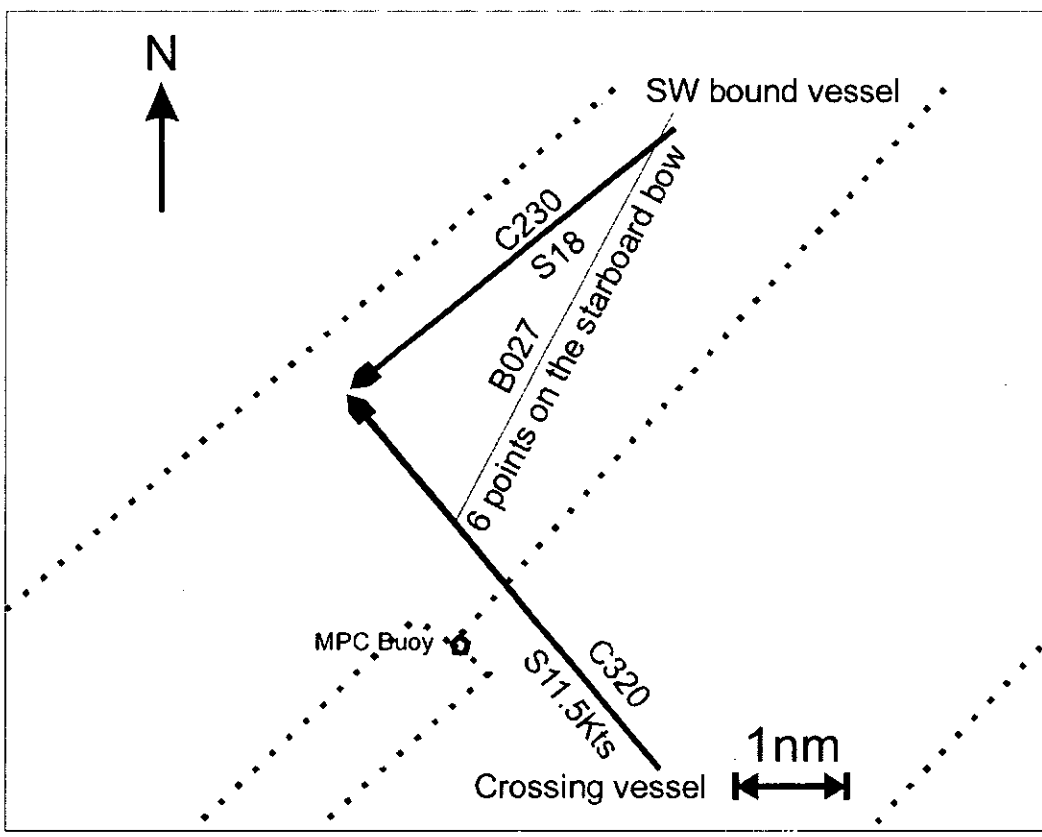


Figure 4-2 Two gas tankers on a crossing situation (MAIB 2005)

The prolonged VHF conversation held between the two ships lead them into a CQS. According to COLREGs Rule 15, a ship that has the other in sight and on her starboard in a crossing situation shall keep out of the way and avoid crossing ahead of that ship (IMO 2003b). Clearly, the channel crossing and give-way ship failed to do so. The OOW on board the channel crossing ship determined that the

Southwest bound ship would pass astern at close range. As the channel crossing ship was 1 nm away from leaving the Southwest TSS lane, she therefore suggested the Southwest bound sister ship to alter course to port. Both ships spent time communicating via VHF discussion creating risk and panic in late manoeuvring, as the two ships appeared to be running into each other. A diagram of the decision-making process on board the two ships is shown in Figure 4-3. AIS information was considered by the OOWs in a chain of decision making in target detection and target classification.

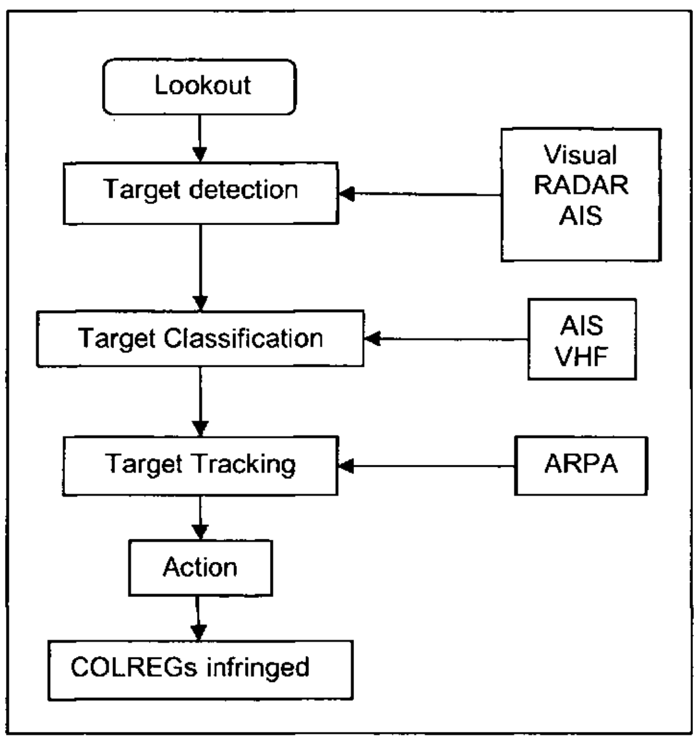


Figure 4-3 Decisions made onboard the two tankers

4.2.3 Lykes Voyager/Washington Senator

This collision occurred between UK registered Lykes Voyager and German registered Washington Senator in the Taiwan Strait in 2006 (MAIB and BSU 2006). From the evidence given by the officers and captains, the traffic was normal with four cargo ships and groups of fishing boats present in the area. The sea condition was moderate, but heavy fog appeared so that visibility sometimes deteriorated to around 200 metres. Throughout the incident, both captains were with the watch officers on the bridge.

At the beginning, the Northeast bound Lykes Voyager was concentrating on overtaking a Panamanian registered bulk carrier Notori Dake when she spotted the Southwest bound Washington Senator at a range of 8 to 9 nm (Figure 4-4).

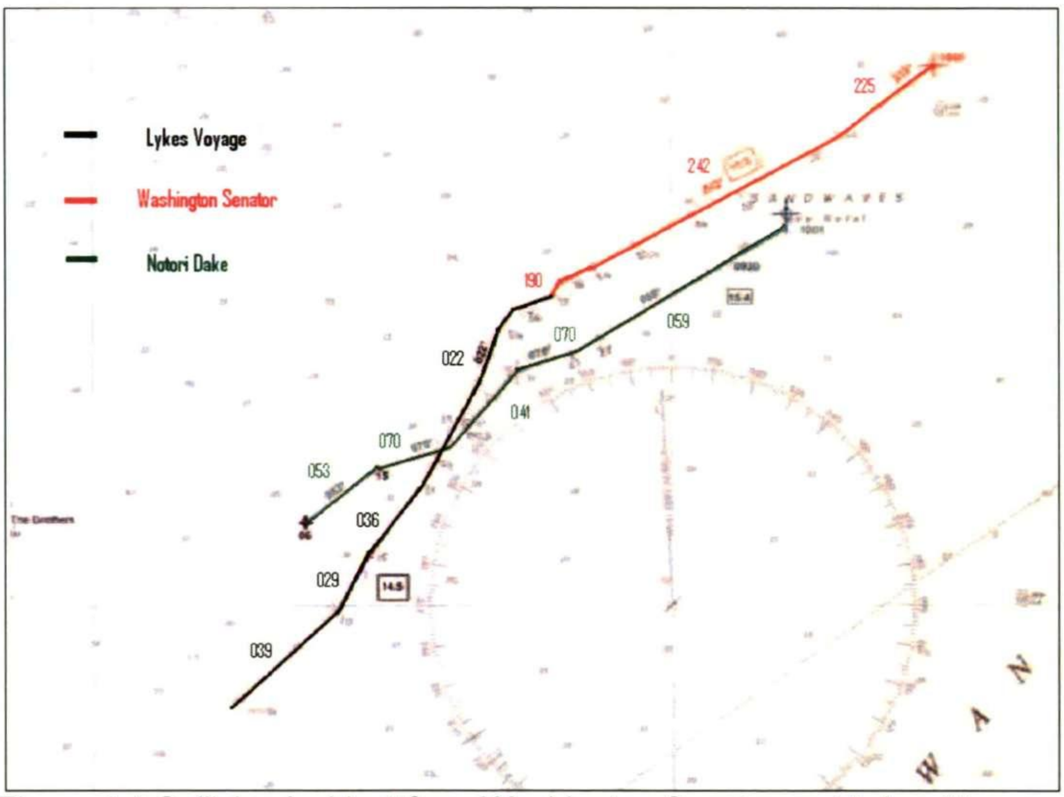


Figure 4-4 Collision incident from Washington Senator and Lykes Voyager (MAIB and BSU 2006)

A series of course adjustments were made by Lykes Voyager to increase the CPA from Notori Dake. With little realisation that the Washington Senator was approaching her, the manoeuvres actually decreased the CPA to a few cables with Washington Senator at a closing speed of 36 knots. Hence, there were only 12 minutes left to collision when the range was down to 7nm. Additionally, the captain had distractions from reading weather facsimile and he did not realise the threat of the oncoming ship until the range reduced to 4.5nm on RADAR (7.5 minutes to collision contact). As the visibility was heavily reduced, Rule 19 COLREGs applied and the Lykes Voyager's captain soon ordered a starboard 20° course alteration, but this was too late to avoid collision.

The Washington Senator was heading towards Hong Kong and there were three persons on the bridge including the captain and an Able seaman (AB) lookout because of the poor visibility. Due to the presence of two slower targets (one merchant and one fishing boat) on her bow, the Washington Senator decided to overtake both targets and left two to her port side, where the overtaken merchant ship was identified with a destination from the AIS display. Moments later, the officer spotted another two targets on RADAR which were on her port bow a certain distance ahead. When the range to these two new targets (both were later identified via AIS as Lykes Voyager on the right hand side and Notori Dake on the left) reduced to 7 or 8 nm with a small CPA on ARPA. Instead of prompt action to avoid a CQS, an instruction to obtain more information about the target on the right (Lykes Voyager) from the AIS display was ordered by the Washington Senator captain. Subsequently, the Washington Senator captain asked his chief officer to call on VHF for an anti-collision manoeuvre agreement.

The officer made several attempts on VHF but the name or call sign of Lykes Voyager was not used in the conversation. The VHF conversation later led to a misunderstanding between Washington Senator and Lykes Voyager. Later, the evidence showed that there may have been another ship joining the conversation which was accidentally deemed to be Lykes Voyager onboard the Washington Senator. The OOW on board Lykes Voyager recollected that she only reported her ship's name and position to the unidentified calling ship (Washington Senator), and she and her captain did not continue the conversation assuming that Washington Senator was talking to another ship nearby. According to action in restricted visibility, Rule 19 COLREGs, both ships should alter course to starboard. However, the captain onboard Washington Senator made a decision based on the fact that Lykes Voyager might have difficulty turning to starboard as Notori Dake had just been overtaken and left little space on her starboard side. With this confused agreement on VHF, the Washington Senator later suggested a 'starboard to starboard' meeting where she altered her course to port in order to go between Lykes Voyager and Notori Dake.

The warning of changes in each ship's heading could have been accessed by the OOW onboard Lykes Voyager. Moreover, the ship's names were obtainable via AIS and they could have been included in the VHF conversation preventing verbal misunderstanding. The Washington Senator's captain instructed the OOW to call the other ship on VHF as soon as the AIS identity was acquired, which could illustrate that prompt AIS identification can encourage OOWs to use VHF in collision avoidance. In fact, both ships were carrying a stand-alone AIS MKD, and Lykes Voyager had only a basic system with a three-line alphanumeric display. It is difficult for users to appreciate the function of AIS when it is isolated and far away from the RADAR and main console on the bridge. Even though the Washington Senator was carrying a graphical AIS display, the AIS was only found to be gathering static information throughout the incident.

4.2.4 Summary

AIS is not only an additional device to assist OOWs in anti-collision, but there is no official statement that intentions can be sent via AIS text message. The case involving an AIS text message showed irresponsible use of AIS and a lack of sense in keeping a good seamanship. Moreover, the cases above all indicate the hidden danger of careless VHF calling in ship manoeuvring. Although the target's identity is easier to obtain by the prompt identity result from an AIS reading, the time that could be spent on VHF could be crucial in detecting oncoming collision dangers.

4.3 RADAR assisted collisions

RADAR determines the distance and orientation of objects by measuring the time interval between its transmission of a pulse signal and reception of a signal returned as an echo (Bowditch 1966). An ARPA/RADAR can calculate the CPA/TCPA data of multiple targets simultaneously, which is an advance compared to manual target plotting. Nevertheless, ARPA/RADAR has its limitations because target acquirement might not be guaranteed at all times due to several reasons such as weather conditions and landfall obstruction. Furthermore, the data calculated from a target's echoes might not always give a correct result due to accuracy limits and time lag of scanning function. Thus, the disadvantages resulting from RADAR should not be underestimated. It would be dangerous and irresponsible if OOWs rely only on RADAR information for decision making.

4.3.1 Andrea Doria/Stockholm

A classic example of the mistakes commonly made in 'RADAR assisted' collisions is found in the collision between Andrea Doria and Stockholm in 1956 (Cahill 1997). These two ships met each other at night outside New York on a near reciprocal course. Andrea Doria was heading to New York and Stockholm was heading to Europe when the presence of fog reduced visibility dramatically. Although the use of RADAR at the time was new to the mariners, both ships actually carried a relatively modern RADAR for the time. Both OOWs had also acknowledged the existence of the other ship on their RADARs, although it was doubtful whether they had continuous RADAR watch before the collision. About five minutes before collision (Figure 4-5), the Stockholm started to alter course to starboard without knowing that the Andrea Doria was actually nearby and closing at speed.

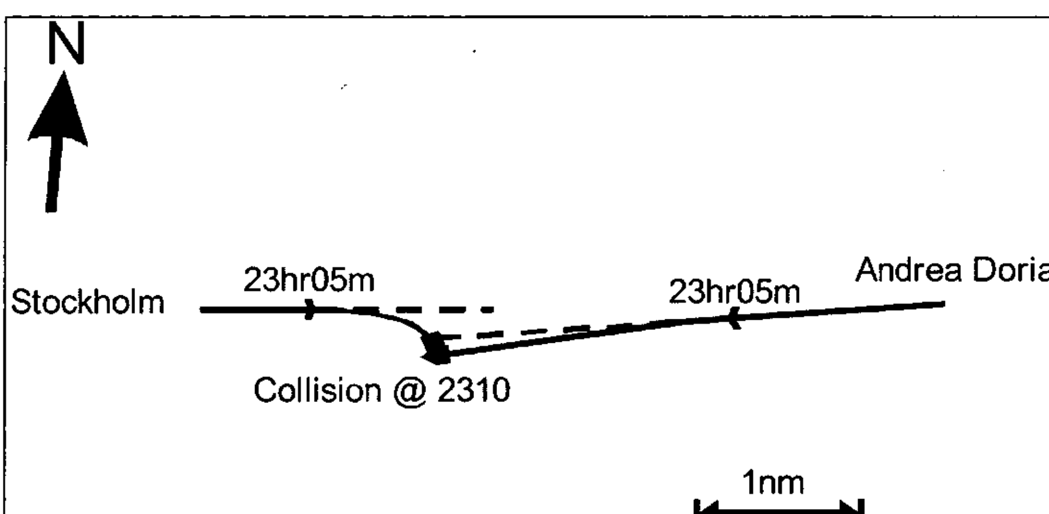


Figure 4-5 Collision incident from Andrea Doria and Stockholm (Padfield 1966)

The captain onboard Andrea Doria did not treat RADAR monitoring as a priority for bridge lookout and the OOW did not have a continuing watch on the RADAR screen (Andersson 1996). The captain had reduced speed only marginally when

Andrea Doria steamed toward the Nantucket Lightship through heavy fog (Lost Liners 2000). In fact, the OOW had spotted Stockholm's return echo from RADAR at a reasonably early stage. The target was interpreted by OOW as a short sea or offshore trading vessel that was travelling on the eastern direction of the western traffic lane. The assumption that the target was a short sea/offshore vessel made the officer less concerned with keeping a continuous watch. An assumption might be made that Andrea Doria expected it to leave the traffic lane soon. Had the OOW got more a positive identification of the return, the OOW would have had time to be alerted and take action. Overall, Andrea Doria failed to reduce speed and poor RADAR monitoring showing a certain degree of reckless navigation.

The misreading of the RADAR by the OOW aboard the Stockholm can be seen as the biggest error (Bright 2006). The OOW might have mistakenly read Andrea Doria's echo on the RADAR screen as 15 nm apart instead of the actual reading, 5 nm apart. In the 1960s, selecting RADAR ranges would probably need a flashlight for verification, especially on a dark night, and it would not have a display of range on the RADAR screen. As a result, there was the possibility that OOW might not have selected the correct range. There was also a typical mistake made in the use of RADAR when Stockholm's OOW claimed and insisted that Andrea Doria was on the Starboard side of Stockholm during the manoeuvre. In fact, Stockholm was operating relative bearings/head-up on RADAR to indicate Andrea Doria's position on her bow and to determine the CPA (Bell 1971). The result could have led Stockholm's OOW to think that Andrea Doria was on his starboard rather than port bow, and that the CPA was to port because of the failure to compensate for yawing (Austin 2002). The two mistakes made by Stockholm's OOW can still happen today when a change of range selection on RADAR can be overlooked. For instance, a lapse of time when switching to a different range is inevitable and a change to a smaller range will eliminate the returns outside of the newly selected range. In addition, the advantages and disadvantages of setting up a RADAR screen as 'Head-up' should lead to caution as errors may appear when the observing ship is yawing.

The collision between Andrea Doria and Stockholm represents an era when RADAR had just been introduced a few years earlier and neither training nor laws for RADAR operation were in place at the time (Brandenburg 2005). Both OOWs showed a lack of knowledge in operating RADAR. In particular, the Stockholm's OOW took scanty RADAR information into the process of decision making. Nowadays, RADAR has become a mature system to assist mariners in lookout and collision avoidance. The evolutions on law enforcement and proper training have been part of the development of RADAR operation.

4.3.2 Norwegian Dream/Ever Decent

On 23 August 1999, at 0115 BST, the Bahamas registered cruise liner Norwegian Dream and the Panama registered cargo ship Ever Decent collided 17 miles off the coast of Margate in Kent. The weather conditions were reported to be good. The Norwegian Dream was nearly at the end of her journey heading for Southampton and she was just about to enter the TSS Southwest bound in the English Channel. After leaving the UK port, the Ever Decent was heading to Europe for her next routeing destination so that she was crossing the TSS channel

(Figure 4-6). Both ships were equipped with up-to-date bridge equipment including the APRA/RADAR; nevertheless, the accident still happened.

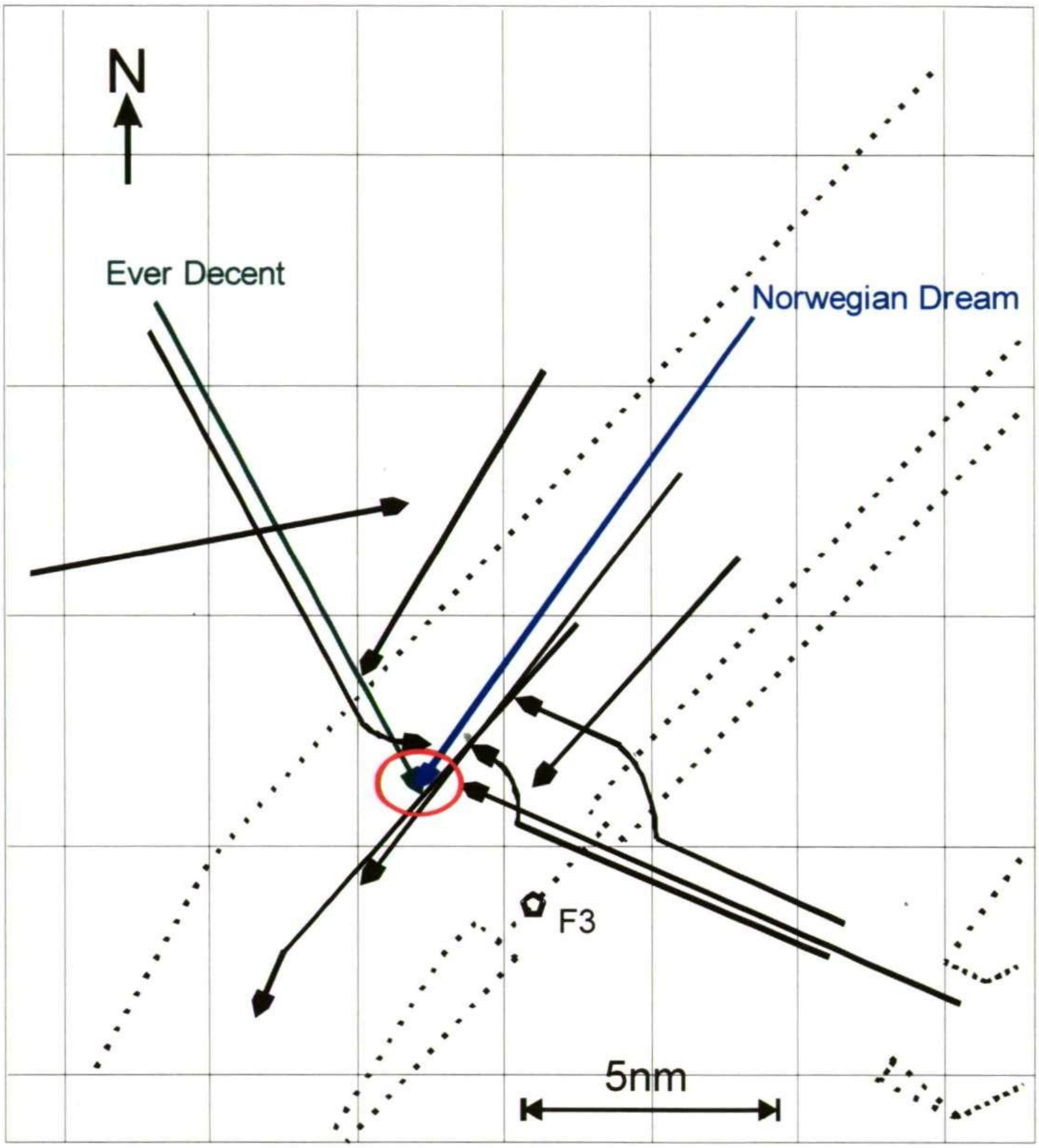


Figure 4-6 Collision incident from Norwegian Dream and Ever Decent (BMA 2000)

There were a number of RADAR associated mistakes found on both ships which can be classified into several categories: the selection of vector, the input of speed, lack of consistent RADAR surveillance and the sense of safe speed. The sequence on Norwegian Dream was that the OOW spent a certain amount of time on ARPA/RADAR before the collision took place. According to the report made by the Bahamas Maritime Authority (2000), the OOW was criticised for not using his ARPA/RADAR to the best function because he used the 'True Vector' of the approaching targets/ships in order to determine the risk when the CQS with Ever Decent developed. Hence, the OOW might have interpreted the vectors displayed on his ARPA/RADAR mistakenly and was confused by the relative and true headings of Ever Decent's echo. Had the OOW on Norwegian Dream used the relative vector, he would have been able to determine the collision risk and he would have also had an aspect of traffic if he occasionally switched to the true vector display. The International Federation of Shipmasters' Associations (IFSMA) summarised a number of mistakes made by Norwegian Dream in using ARPA/RADAR:

- The OOW used the ARPA output on both RADARs in use which means he did not have a single, continuous, reliable plot when matters became critical;
- The OOW used a manual speed input based on estimated SOG, which is wrong in principle. To determine risk of collision using ARPA vectors, only the relative vectors should be used. True vectors should be used to determine aspects.

In theory, the bearings taken from a gyro are always the most precise way to ascertain the risk of collision. The distance to the target is also critical for the length of time in ascertaining the collision risk and the time left for taking positive action (Lee 2001). In reality, this becomes difficult when the number of observing objects increases so that a repeat bearing and range observation increases workload and becomes impracticable. As a result, the function of ARPA RADAR was designed to track and calculate multiple targets within a short period. The Bahamas Maritime Authority made a number of recommendations regarding RADAR operations to the interested parties (AMO 2000):

- When using more than one ARPA/RADAR, an anti-collision plot should be kept on only one;
- All bridge watch keepers should be reminded that speed input for an anti-collision plot should always be STW, not SOG; and
- All watch keepers should be familiar with the bridge equipment.

When both ships were near the entrance of a TSS, both ships were overtaking another ship in an area., Furthermore, both ships were travelling towards each other under a fast closing speed, which left little time for anti-collision manoeuvre. Although there were no indications of any malfunctions in the ARPA/RADAR system in the given evidence, the misunderstanding, misconception and confusion of use all played a part in the final result. In terms of situation awareness, the information provided by RADAR can only be treated as a part of the data sources and OOWs should use all available means to study the target on RADAR. The OOW will have to ensure that RADAR data is genuine and be cautious in taking any information from the RADAR before altering course.

One of the focuses in reviewing the collision was the question why two ships carrying one of the most advanced bridge systems collided. Apparently, the aids from the advanced RADAR were not carefully applied (Hirsch 1999). Moreover, misreadings from the RADAR indicated that it is possible for an OOW to over-rely on electronic aids when on lookout. The incident not only showed a sacrifice of visual lookout, but also over-reliance on electronic bridge systems.

4.3.3 Wahkuna/P&O Nedlloyd Vespucci

This collision happened in the middle of English Channel in 2003 between a 908-foot long container ship, the P&O Nedlloyd Vespucci, and a 47-foot long yacht Wahkuna (Figure 4-7). Both skippers were proved to be expert seaman and both ships did have each other on RADAR. The weather conditions were an easterly wind of force 2 or 3 with very little swell in a sea state of 2. A thickening fog and strong tide were present in the area (50 metres in visibility since 0930 UTC and two knots tidal stream, approximately) and therefore both skippers relied heavily on their RADARs. The collision sank the Wahkuna immediately, but fortunately all crew on board were saved. Surprisingly, the captain and crew onboard the container ship claimed that they did not hear any sound that indicated a collision. During the incident, both vessels had their captains in control of the bridge, and an OOW and a rating were also on the Nedlloyd Vespucci's bridge. Although the two vessels had each other's target return on their ARPA/RADAR, both skippers were found using scanty RADAR information for collision avoidance.

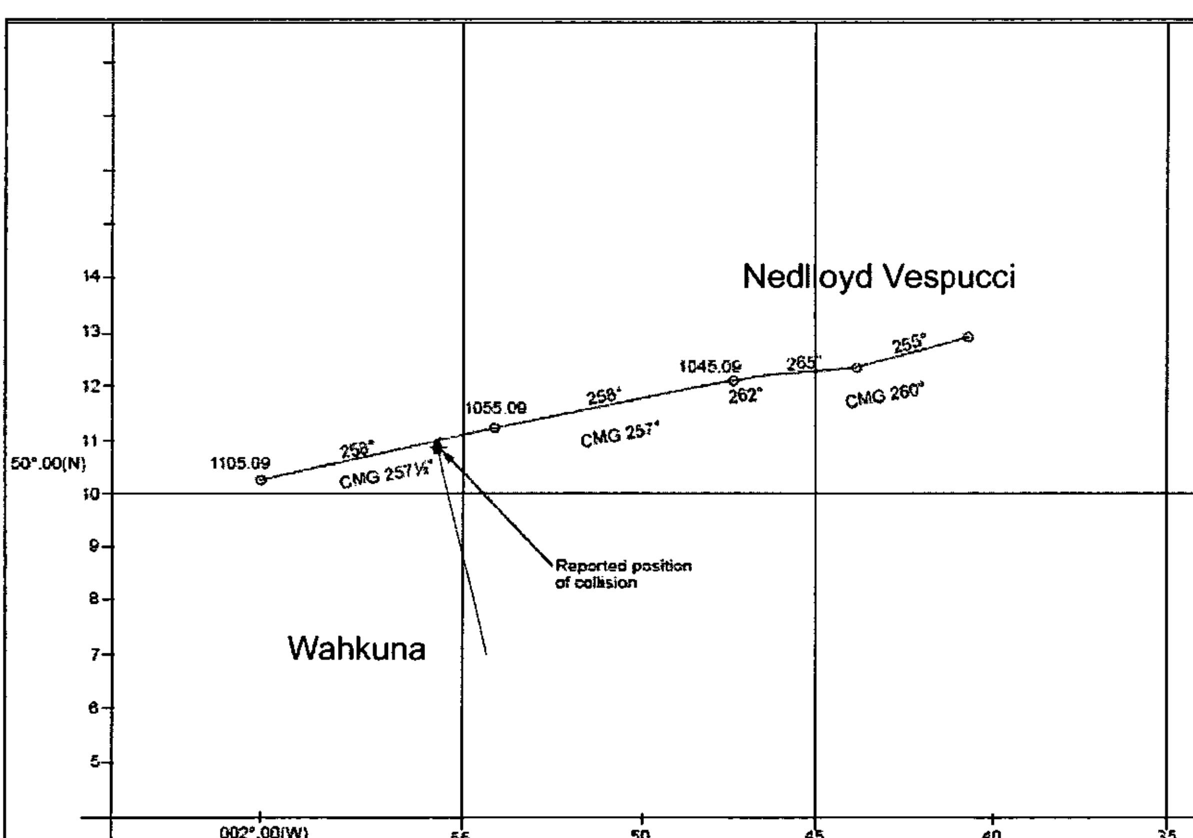


Figure 4-7 Estimation of the track of P&O Nedlloyd Vespucci (MAIB 2003)

The evidence indicated that the Wahkuna skipper was not monitoring RADAR information correctly, only making an occasional check on his RADAR screen (Ellison 2004). Furthermore, all the crew onboard Wahkuna were found to have a lack of knowledge of operating RADAR plotting aids. Hence, the Wahkuna mistakenly predicted that Nedlloyd Vespucci would pass ahead of her bow with a small CPA. The Wahkuna skipper used the ARPA/RADAR result ineffectively to evaluate the CPA of the Nedlloyd Vespucci, which caused him to stop the engine and lose manoeuvrability. Had the Wahkuna kept proceeding at the same speed, the collision would have been avoided. The decision based on an incorrect RADAR reading actually led the Wahkuna to collision.

The master of the large container ship Nedlloyd Vespucci also picked up the Wahkuna's echo on his ARPA/RADAR and interpreted the Wahkuna on a bow crossing with a small CPA ahead. At this moment, the master did not endeavour to leave a safe distance as he was satisfied with the result of the CPA coming from his ARPA/RADAR. As a result, he decided to leave a 2-cable length of CPA off Wahkuna.

According to IMO IEC 60954 and IEC 60936 (Table 4-1), a minimum accuracy should be achieved by the given standard under four conditions with one and three minute trends. With such a small CPA to Wahkuna, the captain on Nedlloyd Vespucci, travelling at 25 knots through thick fog, relied on the information from his ARPA RADAR alone.

Condition \ Trends	1minute	3 minutes
End on	1.6 nm	0.5 nm
Opening	-	0.8 nm
Crossing	1.8 nm	0.7 nm
Overtaking	2.0 nm	0.7 nm

Table 4-1 Minimum accuracies under four RADAR performance standard conditions (MAIB 2003)

The factors that could reduce the accuracy of relative velocity or triangular calculations carried out by ARPA/RADAR were illustrated in the MAIB report (2003) for this collision case:

1. Where there is a large own ship vector produced by high speed;
2. Where course and speed information is reliant on own ship sensors and equipment for course and speed information;
3. Where the speed of the RADAR target is small in relation to own ship speed;
4. Where the RADAR target or own ship is continually changing courses and speeds;
5. Where the speed information is ground-based rather than water-based in areas of strong tidal streams.

The performance of ARPA/RADAR could be affected dramatically by the situations mentioned above. Therefore, the information provided by ARPA might not be reliable and accurate throughout the observation. The Wahkuna slowed down and intended to 'give away' to Nedlloyd Vespucci.[14] This action confused the captain of Nedlloyd Vespucci who remained on the same course and speed without knowing that the two ships were on a collision course. The Captain of the Nedlloyd Vespucci kept RADAR's range scale at 3 nm even though he was aware that the small target, the Wahkuna, was a few miles away. Had he changed to a larger range scale, the speed change made by Wahkuna might have been detected and an avoiding action deployed.

[14] The skipper of Wahkuna misinterpreted a crossing situation instead of an action in restricted visibility, Rule 19.

The collision was not noticed by Nedlloyd Vespucci due to the size of the Wahkuna and the background noise. The danger of small targets not being effectively detected by RADAR has been acknowledged, especially when the sea condition worsens. A bigger ship should always consider the possibility of undetected targets at sea and make an effort to build situation awareness with as many resources as possible. The collision between Wahkuna and Nedlloyd Vespucci represents another case of RADAR assisted collision where inadequate reading and over-reliance on ARPA RADAR could put mariners into danger. The limitations coming from operating RADAR should be appreciated and taken into account. This collision case showed mariners depending on navigational devices and sacrificing the time necessary to maintain a proper lookout (Figure 4-8).

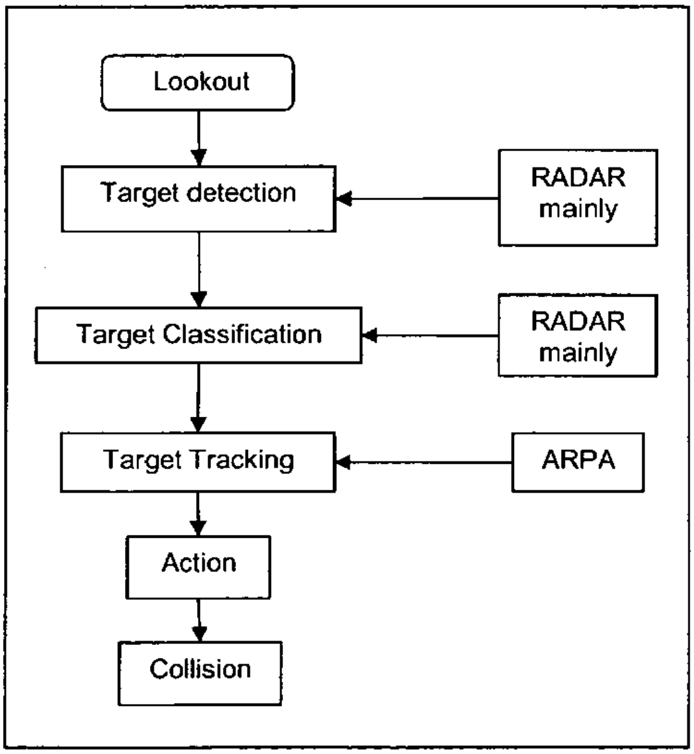


Figure 4-8 Decisions made onboard the Wahkuna and Nedlloyd Vespucci

4.3.4 Two Gas Tankers near miss collision

This case (see Section 4.2.2) is a near miss collision and there was also a concern in the use of RADAR during the collision avoidance. Two sister ships clearly saw each other and had positive contact on their respective RADAR screens. The actions made by both ships were criticised by a MAIB report (2005) regarding the operation performance of ARPA RADAR:

> After altering course, ARPA has an information processing delay and can give unreliable information for up to 3 minutes, once steady on the new course. During this time, reference should be made to alternative methods of assessment of risk of collision, such as a series of compass bearings.

The OOW should not have relied on RADAR, especially when the range to the other ship was small. He should also have noticed that the change in heading could give a wrong impression for his plotting result from ARPA/RADAR. When compensating for a lack in consistent RADAR observation when turning the ship around, the OOW should always keep a visual lookout, primarily in order to improve situational awareness. As a give-way ship in a crossing situation, there should be no excuse for not making a prompt and positive action at an early stage. Although the collision did not take place, the dependence on RADAR information and non-compliance with the COLREGs should be learnt from to prevent similar mistakes happening.

4.3.5 Summary

RADAR can be affected by weather influences, as well as having limitations in line of sight detection. The accuracy is questionable and this should be recognised among system limitations when operating RADAR. Even if there is no error coming from system itself, mistakes caused by human operation can still lead to accidents

(Bonnor 2005). As a result, the trend in RADAR development has been to reduce the errors coming from human-machine-interference. User friendly environment became one of the improving objectives for modern RADAR development.

COLREGs Rule 19 recommends the use of RADAR in restricted visibility. Rule 19 suggests that a danger target detected by RADAR at a longer range should give a ship enough time to keep clear of a development of CQS. Furthermore, an accepted range of CPA can also be acquired by ARPA, which can also be considered to keep the encountered vessel at a safe distance. Despite the information provided from ARPA/RADAR, the reluctance to take action to avoid collision can still be found at sea.

RADAR should only be operated at the right time, in the right place with well trained personnel. In the viewpoint of RADAR itself, it is certain that too much trust on RADAR (including ARPA) could lead to reckless and scanty information. In the viewpoint of RADAR operators, the advantages and disadvantages of RADAR operation should be thoroughly studied before applying it in the decision of collision avoidance.

In addition to the functions of identification and information transmission, there is more information to be provided via AIS. The OOWs can have two different systems to track targets. Nevertheless, most mariners have already adopted the use of ARPA/RADAR to obtain manoeuvring information. It will be a challenge whether AIS data can be applied functionally into OOWs' situation awareness.

4.4 Collisions in VTS areas

VTS provides a traffic monitoring system that can keep track of vessels' movements and provide navigational safety in a limited geographical area. In 1985, the Resolution A.578 (14), Guidelines for Vessel Traffic Services was adopted by IMO to determine the VTS (IMO 2002d):

- VTS was particularly appropriate in the approaches and access channels of a port and in areas having high traffic density, movements of noxious or dangerous cargoes, navigational difficulties, narrow channels or environmental sensitivity.
- The Guidelines made clear that decisions concerning effective navigation and manoeuvring of the vessel remained with the ship's master.
- The Guidelines highlighted the importance of pilotage in a VTS and reporting procedures for ships passing through an area where a VTS operates.

VTS is not a static facility, but aims to collect and transmit traffic information among the ships and with shore stations. In a control centre, VTC can be directly in control of vessel movement nearby and also assist them via VHF communication regarding collision and grounding avoidance based on its reading of a RADAR surveillance range. Compulsory traffic control may prove useful in preventing ship collisions in a busy water (De Jong 1993). Initially, VTS was established when the harbour RADAR centre could see further than an individual vessel, meaning that the authority could give advice to vessels. In some areas, VTS has acted as a more powerful authority that could lead ships and be in control of the traffic flow to some degree. In these cases, freedom of manoeuvre becomes of secondary concern in order to fulfil the function of regional traffic control. Next, collisions in VTS areas will be discussed.

4.4.1 Arizona Standard/Oregon Standard

The tanker Arizona Standard and her sister ship Oregon Standard collided near the Golden Gate Bridge on 18 January 1971 at 0141 local time in low visibility. The Arizona Standard was approaching the harbour where the Oregon Standard was leaving her berth (USCG 2005). Both ships were heading towards each other. The Harbor Advisory Radar Project (HARP), San Francisco, had two ships under its surveillance, but one of the sister ships failed to receive a warning from the HARP minutes before the collision.

Both ships had acknowledged each other's presence in the area, but VHF communication was not established either between the sister ships or between ships and the HARP. The HARP clearly indicated a failing of VHF communication to the Oregon Standard. Oregon Standard was criticised for ignoring information coming from VTS, meaning that she was left alone without any help when transiting in busy water and poor visibility. Without successful communication with the Oregon Standard, the VTC operators could not do anything but watch the collision happen. The case was later illustrated and emphasised as a VTS collision example by the USCG. The U.S. National Transportation Safety Board (NTSB) found that the causes of the accident were:

1. The failure of the vessels to establish and maintain communications;
2. Navigating a narrow channel in dense fog;
3. Failure of the Oregon Standard to make timely RADAR contact;
4. Loss of RADAR contact by the Arizona Standard; and
5. Negligence on the part of both masters.

The Pilots and Masters opposed the introduction of the HARP in San Francisco and elsewhere (Hughes 1998), given that conflicts could occur between OOWs and the VTS operators. In practice, a master will always have the right to control his ship and also bear any burden if an accident happens (see Section 4.4.3). The freedom to sail has to be compromised when taking part in VTS advised transit. As VTS is able to watch the traffic in a wider area than a single ship, the information resulting from VTS surveillance could be useful to the mariner's safety in transit.

4.4.2 Western Winner/British Trent

The Panamanian bulk carrier Western Winner collided with the Bermudas British Petroleum products tanker British Trent at 0543 local time in 1993 when both ships were in a VTS monitored area (MAIB 1995). During the night, the visibility was down to a few hundred metres (200 metres visibility was reported about 15 minutes before the collision) due to fog. The traffic was complex with an East/West bound TSS deployed west of the Wandelaar Pilot Station (Figure 4-9) and frequent North/South bound crossing traffic. The VTS had both ships on its RADAR surveillance throughout the incident. Nevertheless, one of the ships' identities was not clear as the inbound ship Western Winner did not report to the VTS at the beginning. It turned out that the Belgian VTS authorities may have failed to contact the Western Winner due to language problems with Korean-speaking crew members or communications difficulties (Moloney 1993). The failure to participate with the VTS system meant that the Western Winner's master was not aware that his ship was not listed on the VTS RADAR monitor. The Western Winner was not identified by VTS until she made a call to the pilot. In short, it was found that the master was not familiar with the VTS water as the Western Winner proceeded at full speed throughout the area.

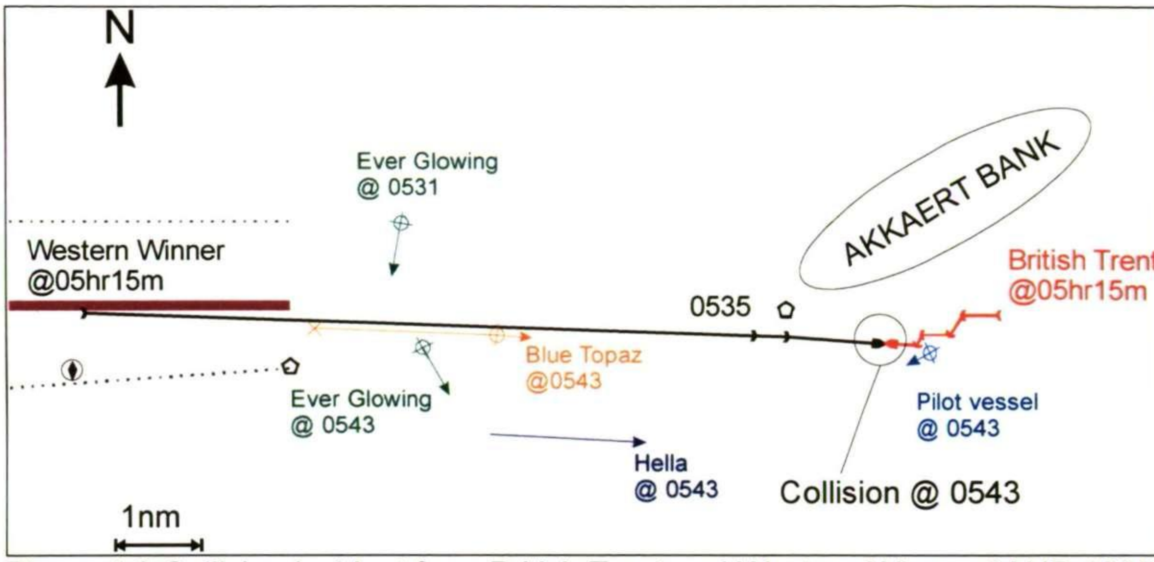


Figure 4-9 Collision incident from British Trent and Western Winner (MAIB 1995)

The VTS had the identification of the British Trent on its RADAR since she left the berth. The VTS was also aware of the presence of Western Winner, but only as an unidentified target on the RADAR monitor. The reduced visibility in the area of the Wandelaar Pilot Station (Southwest of the Akkaert Bank) was reported and acknowledged by VTS. Nevertheless, the VTS did not spot the collision risk between Western Winner and British Trent even though it had RADAR contact of the Western Winner as an unknown East bound approaching target.

In order to be aware of which vessels were in the area, a proper use of RADAR, VHF monitoring and participation in the VTS system could all have been applied (MAIB 1995). The failure to give a Notice of Arrival (NOA) from Western Winner to the Belgian VTS was the result of a language barrier, unsuccessful attempts on VHF calling and identification. Had the Western Winner's identification and speed been provided by an independent device, the NOA could have been established earlier and a proper procedure of transit in the VTS area would have been given to

Western Winner. The broadcast of the danger could have been sent even if the ship reporting by Western Winner had not been established.

4.4.3 Orapin Global/Evoikos

The collision case between Cypriot-registered laden tanker Evoikos and Thai-registered Orapin Global happened at 2054 local time in one of the world's busiest VTS controlled areas. The Northeast bound Evoikos had just turned to port and started to cross the TSS lane heading for Singapore for her pilot station, while the Southwest bound Orapin Global was travelling on the wrong traffic lane because it was overtaking a slower vessel. The visibility at the time of the incident was about 5 nm and the masters of both ships had warning of the impending collision from the VTS authority a few minutes before the collision.

As the depth of the TSS water was restricting for both ships, Evoikos and Orapin Global actually stayed close to the separation zone (Figure 4-10), also known as the Deep Water Route (DWR). Additionally, the buffer zone shown by the thick red lines, which is between the two TSS lanes, is only one cable wide. The sea room and manoeuvrability of large cargo ships are strictly limited by depth. The oncoming traffic on the Southwest bound TSS would be affected by the channel-crossing tanker. Moreover, the Orapin Global went into the wrong lane (Northeast bound TSS lane) to overtake a slower vessel several minutes before returning to her right track. During the overtaking manoeuvre, a conversation was established between the VTS and Orapin Global, when Orapin Global gave her intention as coming back to her Southwest lane a certain time after clearing her overtaken vessel. If Orapin Global did not turn back to the Southwest bound TSS lane, she could have missed the collision with Evoikos. This does not legitimise the wrongdoing on behalf of Orapin Global as travelling on the wrong direction of a TSS lane is highly dangerous.

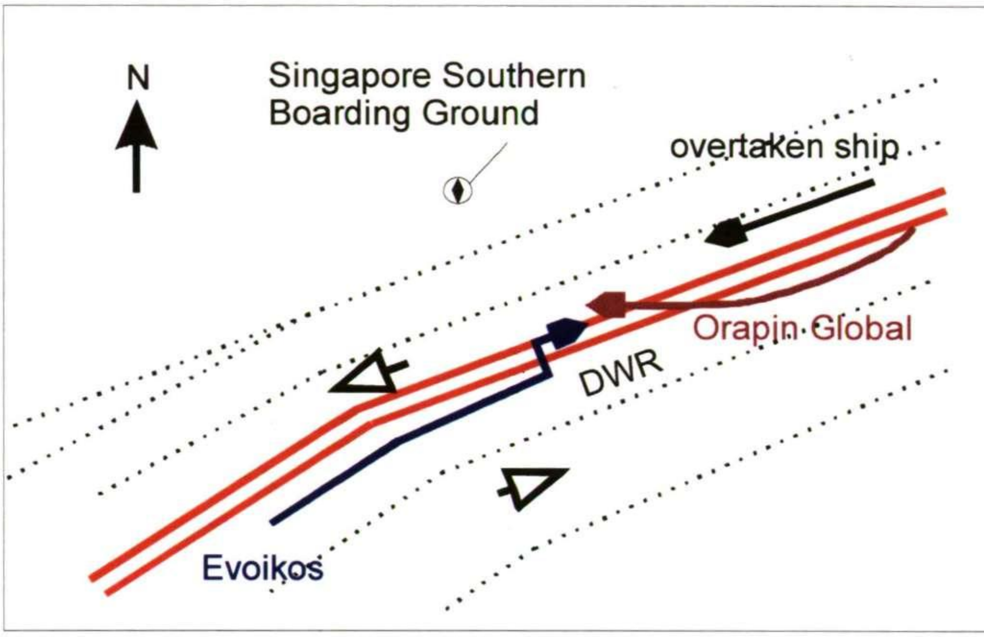


Figure 4-10 The TSS where Orapin Global and Evoikos collided (Woinin 1997)

Nevertheless, it does reflect one of the many complicated traffic scenarios vessels can encounter in VTS or TSS areas. The information fed from VTS to vessels under its surveillance can be valuable to safe transit. In fact, the Singapore VTS did not notice that the Evoikos also altered course to starboard after Orapin Global had returned to the Southwest bound lane. As Evoikos also turned to port in order to cross the Southwest TSS lane, a collision risk was developed at this time. In addition, Evoikos could have easily occupied the whole TSS lane considering the length of the ship. A temporary blockage can be assumed when such a Very Large Crude Carrier (VLCC) crosses a narrow TSS lane.

One of the problems with the current VTS system is that so much of the operator's time is spent checking in and establishing identity that important transmissions are lost in the chatter (Speares 1998). During the incident, the VTC warned both ships of a collision risk ahead of them about eight minutes before the collision. Despite the brief warning, there was no further information from the VTS controller, neither the ship size (including draft), nor the destination of the approaching vessels were given to Evoikos and Orapin Global.

A rare and unusual combination of courses and speeds can lead to a situation where a collision could have barely been avoided by the skills of the two masters alone when large ships are involved in a restricted water (Woinin 1997). The limited sea room in a restricted area increases ships' risk of accidents, even if a ship does spot an oncoming danger. In addition, the high traffic density in a designated area might also cause difficulties in establishing a VHF communication with an opponent. Hence, a VTS with approved design of its traffic lanes, better working communications and adoptable traffic customs is needed for decision makers when commanding their bridges.

4.4.4 Summary

The collision cases involving VTS operation show the problems that occur even though VTS is aimed at maintaining the safe transit of a designated area. Considerable opposition to VTS came from pilots and ships' masters in the early years when some unqualified Coast Guard VTC controllers attempted to impose guidance and advice on the navigation of vessels (Cahill 1997). The cases above have shown difficulties in ships reporting to the VTS and efficiency of communication between VTS and vessels. As these normally happen during the busiest time of lookout, a reduction in ship reporting to the VTS could be seen as a great advantage in gaining more time on lookout. The ship reporting could be done automatically by AIS. A prompt AIS target identification with the assistance of polling and assigning modes could all be applied in VTS monitored waters. The amount of verbal communication to accomplish ship reporting can be reduced by ships identifying themselves to the VTC. More direct indication can be carried out between the concerned vessels and the VTC.

4.5 VHF assisted collision

An early communication of an impending risk of collision can clarify the intention between vessels (Cockcroft and Lameijer 2003). This has proved useful in reducing accidents in the Great Lakes, where American pilots use the same language and are familiar with the geographical environment, and so usage was extended to the international maritime world.[15] While VHF may be useful as a tool in collision avoidance, the COLREGs remain paramount (Bonning 2002). Consideration of the use of VHF should also bear in mind the issues of loss time in visual/RADAR bearing taking and misunderstanding during a conversation.

4.5.1 Arizona Standard/Oregon Standard

This case of two sister ships that collided under the Golden Gate Bridge in San Francisco in 1971 is noteworthy not only because the VTS HARP was involved, but also in the misuse of VHF that contributed to the whole incident (USCG 2005). After the HARP gave information about the outbound ship Oregon Standard to the

[15] VHF radio was first used by pilots in the Great Lakes and the Delaware Bay and river as an anti-collision aid in the early 1950s.

inbound ship Arizona Standard near the Golden Gate Bridge, the master of the Arizona Standard attempted several times to make VHF contact with the Oregon Standard. Yet he failed in this because there was no reply from the Oregon Standard throughout the incident. On the other hand, the master of the outbound ship, Oregon Standard, did nothing to obtain traffic information from the HARP. Had Oregon Standard contacted either her sister ship or the HARP, she would have recognised the presence of her sister ship near to the entrance of the harbour. The collision became a leading case, which led to further enforcement of VTS in US water regarding VHF communication for manoeuvring.

Cahill (1997) gave an opinion referring to the use of VHF,

> Establishing contact with an approaching vessel, particularly where there may be some difficulty in making ready identification, requires a degree of concentration that can distract the conning officer if he takes that task upon himself. It follows from this that the establishment of initial contact should be made well before any subsequent need to manoeuvre, so that any succeeding VHF communication can be carried out with an absolute minimum of distraction.

Ideally, VHF communication should be kept as short as possible when needed, and not to the sacrifice of lookout time. In fact, both ships needed time on the VHF in order to identify each other with their RADAR. Even when contact is achieved by VHF, an agreement between ships to alter course and speed can take time. Direct VHF communication between vessels and the HARP would have been preferable. The time of initial contact and the way ships communicate are both critical to the real effect of applying VHF in collision avoidance. Hence, a prudent use of VHF will be necessary not only to affect the interactive movement after the agreement on air, but also to maintain a proper lookout at all times.

4.5.2 Hanjin Madras/Mineral Dampier

On 22nd June 1995, 0330 local time, the Mineral Dampier and Hanjin Madras collided in the East China Sea. Both ships had one another on their RADAR screens during the incident. There were also attempts at VHF contact, in which one attempt proved to be positive and the other was not. The positive, earlier VHF voice radio attempt sorted out intentions between the two ships. By failing to take action as promised on the first VHF attempt, the second VHF attempt was reckless (BAILII 2001). Eventually, both vessels came in sight of each another at 3nm.

In some circumstances, when two ships that are approaching one another are in VHF contact, it can be helpful if the ship which is required to give way informs the other one of any action being taken based on COLREGs (BAILII 2001). Apart from RADAR surveillance and VHF communication, the Mineral Dampier and Hanjin Madras did not undertake a clear manoeuvre until they had each other in sight (Figure 4-11).

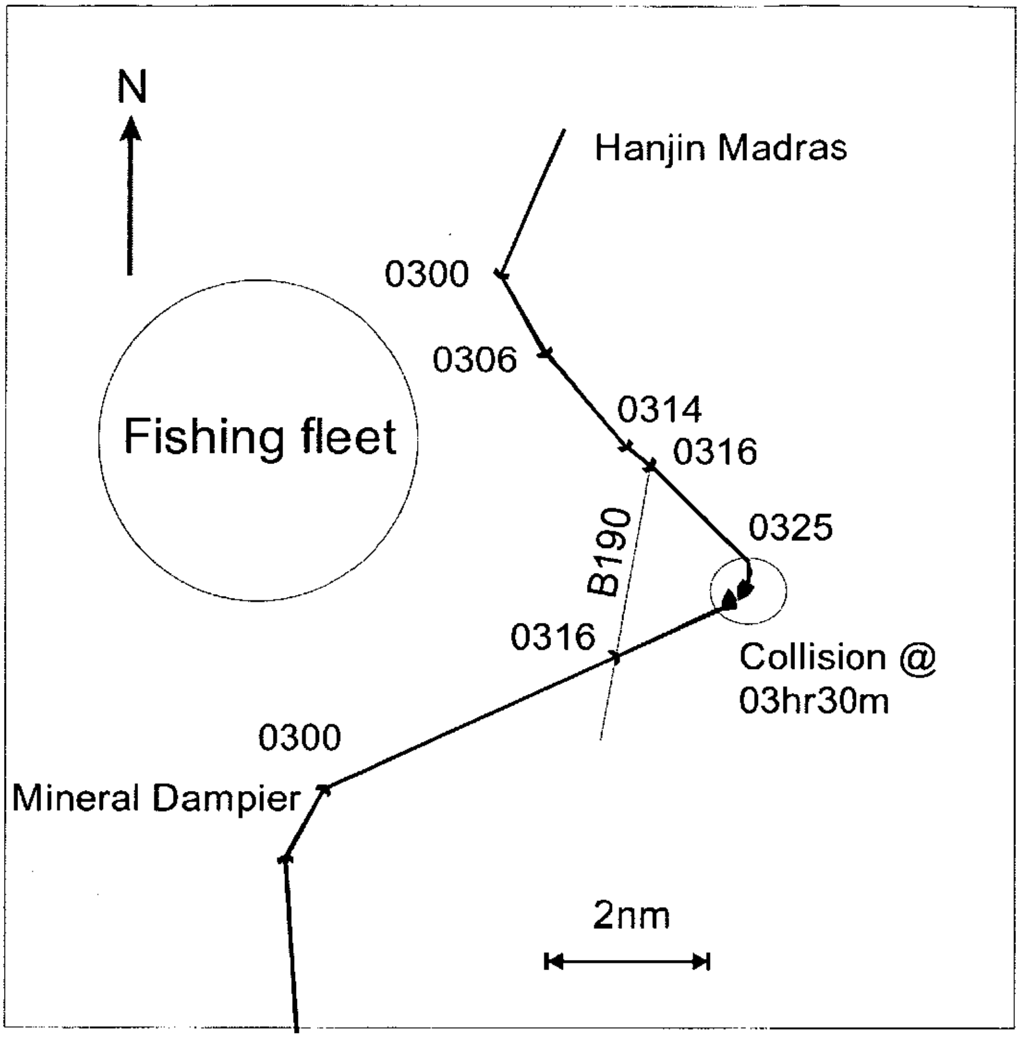


Figure 4-11 Collision incident from Hanjin Madras and Mineral Dampier

There were two VHF conversations that took place between the Mineral Dampier and Hanjin Madras. The Mineral Dampier started the VHF contact when the two ships were at about 4 to 5 nm distance. Using VHF, they both confirmed each other's roles according to the COLREGs. Additionally, both ships agreed to pass 'port to port' (or 'red to red') 30 minutes before the collision. Consequently, Hanjin Madras did not alter her course as the OOW later gave evidence stating that he had encountered a fishing fleet on his starboard side, resulting in a delayed manoeuvre. The second VHF conversation was made when two ships were in sight and this was initiated by the Hanjin Madras. The Hanjin Madras's OOW told the Mineral Dampier to maintain her present course and speed as Hanjin Madras was still willing to give way to Mineral Dampier, but wished to make sure that the Mineral Dampier did not alter course at the last minute.

The second use of VHF largely contributed to the resulting tragic collision and it was criticised later because the two ships were 3 nm apart and there were only 13 minutes to the collision. The Hanjin Madras should have altered her course earlier but she failed to do so, which left less sea room and time to avoid a disaster. As an agreement had been reached in the first VHF conversation, the Hanjin Madras should have concentrated on the ship manoeuvre. An exchange of VHF information can thus cause misunderstanding and produce the opposite result to avoiding a collision. Although the first contact via VHF between Hanjin Madras and Mineral Dampier was approved by the Court and nautical assessors, the second was blamed as being too late, and having too little to do with the situation.

4.5.3 Norwegian Dream/Ever Decent

In this case, the OOW on the Norwegian Dream was found to be overburdened with work on the bridge, had over-relied on his electronic navigational systems and had misused the ARPA RADAR. However, the Ever Decent was also at fault. The Norwegian Dream was advised of the collision course and a course alteration to starboard was proposed by the Ever Decent on VHF about 5 minutes before the collision (AMO 2000). Following this, the Norwegian Dream responded to the Ever Decent. It was later proved that the time spent on VHF by the OOW would have been better spent altering course (IMO 2003a). Although the whole incident was caused by a number of issues, the use of VHF radiotelephone did worsen the situation. It is believed that, as a stand-on ship, the Ever Decent had acknowledged the dangerous CPA when she was proceeding at full speed and about to cross the TSS channel. The only effort that Ever Decent made was to contact the Norwegian Dream via VHF. By using VHF to solve the difficulties, the Ever Decent actually failed to apply the COLREGs Rule 17 (b) to make sure when the collision avoidance cannot be completed by two parties. Furthermore, the fact that communication took place at the last minute showed the danger of VHF communication taking place in a CQS. Because of its fast closing speed, Ever Decent was only about 1.6 nm (or 5 minutes) from the impact when the VHF contact took place.

Unfortunately, the OOWs were too busy with VHF communication to make a proper visual evaluation when the visibility was clear. The VHF itself did not lead the two ships to collide, but the time spent on the VHF did take the last possible minutes when it was still possible to avoid the accident. The VHF communication established between Norwegian Dream and Ever Decent was at the wrong time and in the wrong place.

4.5.4 Hyundai Dominion/Sky Hope

Before the collision between Hyundai Dominion and Sky Hope (See Section 4.2.1), a dispute using VHF communication took place between the two OOWs (Sinke 2005). Unlike the Hanjin Madras/Mineral Dampier case (see Section 4.5.2), Hyundai Dominion and Sky Hope had a disagreement as to whether the situation was an overtaking or a crossing situation (Institute of Navigation 2005). Approximately 8 minutes before the incident, Hyundai Dominion was travelling at 22 knots and initiated VHF calling when both ships were in a CQS (3nm between two ships). However, there was no agreement reached through the VHF conversation and the two ships collided.

This example shows that there is a connection between AIS identification and the VHF communication in collision avoidance. The target's identity given by AIS can be used in association with the RADAR. Hence, the OOW can obtain more details of a ship from its AIS in conjunction with VHF calling without prolonged confirmation of each other's identity. However, the risk of using VHF should be considered at all times, as it could lead to a prolonged conversation without helping the situation, as well as losing the few last minutes that could be used to avoid the collision. This case shows that both ships did not have to dispute each other's roles according to COLREGs when a small CPA was acknowledged. Nonetheless, both OOWs tried to use VHF when both visual bearing and RADAR detection were reasonable sources of information. This case teaches an important lesson about the danger of VHF communication even when the time to confirm identities is shortened.

4.5.5 Lykes Voyager/Washington Senator

The collision between Lykes Voyager and Washington Senator also involved a combined use of VHF and AIS in an attempt to avoid collision (see Section 4.2.3). In fact, the initial attempt to use VHF calling by the Washington Senator occurred immediately after the OOW obtained AIS identity of Lykes Voyager. Although the identity was promptly shown on its AIS display, the subsequent VHF conversation was confused and a lot of time was spent on verbal communication. Actually, the OOW on board Washington Senator forgot to mention the opponent's name 'Lykes

Voyager' during the VHF calling. Therefore, it was highly likely that any ship could pick up the VHF telephone and respond to Washington Senator. There were more than two voices heard on the VHF, claimed by Washington Senator. In contrast, Lykes Voyager later claimed that the third officer was the only one who replied to the VHF call. Additionally, no agreement was reached on that VHF conversation by Lykes Voyage. In fact, the mystery voice that accidentally joined the confused VHF communication made the Washington Senator's OOW and captain presume there was an agreement on passing starboard to starboard between Washington Senator and Lykes Voyager. The VHF conversation did not only lead to the CQS, but the officer onboard Washington Senator lost precious time that could have been used to take bold action to manoeuvre his vessel away from Lykes Voyager.

4.5.6 Summary

To use VHF contact for intention confirmation at a reasonable time is approved according to mariners, case discussions and courts' findings. It is a matter of judgement what period of time is reasonable and helpful depending on the traffic, visibility, ships' speeds and conduct of vessels. From the cases related to the use of VHF calling above, the attempts to use VHF for collision avoidance reflect two opposite opinions in public (the comparison is listed in Section 3.4 and Appendix A). In Table 4-2, five cases are compared in terms of VHF deployment. The use of VHF was approved in the first two cases where Hanjin Madras and Mineral Dampier's first VHF contact was positive in confirming intentions in a reasonable time. On the contrary, the blameworthy cases all lead to imprudent use of VHF in the crucial moments for collision avoidance.

Vessels \ VHF issues	**Attempt to deploy VHF**	**Situation Agreement**	**Difficulty in identification**	**Crucial time spent**	**Blameworthy for the collision**
Arizona Standard Oregon Standard	YES NO	-	YES	-	NO
Hanjin Madras Mineral Dampier	YES YES	YES	NO	YES	YES; The 2nd attempt
Norwegian Dream Ever Decent	YES YES	YES	NO	YES	YES
Hyundai Dominion Sky Hope	YES YES	NO	NO	YES	YES
Lykes Voyager Washington Senator	YES YES	NO	NO	YES	YES
Key	- No communication reached.				

Table 4-2 Comparison of VHF deployment in five collision cases

In conclusion, VHF application should only be used:

- At as early a stage as possible;
- With as short/clear messages as possible;
- If VHF contact establishment can be shortened by AIS.

Caution should always be raised if VHF communication is used in collision avoidance. The COLREGs should always be followed and the normal lookout procedure should not be diminished by the use of VHF calling.

4.6 Conclusions

Aids to navigation, especially electronic devices, are aimed at easing OOW's workload where situation awareness of the traffic encountered can be enhanced (Sonnenberg 1988). From the illustrated collision cases, it can be seen that every electronic aid has its own limitations and conditional operations. Therefore, traditional bearing taking and hearing should not be overlooked. It is not the techniques that lead to a collision, but the personnel who make decisions upon them. To make a decision in collision avoidance will depend on a good balance between advanced and conventional navigational techniques.

Various situations such as weather, system malfunctions, traffic and working load are expected to make bridge operations difficult. Although the electronic aids and VTS both assist the OOW in making decisions for situation awareness, it is the mariners themselves who are in control of the vessel. The applications of AIS have advantages and disadvantages when working with other navigation systems. For RADAR/AIS operation, it is possible to provide real-time targets' dynamic information and independent target coverage based on the GNSS data. For the operation of VTS, AIS will be able to save time by routing ship reporting automatically as target identification, target coverage enforcement, message broadcasting and a designated link between ships and VTC are all available. Finally, the use of VHF/AIS will need to be applied with caution as radio communication itself may lead to the danger of a misunderstanding of COLREGs. Even if AIS is able to support identification of targets in enquiry, communication using VHF should not become a wrongful act infringing on the COLREGs. The collision cases discussed above have indicated issues related to dependence on electronic aids where mariners are confused about applying the COLREGs, lack continued monitoring of RADAR and sacrifice the visual and hearing lookout. Overall, the assistance from the AIS with appropriate training to the current bridge systems should not lead to diminish a good practice of seamanship.

Chapter 5

Research Methodology

5.1 Introduction

The purposes of shipborne AIS are: to help identify vessels; to assist target tracking; to simplify information exchange; and to provide additional information that can assist situation awareness (IMO 2002c). There are two available methods for presenting AIS data: a stand-alone AIS MKD, and a fusion display with the current bridge systems. MKD is the least display requirement for SOLAS ships that were built before the implementation deadline for AIS. Nevertheless, the market and manufacturers have designed the equipment with capability to combine AIS information with other bridge equipment (e.g. ARPA/RADAR and ECDIS). In fact, all new RADARs will be required by IMO to have an AIS display capability from 1st July 2008 (Hughes and Sowdon 2006; Norris 2007). Because international mandatory training requirements for AIS have not been agreed (Winbow 2003), it is necessary to discover the usages of AIS for bridge lookout. This research conducted an investigation of the current use of AIS on board SOLAS ships which is presented in Chapter 6. After this is defined in the literature review and case studies, a series of trials were carried out, detailed in Chapter 7, to test the effects of AIS operation on the ship bridge simulator.

5.2 Survey design

A survey design provides a quantitative or numeric description of some fraction of the population through a data collection process that involves asking questions of people (Fowler 1988). The researcher is then able to generalise the findings from this sample of responses from the population (Creswell 1994). The purpose of this survey research was to study end users' perceptions of operating shipborne AIS. The responses on AIS, the current application of AIS on the bridge and the opinions about the future development of AIS were studied. The research design was a longitudinal survey with a between subjects design and the research work took place over a pre-defined period of time.

5.2.1 Questionnaire design

In order to investigate the use of AIS on the bridge, the end users who were targeted were mainly deep sea deck officers. As the last deadline for fitting AIS onboard SOLAS ships was December 2004, the investigation was separated into pre-AIS and post-AIS surveys. Before the surveys took place, pilot study questionnaires were sent to seafarers. Next, this pilot study questionnaire was also distributed to people who have no mariner background. The responses were made based on the layout of the questionnaire, methods used in the survey and proofreading for the Mandarin Chinese in particular.

The decision for two investigations was also taken to allow a study of developments before and after the full implementation of AIS carriage requirement. For the survey before full AIS carriage requirement, the investigation included expectations of shipborne AIS, the modified implementation schedule, training perspectives and views on non-SOLAS vessels. For the second survey, a satisfaction investigation was carried out. The current use of AIS in bridge lookout was investigated by comparing this with other lookout methods.

5.2.2 Survey population

It was outside the scope of this study to track and administer the questionnaire to same population. Additionally, using a between-subjects design has the effect of negating any carryover effects. Furthermore, the independent variable was the change in AIS carriage requirements and, as there were no other significant maritime events during the period between the two surveys, no confounding variables were identifiable.

The chief discipline required to define this investigated population is making sure that respondents have working experience with SOLAS ships. Because of a connection with Taiwan's shipping companies, deck officers working in Taiwanese shipping companies were mainly targeted.

It was estimated that there were over 400,000 officers (including deck and engineering departments) worldwide in the manning supply in 2000 (BIMCO and ISF 2000). The Organisation for Economic Co-operation and Development (OECD) countries remain the most important source for officers; however, the Far East has increased its share. Among the countries in Far East Asia (Table 5-1), Taiwan has 1.07% of the world officers and 0.33% of the world ratings, according to the report from United Nations Conference on Trade and Development (UNCTAD). The biggest harbour, Port of Kaohsiung in Taiwan, ranked 6th in the world's top 20 container terminals with 8.81 million Twenty-foot Equivalent Units (TEU) throughputs in 2003. In addition, Taiwan placed 15th of the 25 major trading nations with maritime engagements, with a 1.8% share of world trade and 3.0% share of the world fleet (in terms of dead weight tonnage). Three Taiwanese liner companies were listed by the UNCTAD's "Review of maritime transport, 2004" among the top sixteen Asian liner shipping companies (Table 5-2). As the three companies all engage in international shipping routes, the employed deck officers are all qualified deep sea deck officers.

Country or economy	China	Hong Kong	Japan	North Korea	South Korea	Philippines	**Taiwan**	Viet Nam	Total
Officers	8.47	0.31	4.66	0.28	2.36	12.39	**1.07**	0.62	30.16
Rating	5.81	0.08	1.48	0.31	0.85	21.86	**0.33**	0.50	31.22
Key	All data are shown as percentage of world total.								

Table 5-1 Far East Asia economies in seafarers distribution and container business (UNCTAD 2004)

World ranking (Asia ranking)	Operator	TEU capacity in 2004	Existing TEU, % of world total	Number of ships in 2004	Average vessel size of existing ships (TEU)
3 (1)	Evergreen Group	455,000	5.91	158	2,880
18 (11)	Yang Ming	160,000	2.08	58	2,759
22 (14)	Wan Hai	97,000	1.26	67	1,448
Sum of the three companies		712,000	9.25	283	2,516

Table 5-2 Top liner shipping companies based in Taiwan, 2004 (UNCTAD 2004)

The targeted populations were not only qualified as deep sea (international voyage) deck officers under the amended Standards of Training, Certification and Watchkeeping for Seafarers (STCW 95), but the populations were officers who undergo international voyages during the survey. In terms of educational standard, the least requirement for taking a First Class Deck Officer examination is holding a diploma of college degree (The Examination Yuan 2005).[16] In terms of the test subjects, the examinees have to take Navigation, Navigation Safety and Weather, Ship Communications and Maritime English, Cargo Operations, and Ship Operations and Personal Management. An international standard for merchant marine deck officers could establish STCW 95 norms. The baseline for selecting the survey population is deck officers with a recognised international qualification; nevertheless, a world-wide scale of population survey was accepted as a limitation outside the scope of this research.

5.2.3 Sampling

There was a single stage sampling design for the survey population. A single stage design means that a researcher directly samples each individual (Creswell 1994). This procedure of survey sampling was carried out by sending questionnaires to deck officers whose ships use Taiwan's international harbours. As most of the respondents were working for three liner shipping companies, regular visits to Taiwan were favoured. In addition, deck officers who were on onshore training or temporarily on leave were also given questionnaires.

There were 120 and 200 questionnaires sent out for the first and second surveys, respectively. 103 were collected (1 rejection and 16 missing) for the first survey;[17] 190 respondents returned questionnaires (10 missing) for the second survey.

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[16] Eligibility educational requirement for Taiwanese mate is "Persons who have graduated and hold an associate diploma from the department, division, or program of Marine Navigation, Merchant Marine, Shipping Technology, and Marine Transportation ..."

[17] The mariner did not give an interview as he was not sure if the company was allowing its crew to be interviewed.

5.2.4 Data collection and analysis

In order to generalise the findings from the sample of responses by a population, the data are collected. For the collection of some kinds of data, a questionnaire is both an instrument and a measurement tool (Oppenheim 1993).

To analyse the data that was collected, a descriptive statistic was adopted. The measurement used for the respondents' attitudes was based on the level of satisfaction. A cross-sectional analysis was used to differentiate any different opinions that occurred between the respondents. The demographic data, mainly the ranking and ship type that the respondents were currently working on, was used for comparison via a cross-sectional analysis. The decision to compare between different ranking officers was taken because of the different levels of training, examination and experience. The comparison between types of ship was undertaken because officers might have different operational experience in different types of ship. Furthermore, there were certain numbers of respondents who were not working onboard when the survey took place. These respondents were also grouped to be compared with the groups of respondents who were working onboard ships. To add a strong statement that could underpin the descriptive statistics, a hypothesis was set to test whether there was any difference among the officers' ranking and their serving types of ships.

5.2.4.1 Descriptive statistics

The descriptive statistics reveal what proportion of a population have a certain opinion or characteristic, or how often certain events occur together (Oppenheim 1993; Yang 2005). To project the estimated view among the population, the collected data was examined by the frequency and percentage of overall responses to questions.

The survey also looked at the impact of AIS operation on the bridge by means of a seafarer attitude measurement. Instead of a Yes/No (agree/disagree) answer, a five-level Likert Scale (Likert 1932) (2 positive degrees, a neutral degree and 2 negative degrees) was used to gauge the attitude response. Only the percentage of responses from the top two levels of the Likert Scale were taken as positive results. The responses from the bottom two levels of the Likert Scale were seen to indicate negative attitudes.

5.2.4.2 Non-parametric statistics

Non-parametric tests are simpler to calculate than parametric tests because they take into account whether certain scores are higher or lower than other scores regardless of a calculation of the exact numerical differences between scores (Greene and D'Oliveira 1982). As opposed to parametric tests, non-parametric tests make no assumptions about the underlying population parameters (Elmes, Kantowitz et al. 1989). In addition, non-parametric tests require little or no knowledge of the distribution of the data (Dytham 2003).

To study the relationship between questionnaire items and the demographic background, a procedure of non-parametric tests was adopted. These were designed to analyse whether independent variables (see Section 5.2.4; officers' ranking and types of served ships) have an effect on dependent variables. The null hypothesis (*Ho*) assumed that there would be no difference of opinion between respondents with different demographic backgrounds (e.g. ranking and types of ships worked). If the null hypothesis is true, all differences of opinions between the ranking groups were due to random sampling as the data sampled was from populations with identical distributions. With a 95% confidence level, there is a 5% chance that at least one of the tests will have P<0.05. This 5% chance does not apply to each comparison individually, but to the entire family of comparisons.

To run the non-parametric tests, the interested items were measured by Kruskal Wallis (KW) tests followed by Mann Whitney (MW) tests. By ranking the measurement of users' attitudes in each of the asked items, the KW tests provide a W value to indicate the relationship between the interested groups in the surveyed sample. Apart from the statistical software for calculating the W value and significance, the W value probability was obtained using a chi-square distribution table (critical value=0.05; degree of freedom= numbers of comparing groups-1). The W value is written in Table 5-3:

$W = \frac{12}{n_T(n_T+1)} \left[\sum_{i=1}^{k} \frac{R_i^2}{n_i} \right] - 3(n_T+1)$	
Key	K: the number of populations
	n_i: the number of items in sample i
	$n_T = \sum n_i$: total number of items in all samples
	R_i: sum of the ranks for sample i

Table 5-3 W value by KW test (Anderson, Sweeney et al. 1999)

Post hoc MW tests with a Bonferroni correction were used to judge the existence of significances among groups (Field 2005). The Bonferroni correction was used to ensure that Type I errors (Table 5-4) did not build up to more than 0.05. The Bonferroni correction was set as a critical value of significance 0.0083 (0.05/6;

there were six pairs from the four ranking groups) and 0.016 (0.05/3; there were three pairs from the three types of serving ships). The significances would only be recognised if they were smaller than the new critical value with the Bonferroni correction.

Conclusion \ Population Condition		*Ho* True	*Ha* True
Accept *Ho*		Correct conclusion	Type II error
Reject *Ho*		Type I error	Correct conclusion
Notes	The form for Null and Alternative Hypotheses		*Ho*: $\mu 1 = \mu 2$ *Ha*: $\mu 1 \neq \mu 2$
Key	*Ho*: Null Hypotheses *Ha*: Alternative Hypotheses $\mu 1$: median from a compared group $\mu 2$: median from another compared group		

Table 5-4 Errors and correct conclusions in hypothesis testing (Anderson, Sweeney et al. 1999)

5.2.4.3 Contingency tables analysis

To study the significances that were found after the non-parametric tests, the results will be represented by a contingency table. As the outcome is a categorical variable, the contingency table is used to summarise the results. Furthermore, there will be a cross-sectional study to discuss the results from these contingency tables.

5.2.4.4 Open questions

The open questions mainly appeared in the first survey. A summary of the results is contained in the survey findings. The reason for using open questions was to provide more freedom for respondents to give their thoughts. The answers would not be limited in comparison with single or multiple choice questions. Nevertheless, a lower response rate to the open answer questions was observed.

5.2.5 Summary

The research in the questionnaire survey was carried out to study the overall opinions of deep sea deck officers on the operation of shipborne AIS. After the survey, trials in operating shipborne AIS were carried out, which will be discussed next.

5.3 Simulator experiments

After the survey, opinions upon the use of AIS were collected. As for bridge lookout, respondents were supporting the idea of AIS-assisted collision avoidance (see Section 6.3.3.7 and Section 6.4.3.6). Furthermore, the recent access to AIS information was acknowledged as an interim alternative (see Section 6.4.3.4). Therefore, most respondents approved that AIS should be better integrated with the other bridge equipment as to be applied to the decision making of collision avoidance. The plan for the future AIS-assisted collision avoidance will be studied based on a fused AIS bridge operation. The research was to measure how the use of AIS is able to enhance the whole bridge lookout operation. To measure the impact of AIS assisted collision avoidance, a fully AIS integrated bridge was adopted.

A marine simulator experiment was carried out to study bridge operation involving AIS. To evaluate performance, scenarios with particular objects were used to formalise simulations. As the research is focussed on the application of AIS to the effectiveness of bridge lookout, the ship handling simulator at the University of Plymouth (UOP) was utilised.

5.3.1 Research design

The use of the simulator in training was initially seen as an addition or complement to the training programmes. Nowadays, OOWs can practice new techniques and skills or transfer theory to real-world situations in a risk-free operating environment, as simulation enables creation of dynamic, real-life situations in a controlled classroom environment (National Research Council (US) 1996). The representation of conditions approximating actual or operational conditions is referred to as simulation, and a simulator refers to the hardware or apparatus that generates the simulation.

Collision avoidance scenarios can be applied to a particular ship which can be navigated in any charted region of the world (Blackburn 1995). With both manoeuvring characteristics (response to rudders, engines and thrusters) and motion characteristics (response to wind, waves and currents), the simulated ship can accurately reproduce and be modelled on real ships (Kunze 2000).

The development of deck officers' skills can be achieved by a computer-based ship bridge simulator. Simulated areas could include (National Research Council (US) 1996):

- Bridge Team Management (BTM);
- Bridge Resource Management (BRM);
- ship handling;
- docking and undocking;
- bridge watchkeeping;
- rules-of-the-road;
- emergency procedures.

The STCW 95 and IMO Resolution A.482 (XII) proposed the adoption of the marine full mission simulator because its capability of simulating full visual navigation bridge operations, including capability for advanced manoeuvring.

The simulator used in the research was a TRANSAS Navi-Trainer Professional 4000 (Version 4.51). Apart from the simulator's AIS MKD (Figure 5-1), RADAR and ECDIS are able to overlap the target's information as supported by AIS. The arc of visibility from the wheelhouse was 135 degrees ahead, and views were also adjustable to see the rest of the scene.

Figure 5-1 TRANSAS AIS MKD on the main console

5.3.2 Decision making

The impact of AIS operation on bridge lookout was observed. As one of the electronic aids to navigation, the process of decision making would be measured to show any impact caused by using AIS. By including AIS information in collision avoidance, a certain degree of situation awareness would be expected. Cognitive processes and human factors should be taken account of in the decision making.

5.3.2.1 Situation Awareness

Adam (1993) described Situation Awareness (SA) as, 'knowing what is going on so you can figure out what to do'. SA is a mental representation and understanding of objects, events, people, system states, interactions, environmental conditions and other situation-specific factors affecting human performance in complex and dynamic tasks. SA refers to the active content of a decision-maker's mental model of his or her ongoing task situation, its purpose being to enable rapid and appropriate decisions and effective actions.

In Endsley and Jones's model (1997) for SA, three levels are included. Firstly, Perception (Level 1 SA) involves 'monitoring', 'cue detection' and 'simple recognition'. Level 1 SA is an awareness of multiple situational elements (objects, events, people, system, environmental factors) and their current states (locations, conditions, modes, actions). Secondly, Comprehension (Level 2 SA) involves 'pattern recognition', 'interpretation' and 'evaluation'. Level 2 SA is an understanding of the overall meaning of the perceived elements. Thirdly, Projection (Level 3 SA) involves 'anticipation' and 'mental simulation'. Level 3 SA is an awareness of the likely evolution of the situation, its possible/probable future states and events. Achieving and maintaining SA involves the acquisition, representation, interpretation and utilisation of any relevant information in order to make sense of current events, to anticipate future developments, to make intelligent decisions and to stay in control. Lacking SA or having inadequate SA has consistently been identified as one of the primary factors in accidents attributed to human error.

5.3.2.2 Cognitive hierarchy

Cooper (1995) indicates the cognitive hierarchy can be formulated as:

Cognitive hierarchy = DATA-INFORMATION-KNOWLEDGE-UNDERSTANDING.

Data that is correlated becomes information; information converted into SA becomes knowledge; knowledge used to predict the consequences of actions leads to understanding. For a task analysis, decisions made for collision avoidance can move through target detection, classification and tracking to output decision making.

The Cognitive hierarchy provides procedures before the action for collision avoidance was taken by the OOWs. The fundamental method of the simulator experiments was based on the variation of input data. The outcome was defined by measuring the result at the end of the hierarchy (procedure), i.e. Understanding. After the understanding of the situation, OOWs ought to take action or not take action toward any developing collision risks.

5.3.2.3 Human factors

Human factors are sets of human-specific physical, mental and behavioural properties which can either interact in a critical or dangerous manner with technological systems, the human natural environment and human organisations, or should be taken under consideration in the degree of ergonomic human-user oriented equipment.

The choice/identification of human factors usually depends on their possible negative or positive impact on the functioning of human-organisation and human-machine systems. Human Factors were taken into account especially in simulation familiarisation exercise (see Section 5.3.5.2). This familiarisation session of the simulator trials was aimed to reduce bias that might occur between human and machines.

5.3.3 Scenario construction

Information delivered by ARPA/RADAR can support decision-making for collision avoidance (Ishioka, Nakamura et al. 1996). The operation of ARPA/RADAR will need to be considered in the construction of AIS scenarios. In short, AIS information assists RADAR as an additional navigation aid to the bridge.

To test the effectiveness of AIS on bridge lookout, an independent variable was adopted by separating participants into two groups. One group was able to obtain AIS information on the bridge (Group A). The other group (Group B) did not have any access to this data throughout the exercises. The null hypothesis (for statistical tests) assumes no difference of performance between the two designated groups. If there is a significant difference (critical value at 0.05), a suggestion would be made that AIS information does affect decision making during a bridge lookout.

5.3.3.1 Scenario background design

Sandberg and Stewart (1996) proposed a number of steps to create a ship simulator scenario for an examinee:

a. 4-6 ships seem to be a reasonable number for an examinee to consider during a particular scenario;
b. A minimum of 6 minutes is needed for identification of other vessels and assessment of the situation;
c. The RADAR should be available for use by the examinee from the start of the exercise, as this option would more closely represent real-life conditions;
d. The simulator run time needed to identify other vessels, assess conditions and take appropriate 18 minutes.

The scenarios were created having considered the above suggestions. To construct scenarios involving AIS operation, the collision cases, AIS functions, operating visibility, bridge control and limitations were also taken into account. All the exercises were tested by staff with deep sea deck officer experience beforehand.

5.3.3.2 Collision cases

Collision cases involving AIS operation (see Section 4.2) have led to the combined use of VHF communication with AIS in ship manoeuvring. The dangers of VHF assistance in collisions were shown. In terms of bridge lookout, AIS information can assist decision making through many functions. To explore AIS information in ship manoeuvring, RADAR assisted collision was emphasised as a reference to the potential risks of AIS assisted collision. In fact, the collision cases when operating RADAR were discussed over different periods of time (see Section 4.3). Maritime RADAR was introduced in the 1940's and has been under continuously development by means of functional and operational upgrades. The inclusion of RADAR operation in COLREGs 72 (modification to the previous COLREGs 67) reflects the importance of RADAR in collision avoidance. Since then, RADAR has not only obtained its legitimate role in the Rules operated at sea, but has proved useful to mariners. However, collisions involving RADAR operation still exist. Because there is little evidence of RADAR malfunction, in most cases it was found that the decision makers were responsible.

The four pairs of simulated exercises were hypothetical. To enhance the reality of the simulated scenarios, the collision cases discussed were considered in the construction of the simulator exercises.

5.3.3.3 AIS functions

AIS provides an independent platform of traffic information that is able to improve and support RADAR in collision avoidance manoeuvring. For instance, the target's ROT and speed can be obtained from AIS dynamic information. The target's navigational status can be shown by AIS static information. Moreover, AIS voyage information contains a target's destination. To be able to test these functions, course alteration, speed change and privileged status were available on every target ship for Group A. In short, AIS information could be obtained on three displays – RADAR, ECDIS and MKD with an optional graphical display – of the bridge consoles.

5.3.3.4 Conduct of the vessels

In section II, COLREGs (IMO 2003b), three meetings, overtaking, head-on and crossings are illustrated. Apart from the head-on situation, two vessels in visual contact overtaking or crossing would have explicit roles to obey, i.e. being the stand-on or give way vessel.[18] In addition, Rule 18 (a) COLREGs lists four situations of a target vessel that an underway power-driven vessel should keep clear of. A privilege was forced upon vessels in these four situations.

Section III COLREGs determines the conduct of vessels in restricted visibility. Vessels not in sight of one another should all be give way vessels if a CQS is going to develop. The use of RADAR was particularly mentioned in order to avoid a CQS.

5.3.3.5 Reduced visibility

The advantage of RADAR is recognised during periods of reduced visibility (Valentine 1985). An earlier detection of oncoming traffic can be obtained before the target comes in sight. As a result, visibility setup became an element in the construction of simulator scenarios.

An escape action should be taken by a ship if a target ship is 3nm or less from the own ship (Calvert 1960; Calvert 1961; Cockcroft 1972). Cockcroft further described a collision avoidance taken under 4 nm would be seen as a CQS. 3nm was then set as the visibility range for all simulator scenarios.

[18] In a head-on situation, the preferable action is for two meeting vessels to keep passing port to port.

5.3.3.6 Bridge control

The ship category was set up as a 32,000 grt, 250 metre long container ship for all controlled ships in the simulator. The autopilot was active as a default mode for wheel control. A change of course could be carried out by ordering the new course on the autopilot or by switching to manual control. For the scenarios that took place in an open sea area, the speed was set as full sea speed. For a scenario that took place in restricted water, i.e. TSS, the ship was given a 'half ahead' speed and the engine control was also on standby.

Although the engine was not at immediate readiness in the open sea situation, a five-minute notice could be given to the engine room to request engine stand-by if the participants decided this was necessary. From the author's experiences, a modern ship bridge may not need any notice to the engine room, while a comparably old ship may need up to 30 minutes notice for engine standby. Considering the average time for each exercise, a 5-minute notice to the engine room was required.

5.3.3.7 Limitations

Due to limited access to more qualified mariners to participate the simulator trials, there were a few limitations made during the simulator research. Firstly, the trials were unable to go under different ranges of visibility (see Section 5.3.3.5). A 3 nm restricted visibility was the only set-up visibility throughout the trials. Secondly, the effectiveness of AIS operation between the three potential displays could not be differentiated individually. The Group A participants were not limited to read AIS information from RADAR, ECDIS or the MKD.

Despite the criticism of AIS information maintenance in the real world (Harati-Mokhtari, Wall et al. 2007), the information transmitted via AIS was set/assumed to be all genuine and ready to be used by the participants. For instance, a non-SOLAS fishing boat could still send its ship name, navigational status, etc. to the AIS network in the simulator exercises.

The simulated scenario was mainly interested in ship handling with traffic. Participants were allowed to control both engines and rudder. The tug and thrusters were not considered in the scenarios. In order to limit the measurement of participants' behaviour in collision avoidance manoeuvring, the wind and current were limited and only visibility and weather conditions were involved in the simulator scenarios.

The reason not having each participant to try both paired exercises with and without AIS was to avoid bias that might occur by recalling the same scenario in the simulator experiment.

5.3.4 Simulated scenarios

The five pairs of exercises/tracks are named Exercise A&B (Ex-A & Ex-B), Exercise C&D (Ex-C & Ex-D), Exercise E&F (Ex-E & Ex-F), Exercise G&H (Ex-G & Ex-H), and Exercise I&J (Ex-I & Ex-J). The outline, description and participating vessels for the 5 pairs of exercises are shown in Table 5-5:

Group A n=6	**Group B n=7**	**Exercise description**	**Vessels' codes and types**
Ex A	Ex B	A head-on meeting with a fishing boat	OS: container ship TG1: container ship TG2: passenger ship TG3: fishing boat
Ex C	Ex D	A cross meeting with a privileged ship	OS: container ship TG1: container ship TG2: container ship TG3: bulk carrier TG4: container ship
Ex E	Ex F	A cross meeting with a vessel that is initially more than 22.5 degrees abaft own ship's beam	OS: container ship TG1: container ship TG2: bulk carrier TG3: container ship TG4: trawler TG5: trawler TG6: trawler
Ex G	Ex H	An initial cross meeting with a cross-channel ferry that alters course to give way to the vessels in the TSS channel	OS: container ship TG1: ferry TG2: bulk carrier TG3: container ship TG4: bulk carrier
Ex I	Ex J	A cross meeting with a fast approaching vessel	OS: container ship TG1: high speed craft TG2: container ship TG3: trawler TG4: trawler
Key	Group A: AIS is available; Group B: AIS is not available; OS stands for own ship; TG stands for target vessel		

Table 5-5 Exercise description

5.3.4.1 Head-on meeting (Ex-A/B)

This exercise (Figure 5-2) was to place a small target (Code:TG3) having a reciprocal course with the own ship (Code:OS). Initially, TG3 was 9 nm from the OS. Both OS and TG3 were under full sea speed, the closing speed was over 30 knots and the two ships were supposed to have a CPA of one cable in 18 minutes 33 seconds.

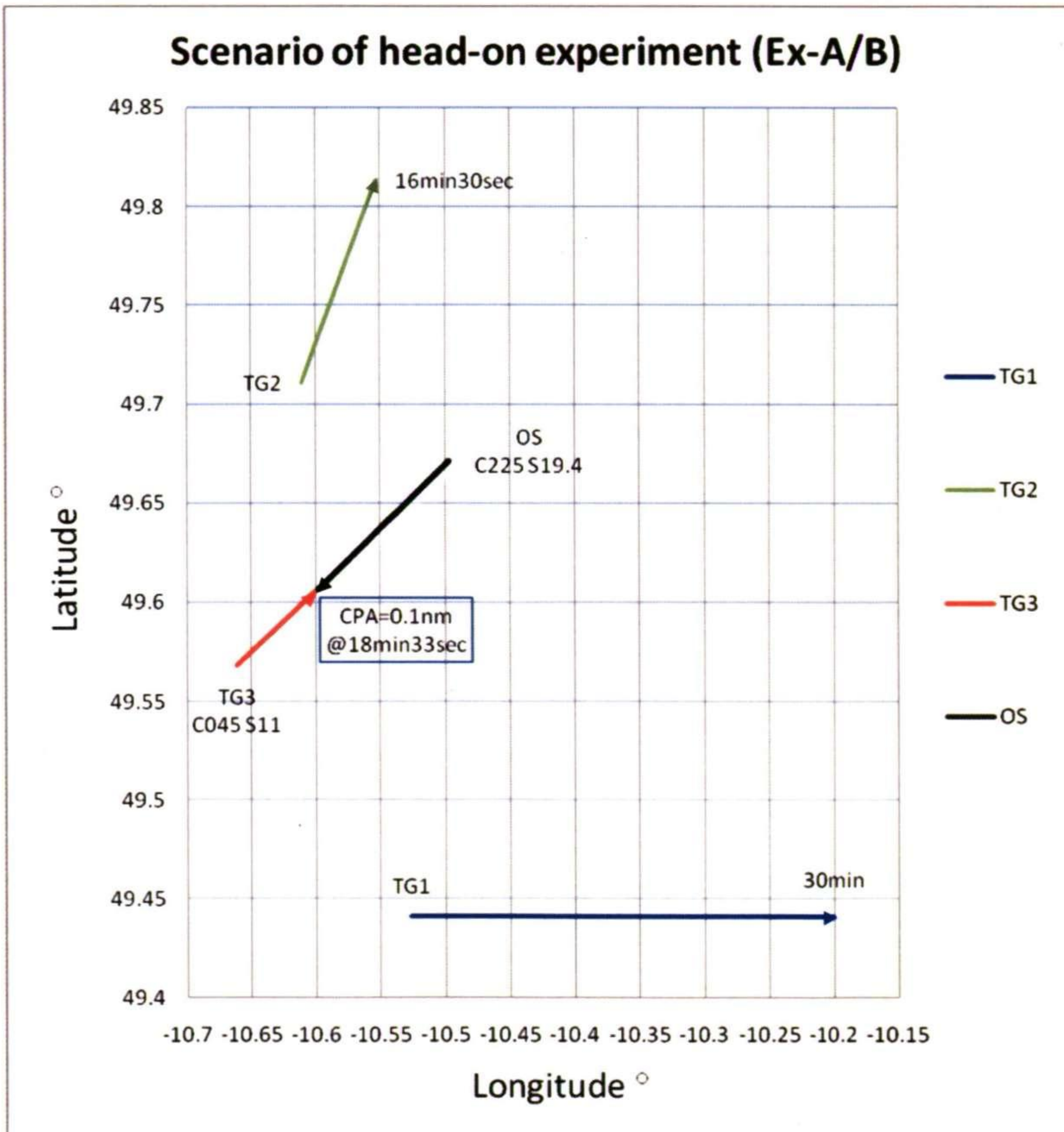

Figure 5-2 Original scenario for head-on experiment (Ex-A/B)

5.3.4.2 Privileged meeting (Ex-C/D)

The navigational status of the vessels is obtainable by AIS. The exercise was designed to observe how participants from Group A took this information when considering Rule 18 COLREGs. A crossing situation was adopted (Figure 5-3) by two target ships (TG3 and TG4). The TG4 soon altered course to keep clear of oncoming traffic, whereas TG3 stayed on the same course and speed throughout the exercise. In order to test the impact of AIS information on participants' decision making, the target ship (TG3) was experiencing control difficulties. Corresponding signals (two round shaped balls) were lifted on TG3 and the privileged situation could also be obtained in Group A via AIS.

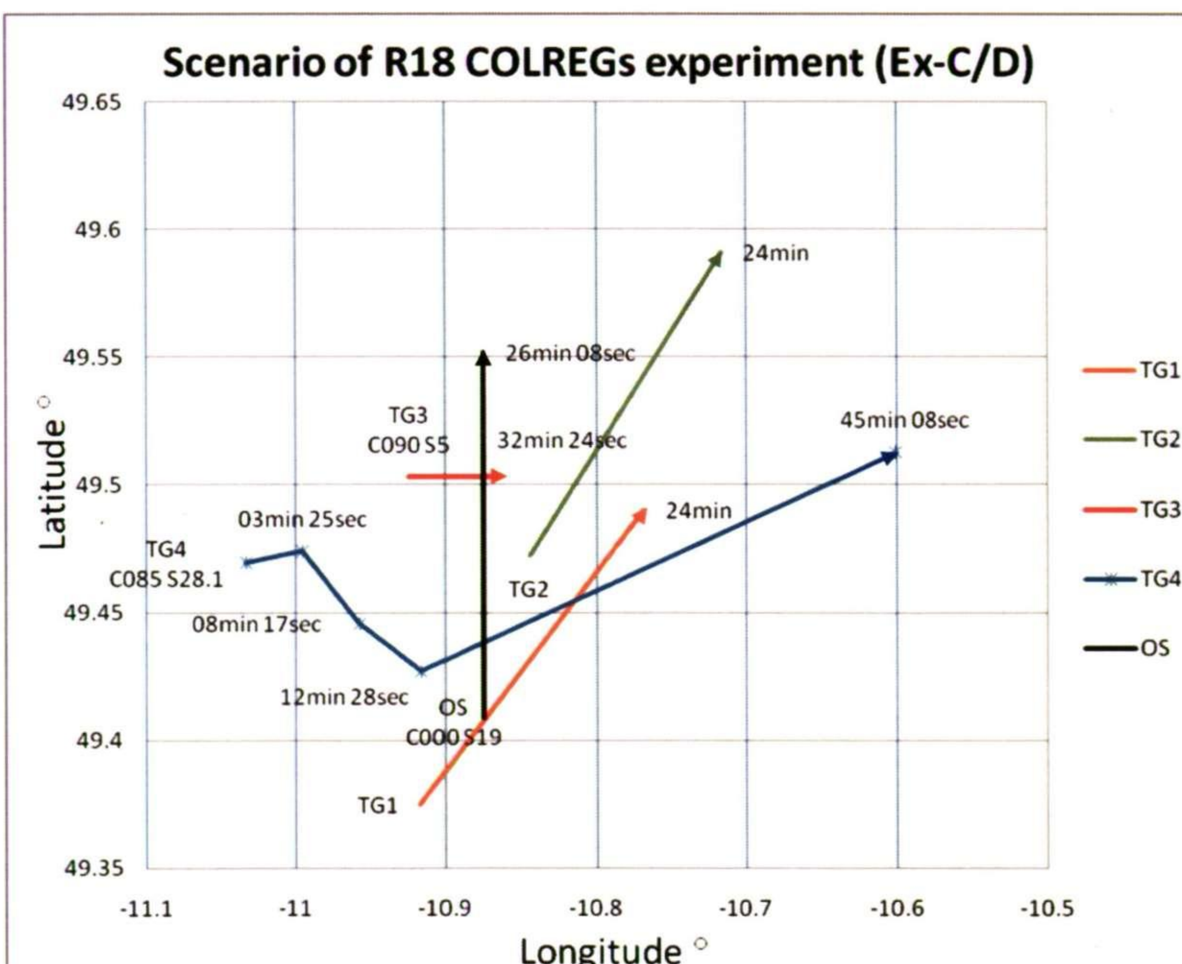

Figure 5-3 Original scenario for Rule 18 experiment (Ex-C/D)

5.3.4.3 Overtaking (Ex-E/F)

In Section 4.2.1, a misinterpretation of a meeting situation from a crossing situation to an overtaking situation was highlighted in the case of 'Hyundai Dominion v Sky Hope'. These two ships both saw themselves as the stand-on ship in the early stages. Cockcroft and Lameijer (2003) illustrated two scenarios (Figure 5-4) with different interpretations when an overtaking situation exists. The upper diagram is deemed to be an overtaking situation, whereas the lower diagram is a crossing situation.

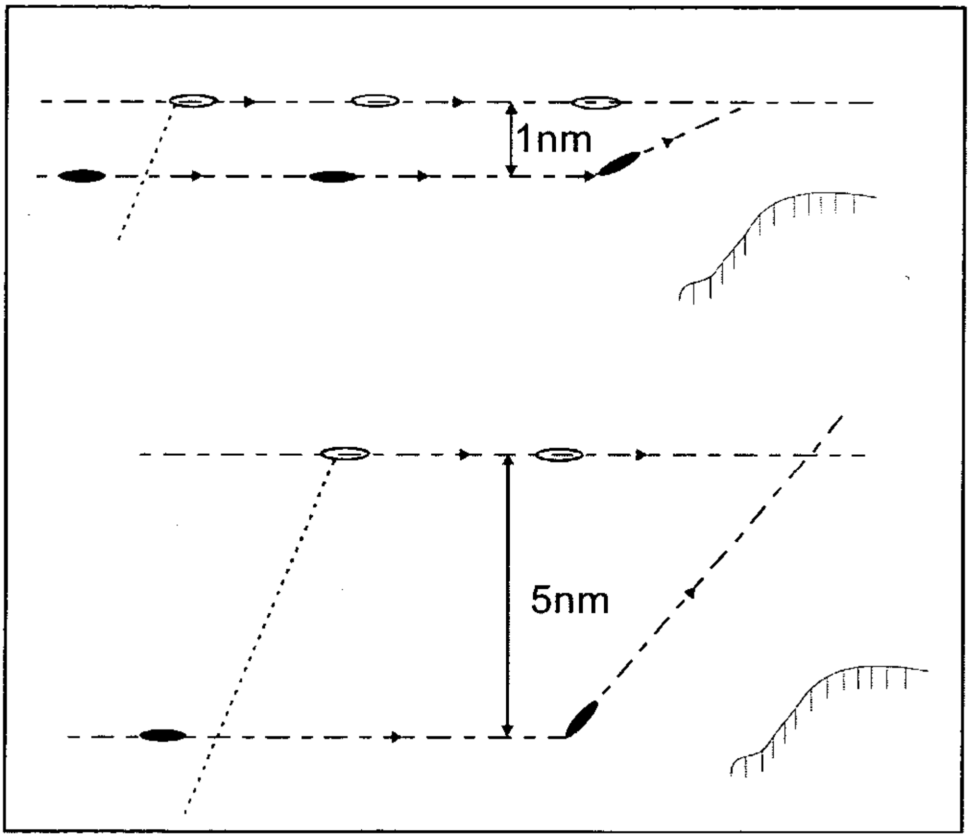

Figure 5-4 Subsequent alterations of bearing (Cockcroft and Lameijer 2003)

Based on the scenario in the case of 'Hyundai Dominion v Sky Hope' and Cockcroft's diagram, Figure 5-5 shows that OS will meet a subsequent course-changing TG3. Initially, the TG3 is on a heading parallel with the OS, where TG3 is 22.5 degrees abaft own ship's beam and over 5nm in distance.

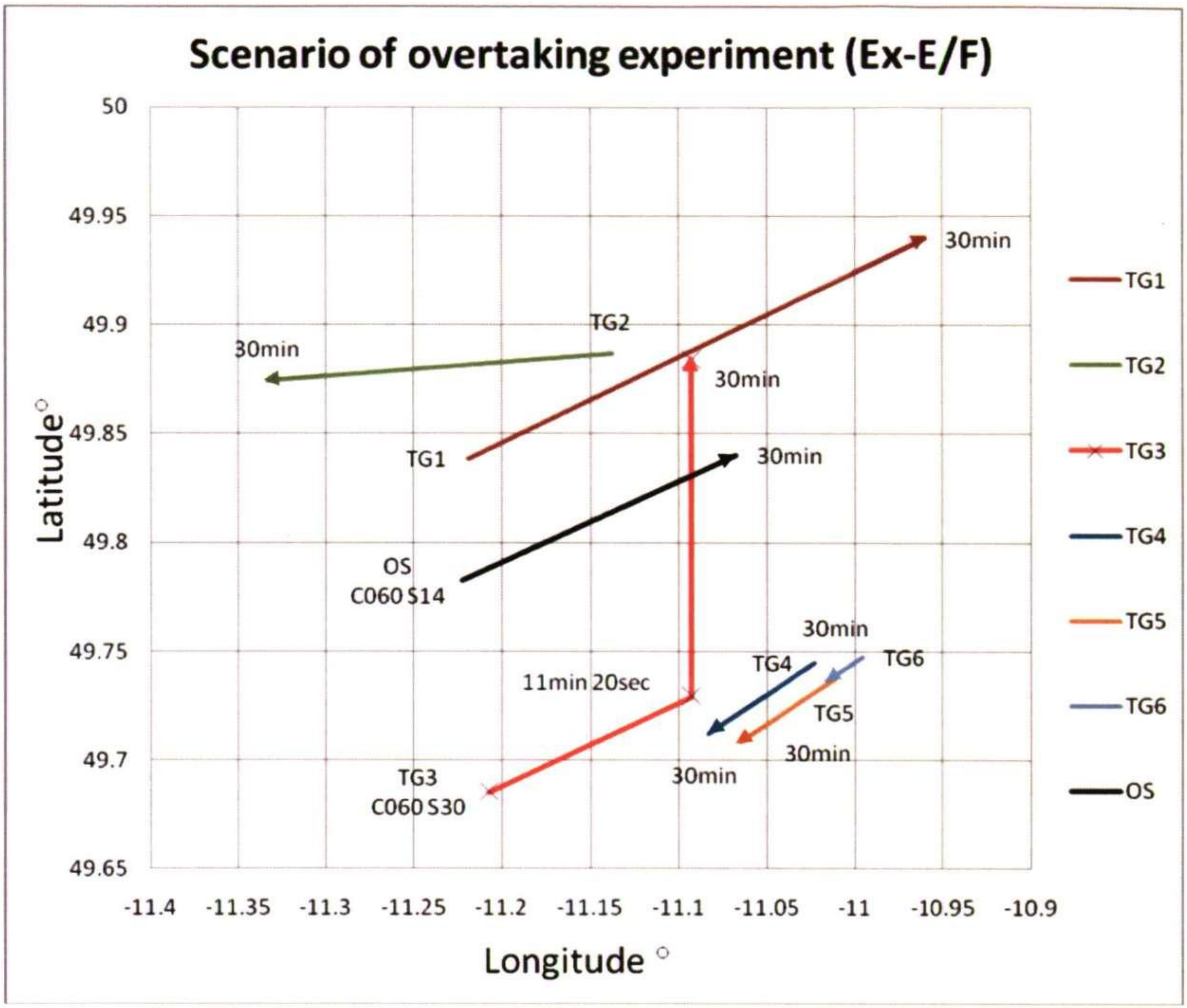

Figure 5-5 Original scenario for overtaking experiment (Ex-E/F)

5.3.4.4 TSS meeting (Ex-G/H)

In coastal waters, the tasks of collision-avoidance and navigation generally occur simultaneously (Berking and Pfeiffer 1995). Redfern's Study (1993) developed a scenario with the same collision avoidance condition in two different types of waters, i.e. open sea and TSS. The comparison was tested and later significance was found between different transit areas. The findings showed confusion among the subjects in understanding COLREGs when a TSS scheme is applied. More traffic information was then suggested in order to assist OOWs in the decision making of safe transit.

Redfern's study (1993) adopted a real RADAR surveillance record in Dover Strait. A meeting between three cargo ships on the Southwest bound TSS lane and a passenger ferry intending to cross the channel (Figure 5-6) was studied. Every participant took four exercises, one on each of the ships (OS1, OS2, OS3 and OS4). Redfern's findings revealed that most participants on board the ferry (OS2) decided to alter course to port to give way to the transit traffic (see Appendix B). The same participants were put onboard one of the cargo ship (OS1) heading Southwest and most of them altered course to give way to the crossing ferry (OS2). A concern was raised from the participants' tracks that OS1 and OS2 came into a CQS with each other or onto a collision course.

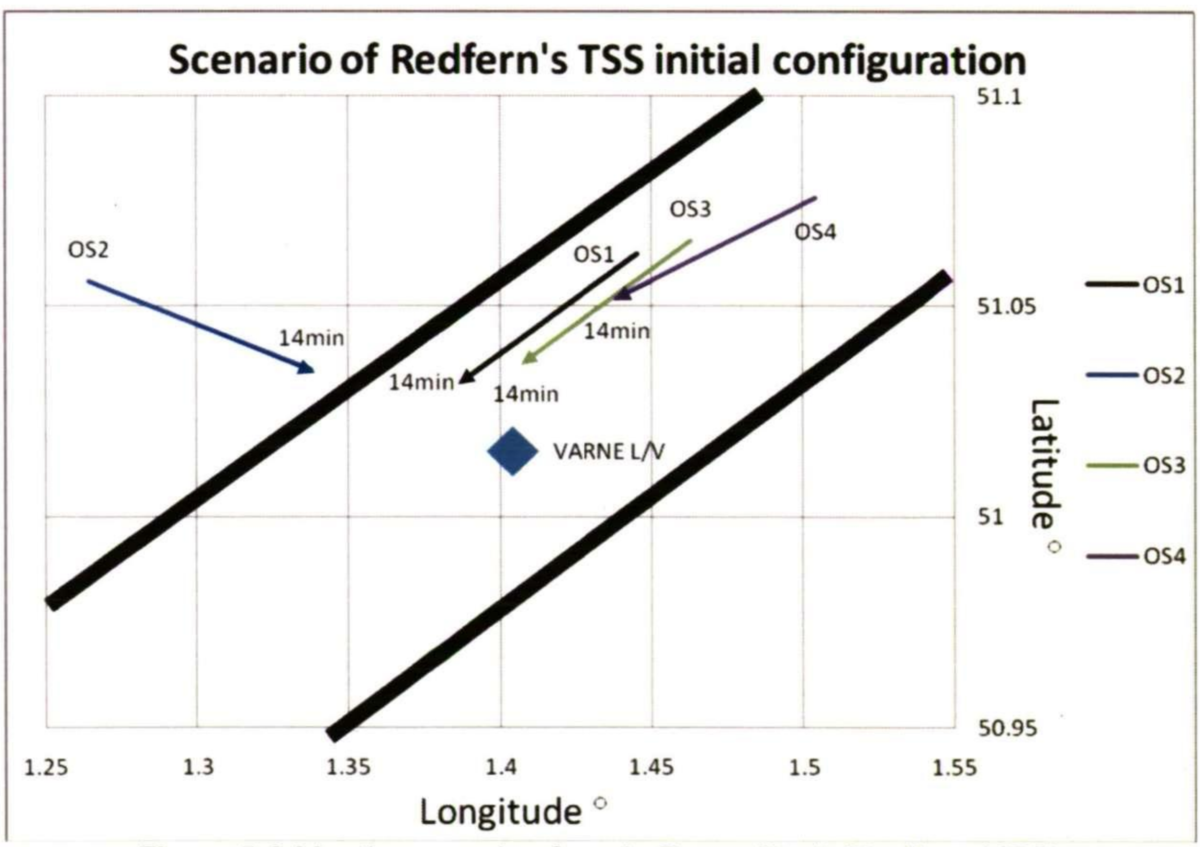

Figure 5-6 Meeting crossing ferry in Dover Strait (Redfern 1993)

The initial positions for the four ships in Redfern's case were adopted and, furthermore, TG1's track (OS2 in Figure 5-6) was modified following the participants' track results in Redfern's findings. TG1 in the modified exercise was bound to alter course to port to avoid crossing TSS in front of three Southwest bound ships (OS, TG2 and TG3) in Figure 5-7. The time of TG1's first course alteration was adopted where OS2 subjects altered course between 1.1 and 6.8 miles from the principle threat, OS1. The mean range at which action was taken by OS2 was 4 nm from the OS1. Prior to the course alteration made by TG1, CPA/TCPA to the OS was 0.021nm/16min. In Ex-G/H, TG1 altered course to port at 7min 45sec from the beginning of the exercise.

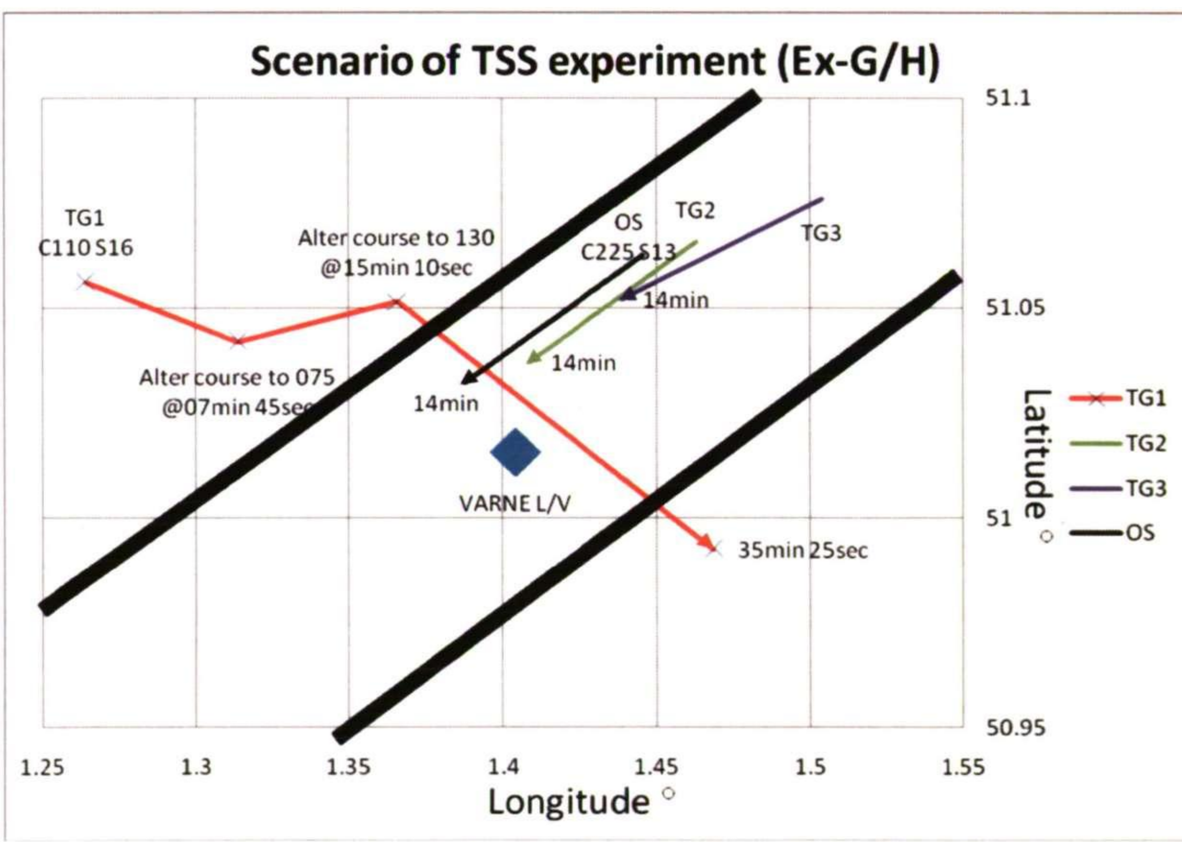

Figure 5-7 Original track for meeting targets in Dover Strait (Ex-G/H)

5.3.4.5 Crossing meeting with speed change (Ex-I/J)

A crossing situation was adopted (Figure 5-8).

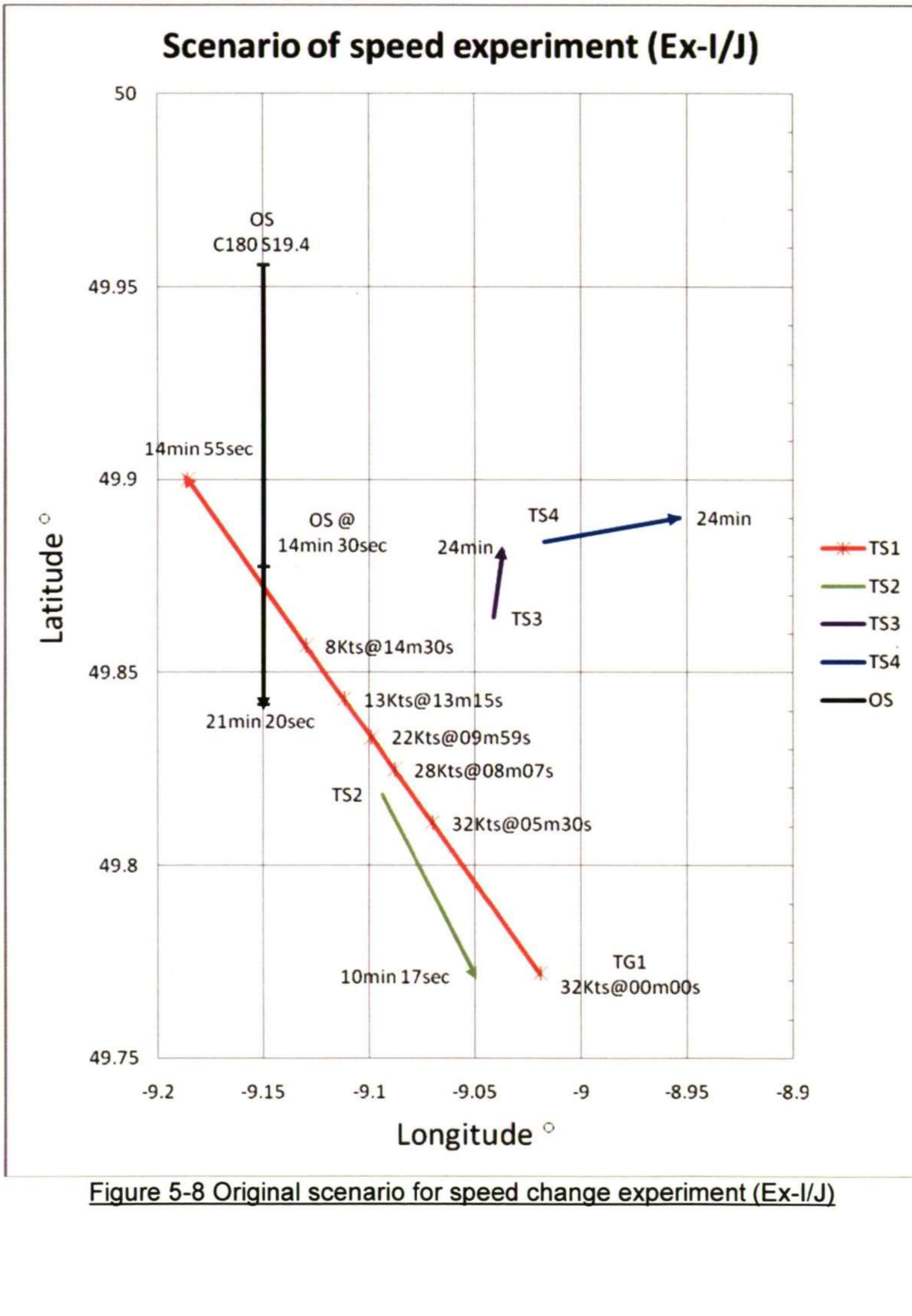

Figure 5-8 Original scenario for speed change experiment (Ex-I/J)

In order to test the impact of AIS information in participants' decision making, the encountered target ship (TG1) was intended to slow down. The participants from Group A were able to obtain TG1 identity as a High Speed Craft (HSC), heading north west, with near real-time dynamic information.

5.3.5 Trial procedure

The participants from Group A undertook Ex-A, Ex-C, Ex-E, Ex-G and Ex-I, as AIS information is available on RADAR (overlapped), ECDIS (overlapped) and MKD (stand-alone). The participants from Group B undertook Ex-B, Ex-D, Ex-F, Ex-H and Ex-J, where AIS information was not provided throughout the experiment.

5.3.5.1 Briefing

A thorough briefing is essential prior to any simulator exercise (Valentine 1985). This briefing introduced participants to the objectives of the research, gave them the right to withdraw, assured anonymity, etc. A research information sheet, a consent form, a sheet of a log book and a form for personal details were handed out to the participants (see Appendix C). The procedure of a warm-up and five exercise sessions was then established. Next, the participants were asked to follow a given track (a voyage plan), which was displayed on ECDIS. If any manoeuvre was taken, the participants should alter back to the given track after the collision risk is cleared.

5.3.5.2 Familiarisation

To minimise the positive and negative influences when using the simulator on each participant's performance, some level of familiarity with the testing platform, i.e. the simulator, is required (National Research Council (US) 1996). After the briefing, an introduction of simulator exercises was made, followed by a warm-up practice. The purpose in holding a familiarisation session is to prevent possible bias occurring from unfamiliar use of the bridge controls during the trials. Redfern (1993) indicated that visual scene, ship handling, use of RADAR, radio and other equipment should be carried for familiarisation. As the research was considered with a view to AIS operation, 6 of the participants were also able to practice the simulator with displayed AIS data.

5.3.5.3 Own ship

There were several types of own ships available in the UOP simulator. In order to simplify the data analysis, there was a focus on the simplicity of the own ship's engine control and steering. Because the majority of surveyed respondents served on container ships (see Section 6.4.3.1), container ships with a displacement of 30,000 grt and a single propeller were selected. The further details of the own ship model are shown in Appendix D. The bridge systems on the own ship had one ARPA/RADAR, one ECDIS and a main control panel.

5.3.6 Data collection

The data was collected by the track presentation from each of the participants. To study the moments of execution (Ishioka, Nakamura et al. 1996), the range at which action was taken (or the TCPA at which action was taken) was recorded. The distance off the given track on ECDIS was also recorded. Lin (1994) used the off track distance to evaluate the effectiveness of a single buoy on a harbour's channels. A ship getting pilot onboard was ahead of the own ship and a given track in the approaching channel (central line of the approaching channel) was available on the simulator bridge. The independent variable was the controlled presence of a channel buoy for the harbour approach. The results obtained by measuring off-track distance indicated the effectiveness of the establishment of a buoy system. To complete this mission, every participant was recommended to turn back to the intended track. Further comments and remarks from the bridge log were also collected for further discussion.

The data collected from the five different scenarios were:

1. Range from the potential collision vessel at which action was taken;
2. TCPA from the potential collision vessel at which action was taken;
3. Action being taken compared to COLREGs;
4. Off-track distance after the manoeuvre to the collision threat.

5.3.7 Data analysis

The data collected from the simulator was analysed by means of descriptive methods and non-parametric tests. In particular, the time of action and off-track distances made by participants were taken into consideration.

There are five pairs of simulator exercises undertaken by two groups of mariners (Group A and Group B). Group A, consisting of 6 participants, was asked to operate AIS during the lookout, while Group B's 7 participants were not able to obtain any information from AIS. For a two condition, unrelated design when different participants are used for each of the conditions, the MW test should be used (Greene and D'Oliveira 1982). As a non-parametric test, MW is criticised for being less powerful than a parametric test, e.g. t-test (Dytham 2003). Nevertheless, non-parametric tests are less likely to find a significant result when there is no real difference. The reason is to reduce the probability of having a Type I error (see Table 5-4, Section 5.2.4.2)

To test the additional information from AIS, the hypotheses for testing the two groups by MW were:

> *Ho*: The two populations are identical in terms of bridge system operation.
> *Ha*: The two populations are not identical in terms of bridge system operation.

By ranking the simulator results (action time and off-track distance), the MW tests calculate a U value (Table 5-6) to indicate the relationship between Group A and Group B. The smaller the U value, the larger the difference between the two compared groups. The critical value of U was set as 0.05. Significances ($P<0.05$) would be defined by rejecting the null hypothesis (*Ho*), showing that there is a significant difference by the independent variable (AIS availability).

$U = n_1 n_2 + \frac{n_x(n_x+1)}{2} - T_x$	
Key	n_1: number of participants in Group A
	n_2: number of participants in Group B
	T_x: largest rank total
	n_x : number of subjects in the group with the largest rank total

Table 5-6 U value, MW tests (Greene and D'Oliveira 1982)

5.4 Conclusions

The surveys for user perception in AIS operation will be discussed in Chapter 6, along with the current status and the role of AIS among other electronic aids to navigation. In Sections 4.2.1-4.2.4, a connection between AIS and VHF communication was shown by the early AIS assisted collision cases. Hence, an investigation of the use of VHF for collision avoidance and a link to AIS identification will be studied.

The simulated scenarios were created based on AIS performance in collision avoidance. How the OOWs performed in the two controlled simulation environments will be discussed and compared in Chapter 7.

Chapter 6

Survey Findings

6.1 Introduction

Two postal sampling surveys were carried out to investigate the usage of AIS onboard SOLAS ships. The objective of a sampling survey is to reduce time, manpower and costs. A population survey was not undertaken was due to concerns of economic costs, time efficiency, total number of the seafarer population, difficulties in reaching seafarers, deterioration and validity. A longitudinal within subject survey was replaced by a longitudinal survey with a between subjects design as a survey for the same respondents in two periods was not available in particularly in tracking the same mariners in two surveys.

There were two surveys arranged after a pilot study: the first (hereafter referred to as Survey I) was completed before the official mandatory deadline for onboard SOLAS ships AIS carriage requirement; and the second (referred to as Survey II) took place one year after the deadline for carriage requirement by the SOLAS Convention.[19] The survey findings will present the response rates and sample composition from the two surveys. Survey I provides a snapshot of the respondents' points of view and expectations, mainly regarding the use of AIS on merchant ships. Survey II is aimed at studying opinions on the role of AIS in the current bridge operation.

[19] The deadline for all SOLAS vessels to carry AIS was the 31st December 2004.

6.2 Pilot Study

A pilot study took place in the beginning of 2004 (see Appendix E). As the survey design was initially aimed at studying users' views on AIS-assisted navigation, there was a focus on deep sea deck officers. The deep sea deck officers in Taiwan are officially called 'First Class Deck Officers' (The Examination Yuan 2005). This terminology can also be used to differentiate these from the deck officers who only serve in short sea/coastal shipping. A comparison of certificated deck officer structure in the UK and Taiwan is listed in Appendix F. Before sending the Survey I questionnaire to potential interviewees, items from the pilot study's questionnaire were examined and tested by the following points:

- Types of questions adopted (single, multiple choice and open questions);
- Arrangement of the questions in order;
- Ambiguous or biased meaning in questions' wording;
- Hint leads in questions' wording;
- Overall layout;
- Consistent meaning of words between the English and Traditional (or Mandarin) Chinese.

6.2.1 Feedback from the seafarers

38 deck officers voluntarily filled out the questionnaire with feedback and opinions on the design and wording. The collected opinions from these officers gave suggestions on the use of maritime terminology. After the questionnaires were collected from the officers, this feedback was used to make some corrections, such as question wording and English-Chinese translation. Finally, the idea of a postal survey was supported by the officers who preferred this to other methods such as an online survey.

6.2.2 Correction after the seafarers' feedback

After the modifications based on the suggestions from the deck officers, the questionnaire was then given to experts in social sciences with no connection to the maritime industry. The aim in this was to achieve a different evaluation, mainly concerned with the overall design of the questionnaire. There were several points suggested about the pilot study questionnaire,

- The number of open questions could be reduced;
- The number of topics should be reduced;
- Avoid ambiguous wording of the question;
- Avoid questions that respondents might not be willing to answer.

The recommendations and collected information from both mariners and non-mariners led to an early design of the Survey I questionnaire. Furthermore, the logical order and layout were reviewed at the end of the pilot study. The postal survey was chosen as the method of delivery, with an online questionnaire available. The interviewees targeted were mainly deep sea deck officers from the shipping companies based in Taiwan.

6.3 Survey I

Survey I started in May 2004 and was distributed to deep sea deck officers who were currently working for three liner companies in Taiwan.[20] The survey obtained views on AIS training willingness, the forwarded timeline for carriage requirement and the expectations of AIS on the bridge. The results of the survey showed that the respondents generally welcomed the idea of AIS transmission in providing an extra data resource, which might have the potential to improve situation awareness and ship manoeuvring decisions.

6.3.1 Preface

Survey I, 'AIS: the users' perspective', is a 46-item questionnaire (see Appendix G). This survey was used to reveal the opinions of AIS by officers who might/might not have used it, in light of the latest time schedule of AIS carriage requirement.

6.3.2 Methodology

The initial interests in AIS operation on the bridge were divided into a number of topics:

- General knowledge of AIS operation;
- Opinions on the issue of forwarded AIS carriage requirement;
- Opinions of AIS Training;
- Preliminary AIS involvement among the existing bridge equipment;
- Specific AIS usage in navigational applications;
- COLREGs involving AIS;
- Concerns about non-SOLAS vessels.

[20] Evergreen Marine Corp. and Wan-Hai Line are both full-container shipping companies. Yang-Ming Line has its own bulk carrier and tanker fleet apart from its full-container fleet. The three interviewed companies are all major players in international shipping (see Section 5.2.2).

The survey questionnaire was designed and processed based on the flow chart shown in Figure 6-1.

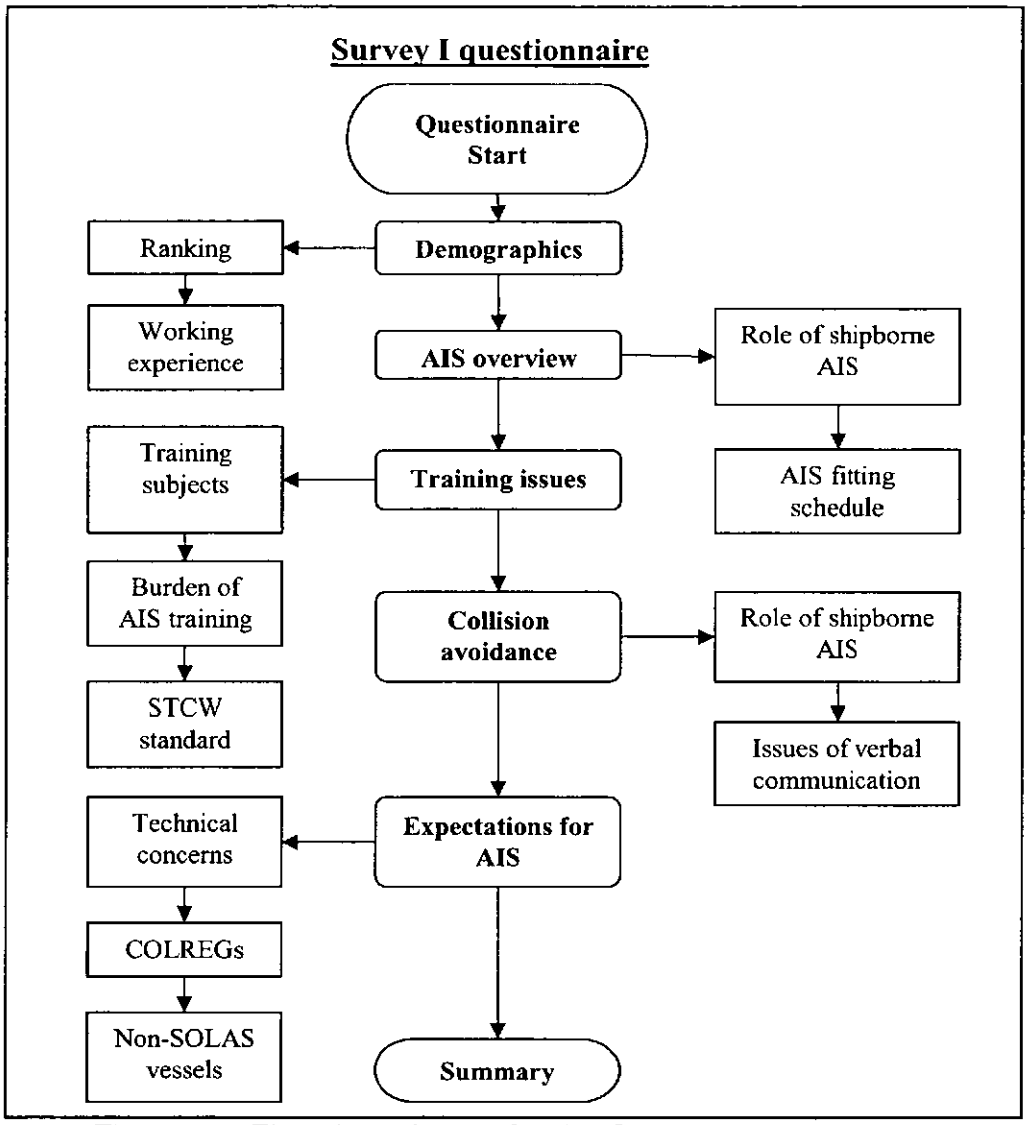

Figure 6-1 Flowchart design for the Survey I questionnaire

The findings of the survey results could be divided in six sub sections:

1. Opinions on the accelerated AIS carriage requirement time schedule;
2. Basic knowledge of AIS and the status of current bridge equipment;
3. Issues concerning AIS use in ship manoeuvring;
4. The use of VHF radio communication in collision avoidance;
5. The need for training;
6. Expectations for a full AIS network service.

6.3.3 Results

There were three liner shipping companies, Evergreen Marine Corp., Wan Hai Line and Yang Ming Line that were sent questionnaires in Taiwan. The results of Survey I are all shown in Appendix H.

6.3.3.1 Demographics

103 First Class OOWs participated in Survey I (Figure 6-2). There were more junior officers than senior ones who took part in the survey, and therefore over half of the respondents (57.3%) had spent less than 5 years at sea (Figure 6-3).

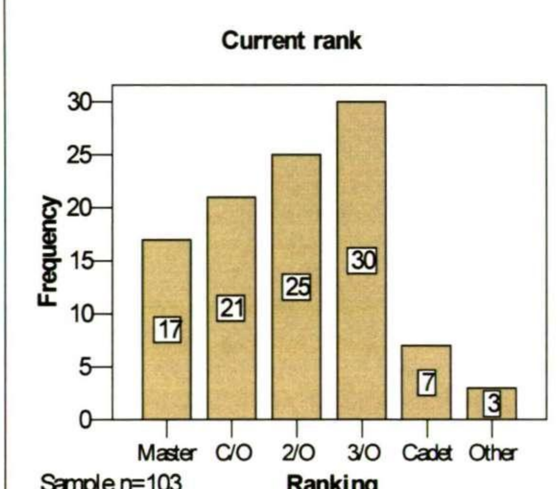

Figure 6-2 Respondents' rank

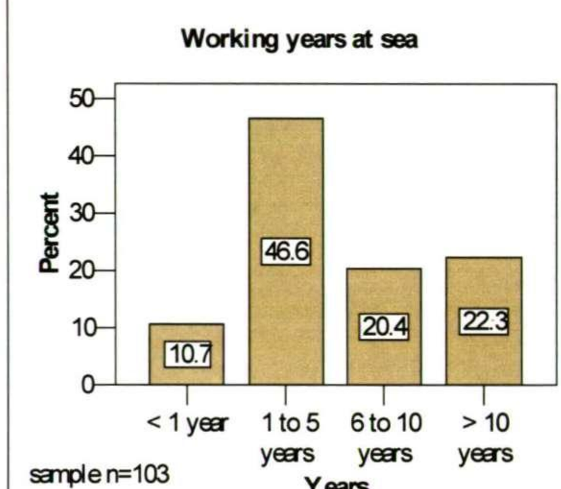

Figure 6-3 Serving years at sea

6.3.3.2 The modified AIS fitting time schedule

The original timeline for fitting AIS on the bridge was changed and moved forward by an emergency IMO meeting in which the US persuaded the world maritime community to shorten the timeframe for AIS installation to achieve completion by the end of 2004. Two-thirds of respondents (66.0%) believed that the reason for changing the schedule was more to do with security measures than the need to improve marine navigation (21.4% did not believe this). A similar percentage (53.8%) also believed that fitting AIS onboard was intended to fulfil the statutory requirements of the ISPS Code. The survey suggests that seafarers' viewpoints related to the motivation of the new schedule plan was mainly for security rather than for the improvement of navigation.

Despite the fact that a large number of the respondents (49.5%) did not give clear opinions (neutral) on the newly modified schedule of shipborne AIS, there were still over three tenths of respondents (32.0%) who felt that the fitting schedule was late (18.4% felt that it was early). Another resounding result was that the majority of the respondents (45.6%) did not approve of the original fitting schedule (21.4% supported the original schedule). Additionally, more than half of the respondents (58.3% against 17.5%) thought that the modified timetable would not cause any problems for seafarers.

6.3.3.3 General aspects of AIS

Three quarters of the respondents (78.6%) had already operated shipborne AIS when the survey took place, and nearly all of the respondents (98.1 %) had already heard about AIS.[21] Moreover, nine tenths of respondents (91.3%) saw AIS as a key navigational aid. Apart from the application in navigation, more than eight tenths of respondents (86.4%) also knew that AIS has other usages.

In Figure 6-4, there are four gauging points for respondents to choose the four staging levels on the integrated use of AIS. The implications for security measures

[21] The remainder (1.9%; 2 mariners) who had not heard about AIS were seafarers working onshore for longer than three-months before the survey took place.

show the lowest degree of bridge integration with AIS. The second lowest degree is the use of AIS in communication, as AIS could neither send a message via its own device nor assist in VHF communication without further bridge integration. Next, the use of AIS in positioning could mean an integration between AIS data and ECDIS. The highest fusion degree lies in the use of positioning and collision avoidance. The most favoured operation was full integration with the recent bridge system for positioning & collision avoidance usages (37.9%), followed by a less integrated degree of communication with an AIS/VHF application (33%). The rest of the respondents fell into a half/medium integration of position fixing with AIS/ECDIS integration (19.4%) and a standalone security measure (9.7%), the least degree of AIS integration into bridge systems. As a result, most of the respondents went for two particular applications, one fully integrated and one less integrated use of shipborne AIS on the bridge.

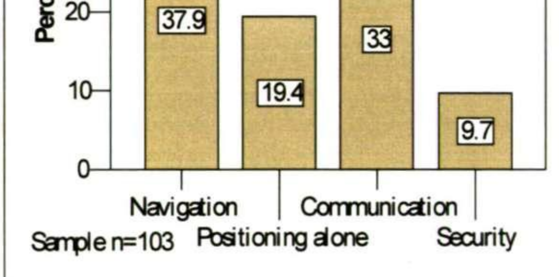

Figure 6-4 Degree of AIS applications

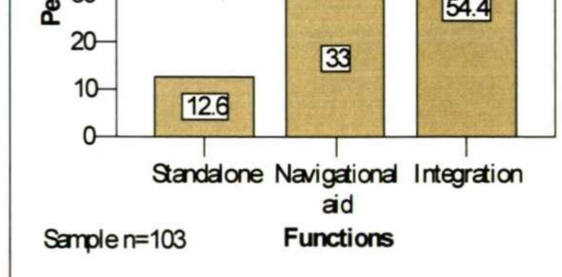

Figure 6-5 Expected AIS functions

In terms of the impact AIS has brought on the bridge systems, more than half of the respondents (57.3%) believed that shipborne AIS is going to bring better integration among the bridge systems. However, over four tenths of respondents (41.7%) thought that AIS is going to add extra information as an independent operation. In the expectations for AIS usage (Figure 6-5), more than half of the respondents (54.4%) would like to see AIS acting as a medium gathering and processing information among the bridge systems. Besides this, over three tenths of respondents (33%) would like to see AIS working partially alongside shipborne navigation aids, whereas one tenth of respondents (12.6%) would like to see AIS working alone.

In order to define the importance of the different AIS roles among the bridge systems, a ranking question was asked. The results are shown in Table 6-1, with the respondents' scores for the onboard equipment for collision avoidance use presented in ascending order:

1. Visual lookout (Mode=6);
2. RADAR (Mode=5);
3. ARPA (Mode=5);
4. AIS (Mode=2);
5. VHF (Mode=2);
6. Other (Mode=1).[22]

Methods \ OOWs	Master	CO	2O	3O	Cadet	Other	Total	Rank
AIS	3	2	2	2	3	1	2	4th
ARPA	5	5	4	5	4	3	5	2nd
RADAR	5	4	4	5	5	5	5	2nd
VHF	2	3	2	3	2	2	2	4th
VISUAL LOOKOUT	6	6	6	6	6	6	6	1st
OTHER	1	1	1	1	1	1	1	6th
Size(n=)	17	21	25	30	7	3	103	
Key	Scores ranged from 1 to 6; The higher the score, the more important in the respondent's opinion.							

Table 6-1 OOWs' views on the importance of navigational aids

[22] Vote for Others: GPS (11 votes); ECDIS (6 votes); Gyro (1 vote); VTS (3 votes); Radio direction finder (1 vote).

6.3.3.4 Considering AIS in Collision Avoidance

Over five tenths of respondents (53.4%) thought that AIS is currently suitable as an aid to collision avoidance. Moreover, the respondents also gave open opinions (see Question 27, 28 and 30, pp H8 ~ H9, Appendix H) approving the prompt identification, dynamic data, RADAR detection assistance and efficient verbal communication. However, there were also opinions reflecting that respondents considered that 'floating objects' and 'non-SOLAS ships' may not be able to transmit their identities via AIS, so that most respondents (87.4%) expressed not to rely on AIS information alone as the sole information resource.

With their knowledge of AIS performance, more than three quarters of respondents (84.5%) will use AIS as a part of navigation operations (10.7% no; 4.9% do not know). A similar proportion (84.5%) do not think that taking AIS into bridge operation will sacrifice the time spent looking out of the bridge window (12.6% felt that reading AIS will sacrifice the time length of lookout).[23] Considering AIS's status as an individual information source, users might have to spend time reading AIS information during visual lookout. In the survey, three tenths of respondents (30.8%) felt that operating AIS might increase workload on the bridge (67% did not think so). Weighing the use of AIS in collision avoidance with the other aids to navigation, the results reflected that AIS would be treated as assistance to decision making in collision avoidance.

[23] When the survey took place, the most modern container ships from the three companies have only got AIS MKD on the bridge, not to mention there are criticisms about the difficulties to read AIS in terms of where it located.

6.3.3.5 Verbal communication assisted by AIS

AIS ship reporting has led to a reduction in time spent on VHF ship-to-ship and ship-to-shore communication. In VHF communication (Figure 6-6), nearly nine tenths of the respondents (87.4%) use a VHF radio telephone to assist in anti-collision manoeuvres (11.7% do not; 1% do not know). When using AIS with VHF communication, the time for confirming a target's name and position will be shortened by the AIS data. In fact, nearly half of the respondents (48.5%) agreed that it will reduce the length of verbal communication. However, nearly half of the respondents did not agree. As more than three quarters of the respondents (81.6%) agreed that AIS should not replace the use of verbal communication during collision avoidance (12.6% do not know; 5.8% yes), AIS could be used to assist VHF communication in terms of target identification. Using a text message via AIS is not appropriate for communication between ships because there is no mandatory requirement to listen to AIS during lookout. In addition, the collision case of *Hyundai Dominion and Sky Hope* (see Section 4.2.1) is an example of irresponsible use of a text message via the AIS network for a manoeuvring suggestion.

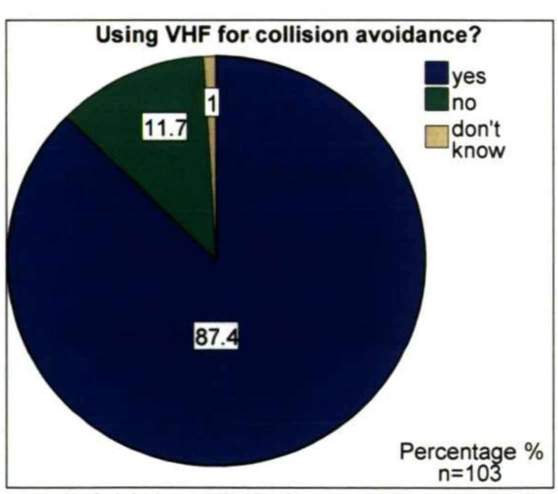

Figure 6-6 Using VHF for collision avoidance

The automatic and autonomous data exchange of AIS could give an advantage to users when operating in congested and busy traffic. Certain ship reporting to shore VTS could be done without interference manually. In fact, nearly three quarters of respondents (73.8%) approved ship-to-ship and ship-to-shore operation under the AIS network (14.6% no; 11.7% do not know). The advantages and disadvantages of using AIS in communication and ship reporting are obvious, but AIS might be applied to encourage verbal communication if an AIS identity is obtainable.

6.3.3.6 Training in the operation of AIS

Survey I looked for opinions about the possibility of training in AIS/navigation as there had not been any training requirement for AIS operation in 2004. The respondents felt both masters (95.1%) and bridge officers (99%) should be trained to operate AIS before using it for navigation. Furthermore, respondents viewed shipping companies, governments and AIS manufacturers as the responsible authorities for the costs of AIS training (Figure 6-7).

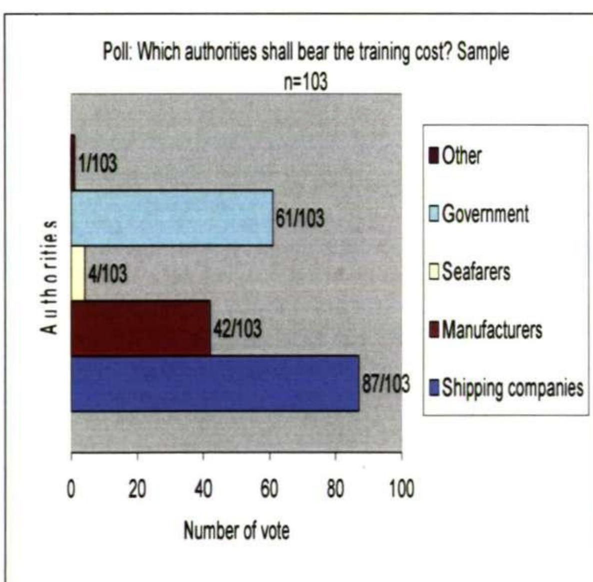

Figure 6-7 Poll for the training cost

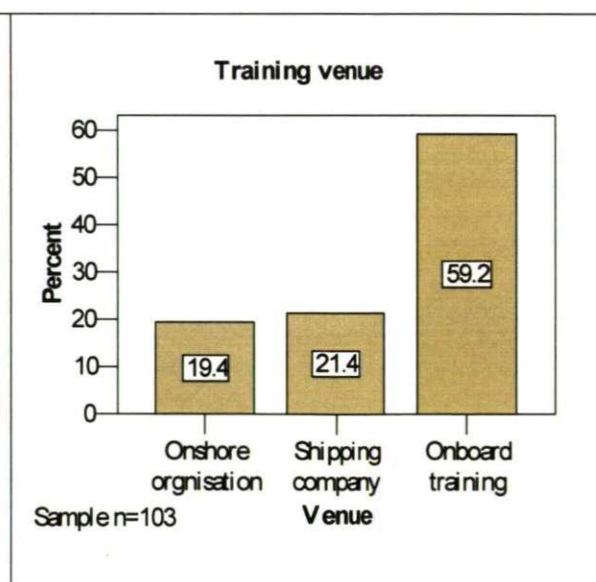

Figure 6-8 Training venues

In terms of training venues, more than half of the respondents (59.2%) would prefer AIS training on board, while 21.4% saw this as a company provision and 19.4% favoured an onshore organisation (Figure 6-8). The results showed that most of the 21.4% of respondents who supported inshore training are seafarers from the company Evergreen, which has a 'sea/land working shift' between onboard and onshore options. For this company, the training course could be taken when they are working ashore. For the majority, 61 respondents who preferred onboard training indicated further in terms of who should be in charge of the onboard training. 38 respondents voted master and 35 respondents voted experienced officers (Figure 6-9) to be in charge of the AIS onboard training.

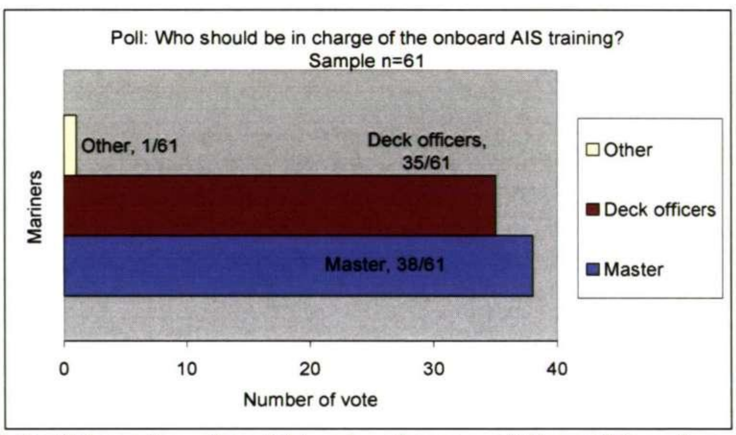

Figure 6-9 Poll for who should be in charge of the AIS onboard training

Most respondents (99%) agreed that qualified OOWs should be able to handle the anti-collision operation with AIS (Figure 6-10). Moreover, over nine tenths of respondents (94.2%) agree that it is necessary to train all OOWs to use AIS (3.9% no; 1.9% do not know), and nearly seven tenths of respondents (68%) thought that AIS should be brought into the STCW standard (22.3% no; 9.7% do not know).

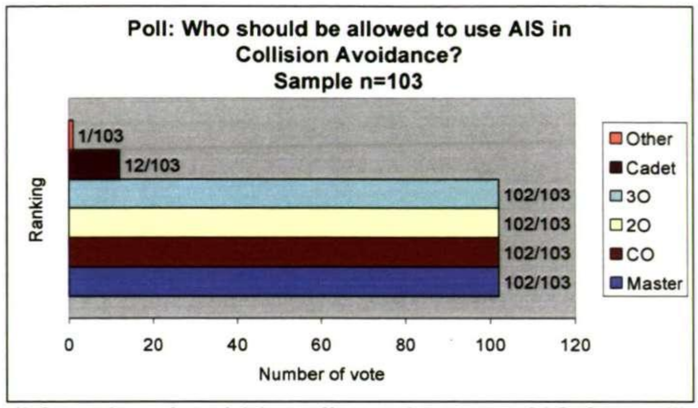

Figure 6-10 Poll for who should be allowed to use AIS for collision avoidance

6.3.3.7 Expectations for onboard AIS operation

The time when this survey took place was at the beginning of the AIS implementation schedule, and thus there were a few hypothetical questions asked. Nine tenths of respondents (90.1%) expected that AIS would enhance navigation in the long term (4.4% no; 5.5% do not know; sample size n=91), and nine tenths of respondents (90.3%) agreed that every OOW should be capable of using AIS for ship manoeuvres after AIS is fully implemented (5.8% no; 3.9% do not know). In fact, the respondents cared more about traffic management and communication than AIS security and environmental measures (Figure 6-11).

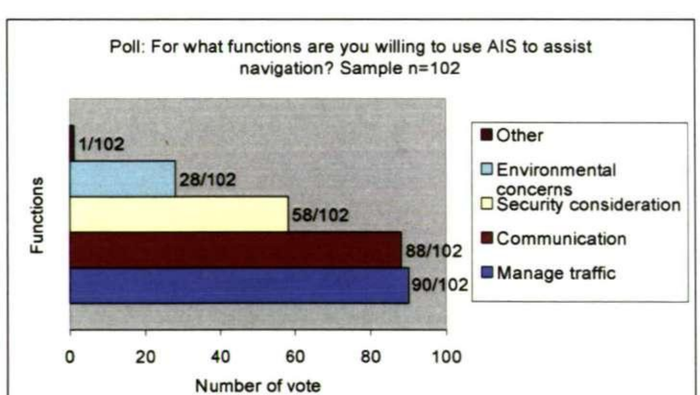

Figure 6-11 Functions to use AIS for aiding navigation

Most respondents (98%) agreed that AIS could also be used for reasons other than navigational use. The respondents indicated other functions for AIS operation, in descending order: Identification, Communication and Security (Figure 6-12).

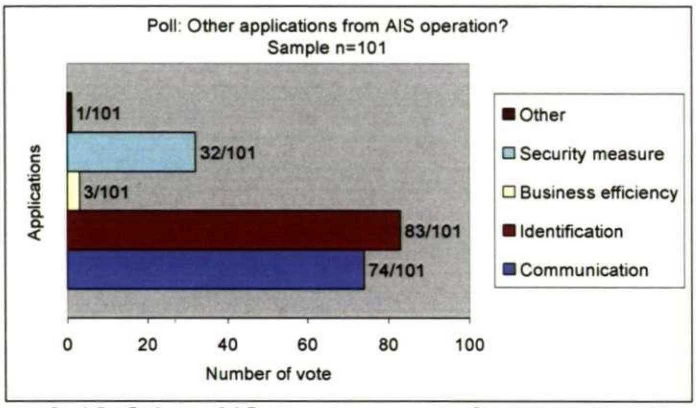

Figure 6-12 Other AIS usages apart from navigation use

The radio communication technology, SOTDMA, can allow AIS VHF transmission up to 400% of its own capacity overload (Basker, Parkinson et al. 2003). Even so, four tenths of respondents (40.8%) worried that the capacity for maintaining AIS transmission might run out (44.7% no; 14.6% do not know) if non-SOLAS vessels are going to carry AIS. As a result, half of the respondents (51.5%) thought that merchant ships should therefore have a priority over non-SOLAS vessels in occupying AIS network channels (41.7% no; 6.8% do not know).

Despite the concern for limited transmission capacity, over seven tenths of respondents (72.8%) did not think that non-SOLAS vessels should be exempt from the compulsory carriage requirement (19.4% against; 7.8% do not know). Seven tenths of respondents (71.8%) agreed that non-SOLAS vessels should be compelled to install AIS (20.4 % against; 7.8% don't know). Merchant mariners agreed that non-SOLAS vessels should fit AIS or AIS like devices for improving detection of their presence at sea. Concerns were raised that smaller targets appear to be poorly detected when using RADAR. In addition, respondents stated that merchant ships (bigger ships) should be able to take priority if AIS/VHF runs out of its transmission capacity. The results suggest a variable coverage of AIS transmission and a compromised AIS function for non-SOLAS vessels.

Finally, nearly half of the respondents (48.5%) agreed that AIS might have an impact in modifying current COLREGs provisions (39.8% against; 11.7% don't know) if there is going to be a consistent navigational use of AIS on a long term scale.

6.3.4 Discussion of Survey I

Survey I investigated opinions of the changed AIS fitting plan. There was little evidence that respondents approved or disapproved of the changed AIS carriage requirement. The accelerated timescale was seen by the respondents as the result of increased security awareness, rather than an urgent measure to improve navigation. In fact, Survey I classified four possible shipborne AIS applications (see Section 6.3.3.3), listed in a descending order:

1. navigation (within IBS operation);
2. communication (with VHF operation);
3. position fixing (within ECDIS operation); and
4. security measure (within offshore surveillance).

The results showed that most respondents chose two respective applications, navigation and communication. As all the respondents to Survey I had only AIS MKD onboard, requests for better integration of AIS into bridge systems were encouraged. Hence, the impact of bringing AIS into IBS or ECDIS operations should be studied.

The AIS was regarded as an important (key) device that could enhance navigation. In the long term, there are a number of issues that needed to be addressed for better AIS performance, such as AIS implementation, capacity for radio transmissions, training standard and compliance with COLREGs. One particular issue is the existence of non-SOLAS vessels with no mandatory requirement for AIS or AIS like devices on board. This is a concern when this group of vessels are most likely to be missed because of poor RADAR reflection. Furthermore, the personnel who are in charge of non-SOLAS vessels are more likely to be under trained according to the requirements of training standards.

Survey I raised a few concerns in determining the role of shipborne AIS. In particular, the survey found that most respondents do use VHF for collision avoidance. As AIS can save time in confirming a target's identity, a VHF communication is expected shortened. The connection and relationship between VHF and AIS needed clarification. The raised points in Survey I needed further study will be carried out next in Survey II.

6.4 Survey II

Survey II took place from October 2005 (ended in June 2006), one year after AIS had been a mandatory device on SOLAS ships. Therefore, the effective samples will be limited to OOWs who had already operated shipborne AIS. The objectives were to investigate end users' opinions/satisfaction with shipborne AIS operation.

6.4.1 Preface

Survey II is a 42-item questionnaire (See Appendix I). The survey is interested in opinions of end users who have operated AIS on the bridge. Hence, deep sea deck officers were the prioritised subjects.

6.4.2 Methodology

In order to bring more precise opinions than the basic, descriptive, statistical findings of Survey I, the questionnaire for Survey II adopted the Likert scale to present a degree of commitment to the questioned topics. The variables of respondents' rankings and working types of ships were considered in the justification of the survey findings. Survey II looked at the impact of AIS operation by measuring respondents' attitudes. The Likert Scale was widely applied in questions and descriptive statistics will be adopted to present the results. Apart from the descriptive statistics, every item will be tested by non-parametric tests. If any significant difference appears, it suggests a different point of view on the items in the independent/interested variables.

The survey questionnaire was designed and processed based on the flow chart shown in Figure 6-13.

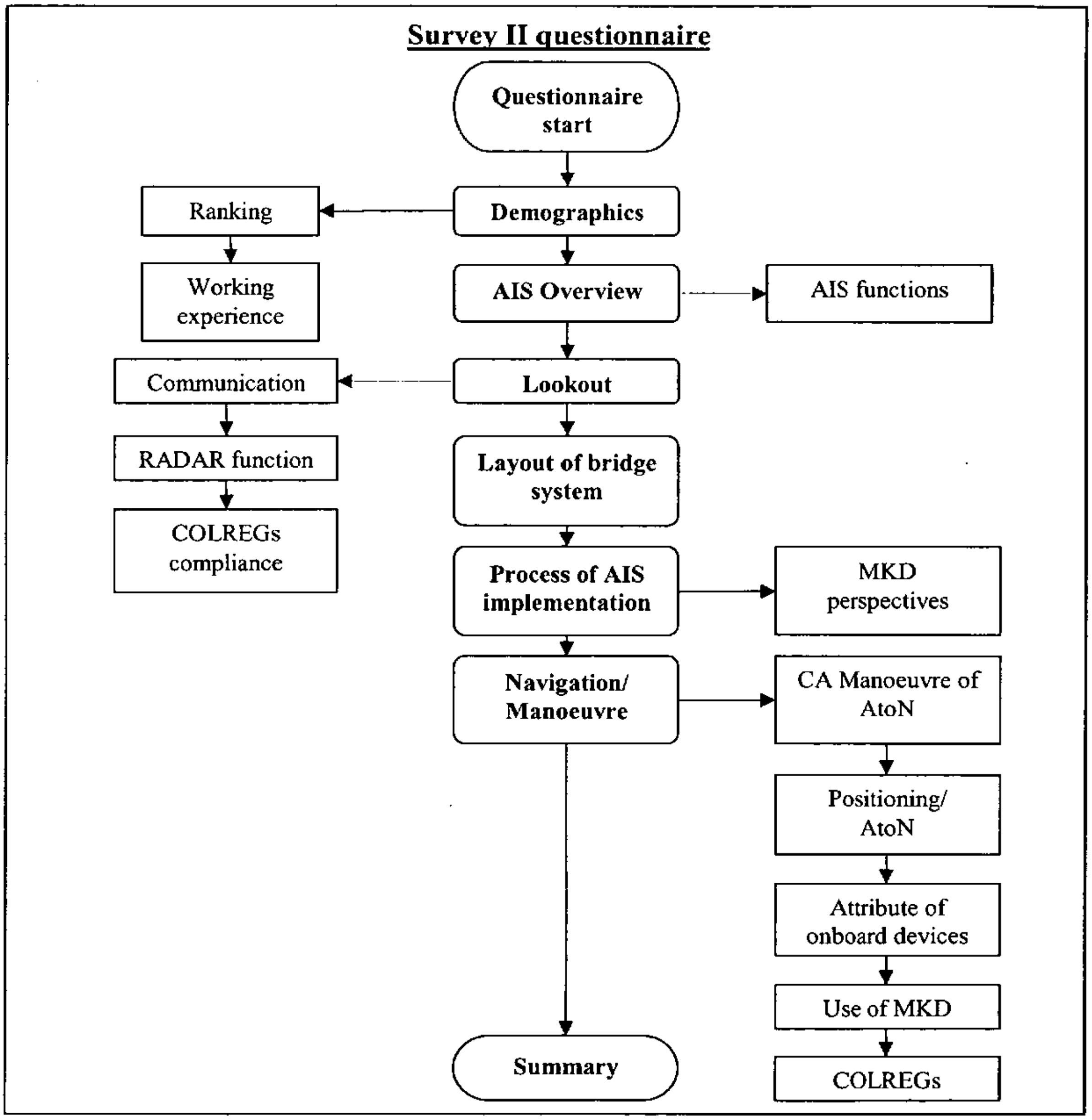

Figure 6-13 Flowchart design for the Survey II questionnaire

The findings will be outlined as follows:

- Demographic data;
- Overview of AIS;
- Lookout and manoeuvre;
- Bridge equipment layout;
- Training, implementation and installation; and
- Collision avoidance.

6.4.3 Results

Survey II was sent to qualified First Class deck officers mainly in Taiwan from October 2005. The survey finished in June 2006, with 190 questionnaires returned in total. The results of the study for Survey II are all shown in Appendix J.

6.4.3.1 Demographics

Survey II questionnaires were mainly sent to deep sea deck officers who work for Taiwanese shipping companies.[24] Compared with Survey I, Survey II invited one more group of ranking officers, i.e. harbour pilots, into the survey. The distribution of serving years is displayed in Figure 6-14, showing that more than three tenths of respondents had over fifteen years sea experience. The companies that the respondents were working for are shown in Figure 6-15. Four Taiwanese shipping companies and the pilot association from Hong Kong were invited to take part in the questionnaire survey.

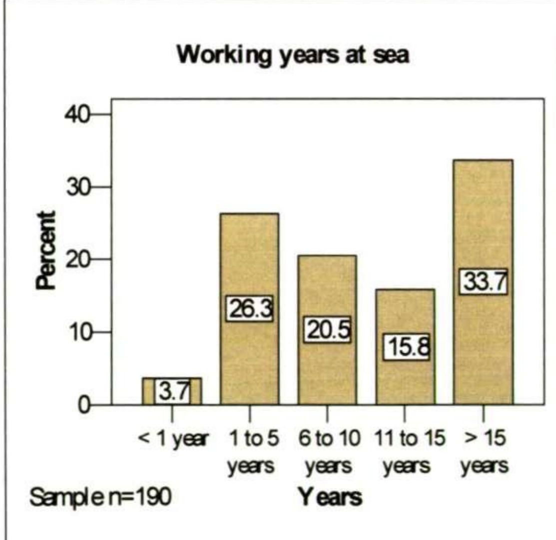

Figure 6-14 Years of service at sea

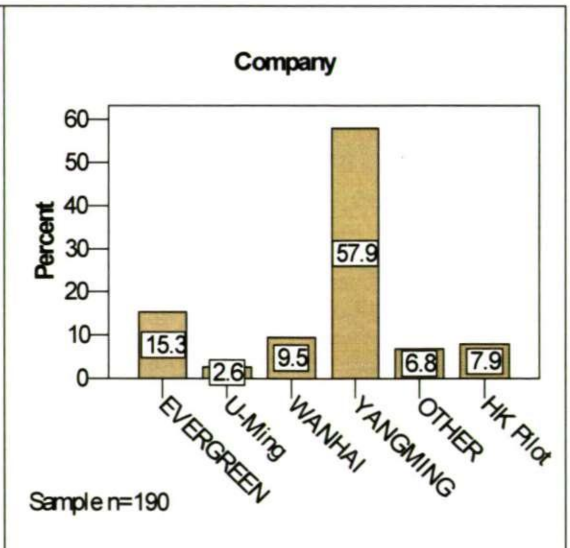

Figure 6-15 Served company

[24] There were a few respondents who answered 'other' work, such as deck officers on board the research vessel Ocean Researcher II, at the National Centre for Ocean Research (NCOR), Taiwan.

The population used for Survey II was different to that in Survey I as the limitation mentioned in Section 6.1 for not carrying out a longitudinal within subject survey. The survey II made an adjustment to this population as to track OOWs who were serving in the Taiwanese shipping companies, OOWs who hold First Class Deck Officers Certificates (see Appendix F), and OOWs who were under STCW 95 standard. In order to maintain a reliable observation between the two surveys, the deadline of SOLAS AIS carriage requirement was the only controlled variable. To be able to carry out a longitudinal survey with a between subjects design, no dramatic event took place in between the two defined survey periods. For example, there were not any acknowledged major changes in between the two periods, i.e. Watchkeeper's training curriculum, OOWs' certificate examinations, modifications to STCW 95, and amendments the COLREGs.

As indicated in Figure 6-16, most respondents had been working on container ships.[25] The second and third ship types were bulk carriers and tankers.

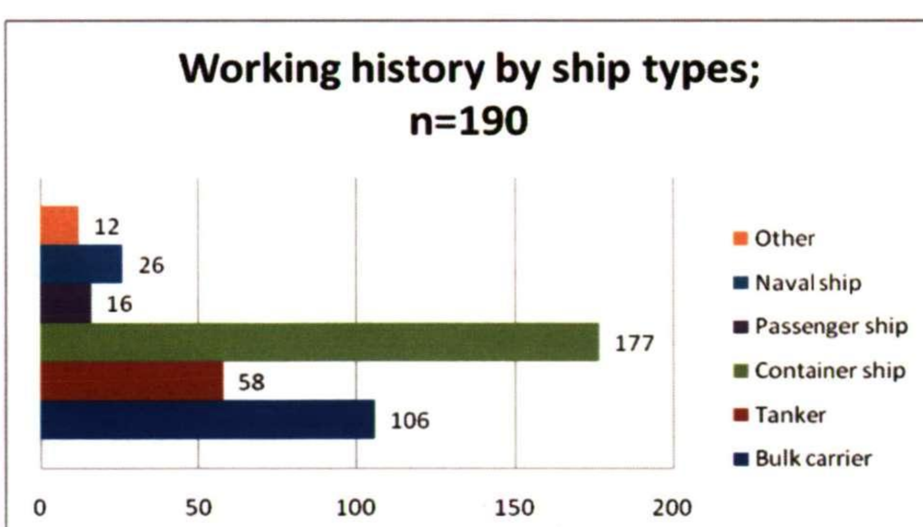

Figure 6-16 Served type of ship

[25] The respondents who selected 'other' types were mainly pilots or respondents who have worked on LNG/LPG and General Cargo ships.

During the survey, more than six tenths of respondents (61.6%) were working on container ships (Figure 6-17) and one tenth of respondents (10.0%) were working on bulk carriers (16.8% worked ashore; 1.1% tanker; 10.5% others). The current voyages of these respondents are shown below in Figure 6-18. Apart from Inter Asia and the Persian Gulf, two other major voyages were Asia to North America and Asia to Europe.

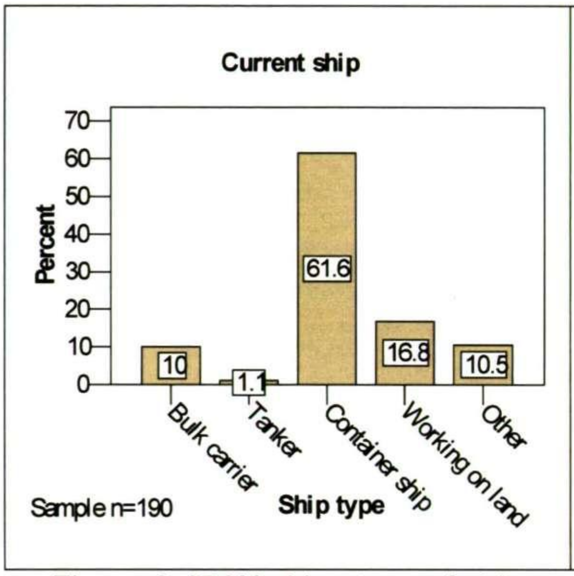

Figure 6-17 Working type of ship

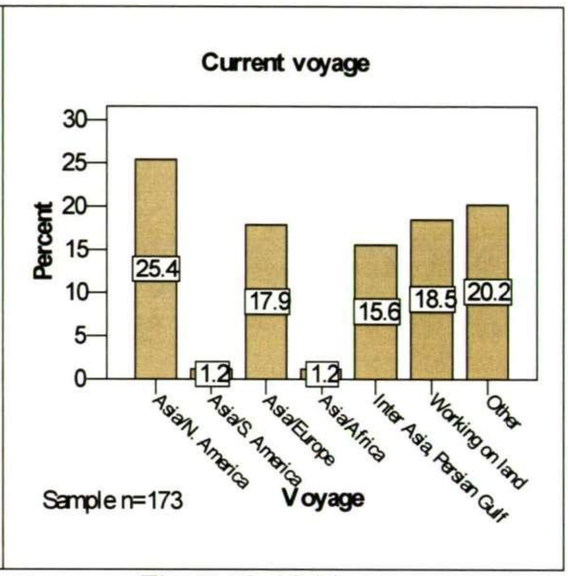

Figure 6-18 Voyage

6.4.3.2 General view

In Survey II, more than nine tenths of OOWs (92.6%) had already operated AIS on board. Of the fourteen respondents (7.4%) who had not operated AIS before, twelve had heard about and knew the shipborne AIS. The research grouped the OOWs who had operated AIS into pilots, masters, chief officers and mates (Figure 6-19). The types of ships which these OOWs were working on were grouped into container ship, non-container ship and sea/land shift (Figure 6-20). The survey findings will generally be based on the 174 respondents who were qualified deep sea deck officers with experience of operating AIS.

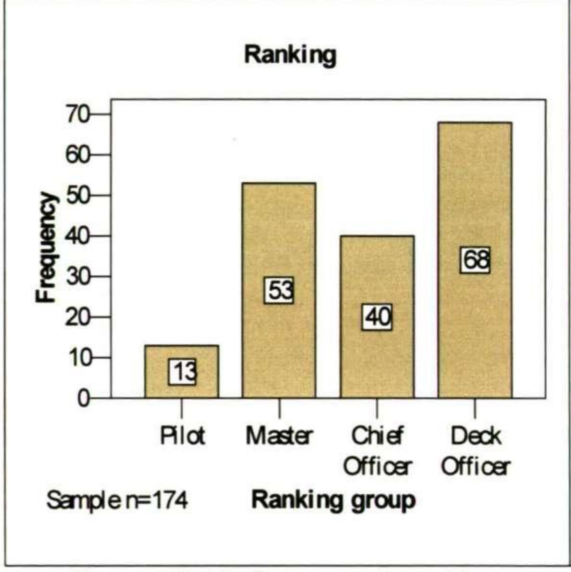

Figure 6-19 Groups of ranking officers

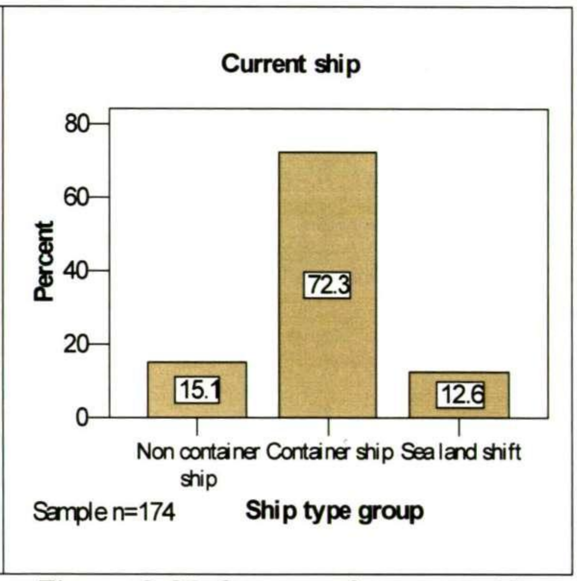

Figure 6-20 Groups of current ship

In Survey II, more than half of the respondents (57.8%) had used AIS data, particularly in collision avoidance (40.6% had not). The respondents were then asked to give their opinion of the four applications of AIS. Figure 6-21 shows that communication was voted the most useful application onboard (72.99%), followed by a security measure (54.02%) and collision avoidance (52.87%), while only a quarter of the respondents (26.43%) felt that it was useful in position fixing.

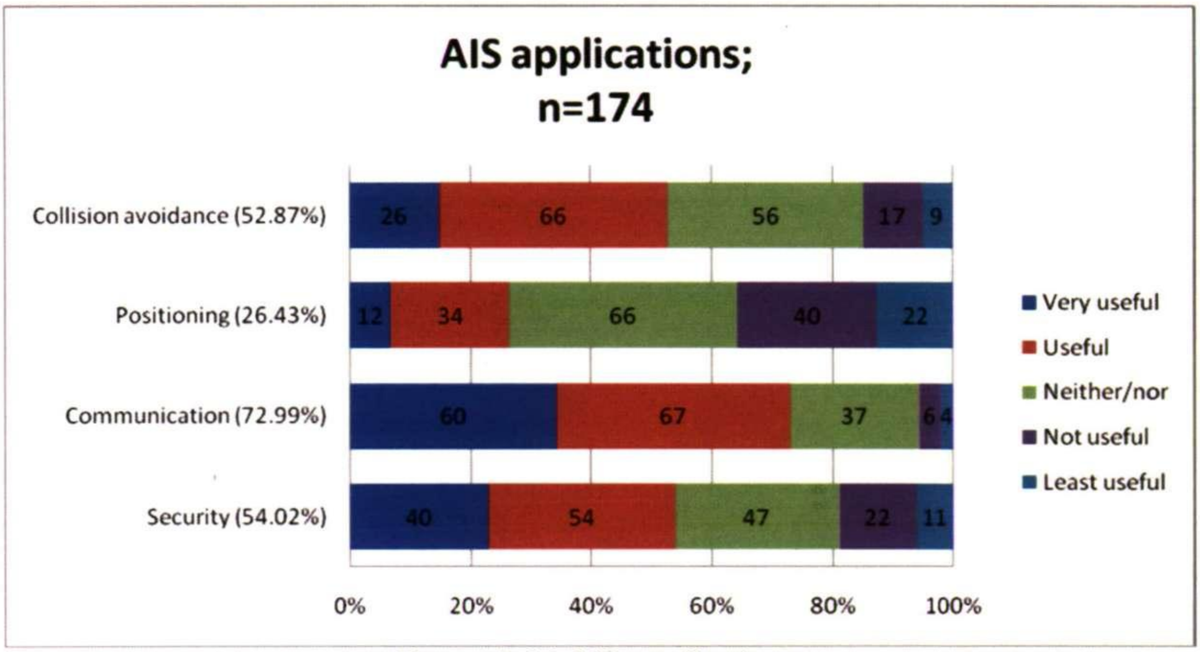

Figure 6-21 AIS applications

In Table 6-2, significances were found in the items 'AIS for positioning' and 'AIS for communication'. In the issue of usefulness of AIS for onboard positioning (Table 6-3), the group of pilots strongly supported the idea that AIS could be useful in position fixing in comparison with the rest of the ranking groups (see Q11_2, page K2, Appendix K). The distinctive difference between the group of pilots and the groups of deep sea deck officers is that in the former group respondents are specifically working in a designated area from time to time. The consistent traffic pattern according to the geographical element of pathway could be found useful by the assistance of AIS information. In the AIS application for communication use, a significance was found between the groups of masters and deck officers. The group of deck officers was more optimistic about this usage than the group of masters (see Q11_3, page K3, Appendix K). In fact, a certain number of masters gave a neutral opinion (neither/nor) on this item.

Item (P<0.05)	Occupation groups	Ship Types
Q11_1 AIS for CA?	0.98710	0.442350
Q11_2 AIS for positioning	**0.00004**	0.280092
Q11_3 AIS for communication	**0.03890**	0.197097
Q11_4 AIS for security	0.13514	0.079305
Key	Bold results are tested significantly	

Table 6-2 The significance level by KW test for AIS general overview

Occupation groups (P<0.0083)	P/M	P/X	P/D	M/X	M/D	X/D
Q11_2 AIS for positioning	**0.0001**	**0.0002**	**0.0007**	0.5393	0.1274	0.0515
Q11_3 AIS for communication	0.0606	0.7520	0.6290	0.0370	**0.0072**	0.8907
Key	Bonferroni correction for P value (P<0.0083) represents 0.05 in MW tests P: Pilots; M:Masters; X:Chief officers; D:Deck officers Bold results are tested significantly					

Table 6-3 The significance level by MW test for AIS general overview

6.4.3.3 Lookout and manoeuvring

The majority of respondents (94.7%) approved the use of VHF for ship manoeuvring; nevertheless, six tenths of respondents (60.0%) agreed that difficulties do exist when establishing VHF communication with other vessels (38.9% do not agree). A hundred and ten respondents who answered the ancillary questions (Figure 6-22) explained that the difficulties were mostly caused by busy traffic (n=80) and target tracking (n=62).

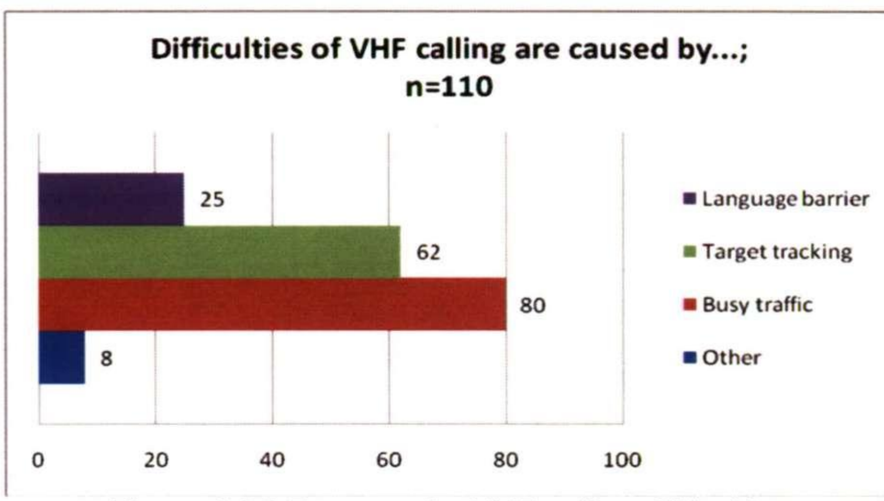

Figure 6-22 Reasons for VHF calling difficulties

Despite admitting the difficulty of using VHF calling, most respondents (94.7%) continue to use VHF in collision avoidance (4.7% no; 0.5% do not know). Moreover, more than eight tenths of respondents (82.0%) would use VHF to assist in manoeuvring if a CQS develops (17.5% no; 0.5% do not know). Finally, the majority of respondents also indicated that they preferred to set their VHF channel 16 to medium volume (Figure 6-23). The neutral option of VHF volume showed the current working environment on the bridge and it has little link to the reasons behind the difficulty in VHF calling to another vessel at sea.

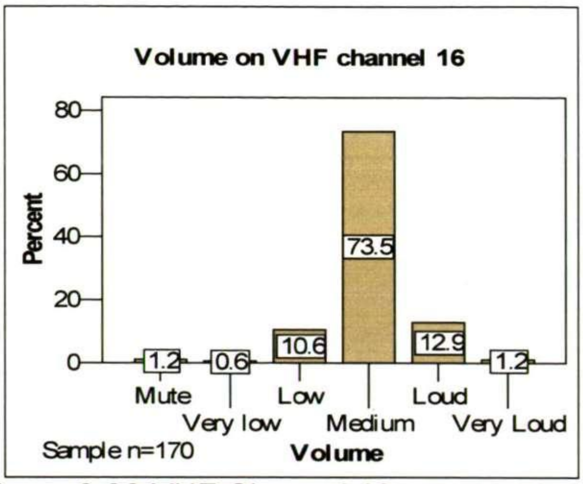

Figure 6-23 VHF Channel 16 set-up volume

A significant value (KW test; P=0.0003) was found for the use of VHF when a CQS develops. In Table 6-4 and Figure 6-24, the pilot group held a different opinion compared to the groups of master, chief officer and deck officer. There were more pilots in this group unlikely to use VHF in a CQS. Considering the possibility that more CQS would be met in pilot waters than in an open area, a prolonged VHF conversation (or even an establishment of the VHF calling to another vessel) might reduce the crucial time to escape the collision risk (see Section 3.4).

Occupation groups (P<0.0083)	P/M	P/X	P/D	M/X	M/D	X/D
Q15 VHF/CQS	**0.0003**	**0.0001**	**0.0011**	0.6139	0.5166	0.2735
Key	Bonferroni correction for P value (P<0.0083) represents 0.05 in MW tests P: Pilots; M:Masters; X:Chief officers; D:Deck officers Bold results are tested significantly					

Table 6-4 The significance level by MW test for VHF/CQS

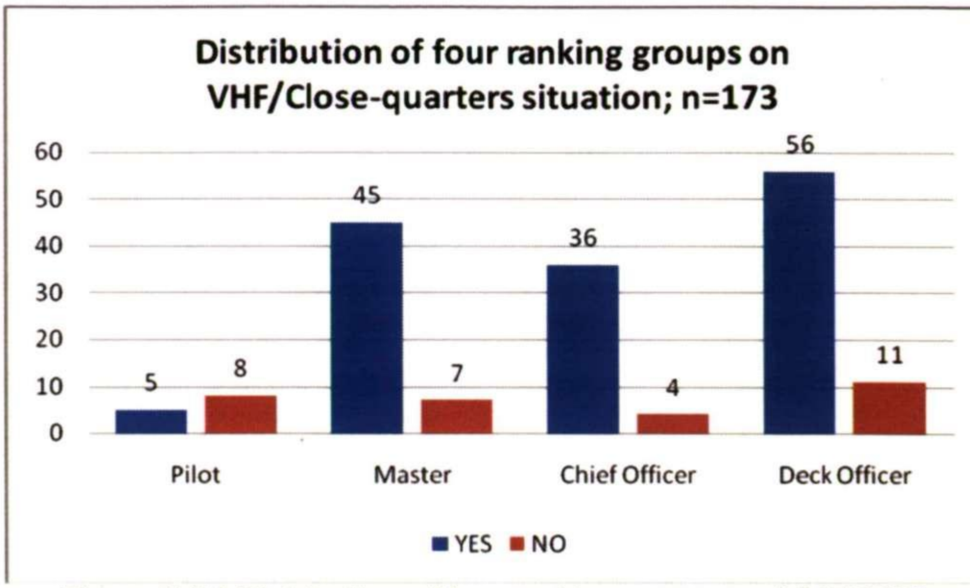

Figure 6-24 Distribution of four ranking groups on VHF/CQS

Survey II investigated the relationship between VHF calling and AIS. Firstly, there were more than eight tenths of respondents (86.8%) who did not agree that AIS text messages should replace verbal communication in collision avoidance (6.9% yes; 6.3% do not know). Secondly, while most respondents use VHF in collision avoidance, over seven tenths of respondents (see Figure 6-21) thought AIS would be useful in communication. The frequent use of VHF calling in collision avoidance could be encouraged by AIS.

ARPA/RADAR can assist OOWs' decision making in navigation and collision avoidance. However, ARPA/RADAR has both advantages and disadvantages. The survey investigated what respondents think about ARPA/RADAR in certain situations. Firstly, more than three quarters of the respondents (78.8%) did worry about detection in a bend or if an obstructed landscape is ahead (20.6% are satisfied; 0.5% do not know). Moreover, nearly nine tenths of respondents (89.5%) feared that smaller boats may not be detected by RADAR (9.5% did not think so; 1.1% do not know). Similar to the clutter effect caused by rain or sea waves, these two issues contribute to the limitation of RADAR detection and coverage. When asked how these respondents operate their ARPA/RADAR, it was seen that the operating mode is raised in terms of ground and water based observation. Thus, more than half of the respondents (52.9%) use a ground stabilised function for their setup when manoeuvring (Figure 6-25), while over four tenths of respondents (44.1%) use sea stabilised setup.[26]

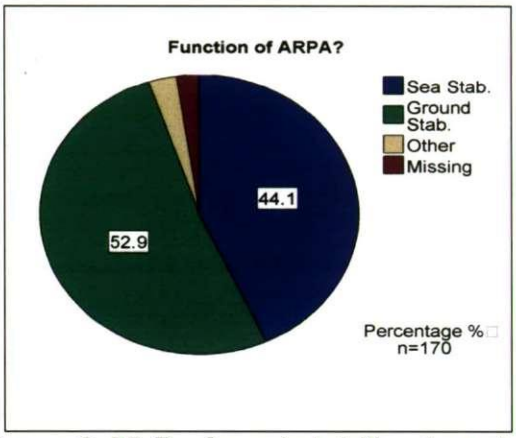

Figure 6-25 Preferred stabilised modes

Next, the concern for COLREGs is discussed. Firstly, six tenths of respondents (62.9%) agreed that ships nearby will respond if they use shapes, lights and sound signals (29.0% against; 9.6% do not know). Secondly, the respondents were asked to give scores for certain types of vessel applying COLREGs at sea: more than eight tenths of respondents (82.18%; 0.57% against) were satisfied with VLCC (Figure 6-26), followed by cargo ships (68.39%; 2.30% against); in third place, more than three tenths of respondents (36.78%; 19.54% against) were satisfied with HSC, followed by naval ships (33.33%; 21.26% against) and ferries (31.03%; 29.31% against). Less than one tenth of respondents were satisfied with leisure boats (7.47%; 57.47% against) and fishing boats (1.72%; 83.33% against).

[26] The respondents who answered 'Others' switched between two modes.

This raised concerns that smaller or non-SOLAS targets might be in danger in terms of traffic awareness. The results above only reflect the opinions from the merchant navy as a representative finding to the SOLAS ship's end users, it is understandable that different point of view could be found in other mariners, such as naval officers, fishing skippers and leisure sailors.

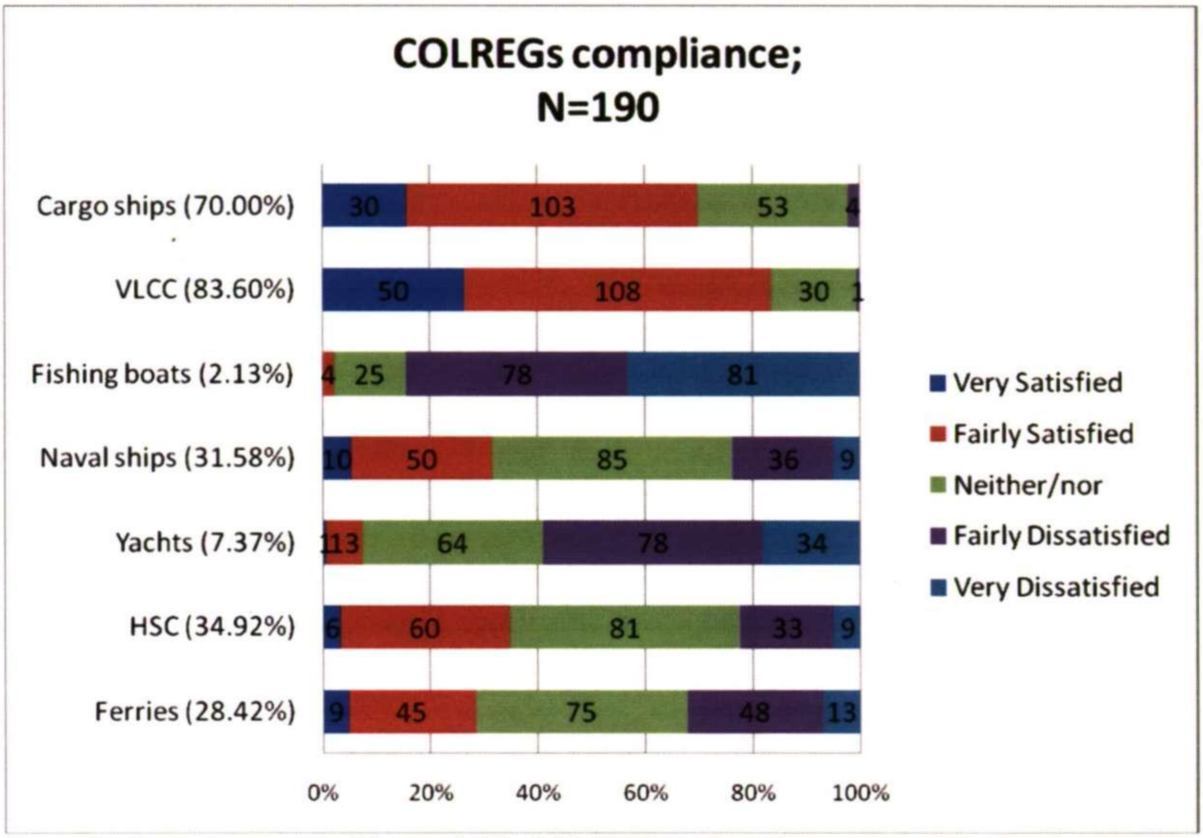

Figure 6-26 COLREGs compliance

Among the ranking groups, significant views concerning COLREGs compliance were found, especially in the opinions on cargo ships (Q20_1), VLCC (Q20_2), naval ships (Q20_4), HSC (Q20_6) and ferries (Q20_7) (Table 6-5 and Table 6-6).

Item (P<0.05)	Occupation groups	Ship types
Q20_1 Cargo ship	**0.00730**	0.67595
Q20_2 VLCC	**0.01905**	0.27254
Q20_3 Fishing boats	0.41193	**0.00027**
Q20_4 Naval ships	**0.00000**	**0.00172**
Q20_5 Yachts & Leisure boats	0.47869	0.35937
Q20_6 HSC	**0.00048**	0.39461
Q20_7 Ferry	**0.00000**	**0.03247**
Key	Bold results are tested significantly	

Table 6-5 The significance level by KW test for COLREGs compliance

Occupation groups (P<0.0083)	P/M	P/X	P/D	M/X	M/D	X/D
Q20_1 Cargo ship	**0.00488**	**0.00065**	**0.00105**	0.56021	0.56949	0.97174
Q20_2 VLCC	0.00961	**0.00091**	0.05156	0.79086	0.23292	0.11802
Q20_4 Naval ships	**0.00000**	**0.00000**	**0.00000**	0.01344	0.62631	0.01265
Q20_6 HSC	**0.00023**	**0.00012**	**0.00000**	0.34493	0.63687	0.55468
Q20_7 Ferry	**0.00021**	**0.00000**	**0.00000**	**0.00617**	0.08725	0.16158
Ship types (P<0.0167)	N/C		N/S		C/S	
Q20_3 Fishing boats	0.03028		0.12402		**0.00021**	
Q20_4 Naval ships	0.03184		**0.00111**		**0.00954**	
Q20_7 Ferry	0.08790		**0.00672**		0.10251	
Key	Bonferroni correction for P value (P<0.0083) represents 0.05 in MW tests Bonferroni correction for P value (P<0.0167) represents 0.05 in MW tests P: Pilots; M: Masters; X: Chief officers; D: Deck officers N: Bulk Carrier, Tanker and others; C: Container ship; S: Sea/Land shift Bold results are tested significantly					

Table 6-6 The significance level by MW test for COLREGs compliance

The details for significant paired groups are shown in Appendix K (pp K4 ~ K8). The group of pilots was more optimistic than the other groups regarding their views on cargo ships, naval ships, HSC and ferries obeying COLREGs. In addition, a significant difference was found between the group of pilots and group of chief officers in views on VLCC. Pilots were more optimistic than chief officers. Finally, a significant difference was found between the group of masters and the group of chief officers in views on ferries. Over four tenths of the chief officers' group (45%)

were not satisfied with the ferries, whereas only two tenths of the masters' group (20%) were not satisfied.

Different opinions were also found between the ship type that the respondents were working on, in the views on fishing boats (Q20_3), naval ships (Q20_4) and ferries (Q20_7). The details for significances paired are shown in Appendix K (pp K9 ~ K11). On the views about fishing boats, the group of the sea/land shift was more pessimistic than the group from container ships. On naval ships, the group of sea/land shift was more pessimistic than the rest of the groups. While for ferries, the group from non container ships was more optimistic than the group of sea/land shift.

6.4.3.4 Layout of navigation equipment on the bridge

AIS MKD should only be seen as an interim solution before the integration of AIS in the content of IBS (Leclair 2002). The location of the AIS MKD was compared with that of other existing bridge systems. From the opinions given on the layout of the navigational equipment (Figure 6-27), respondents were more satisfied with the locations of their ARPA/RADAR and ECDIS. AIS MKD was the least satisfactory in terms of its location on the bridge. There was only a fraction over half of the respondents who felt satisfied with the overall bridge layout. In the opinions on bridge layout, there were no significant differences found between the testing groups (Table 6-7).

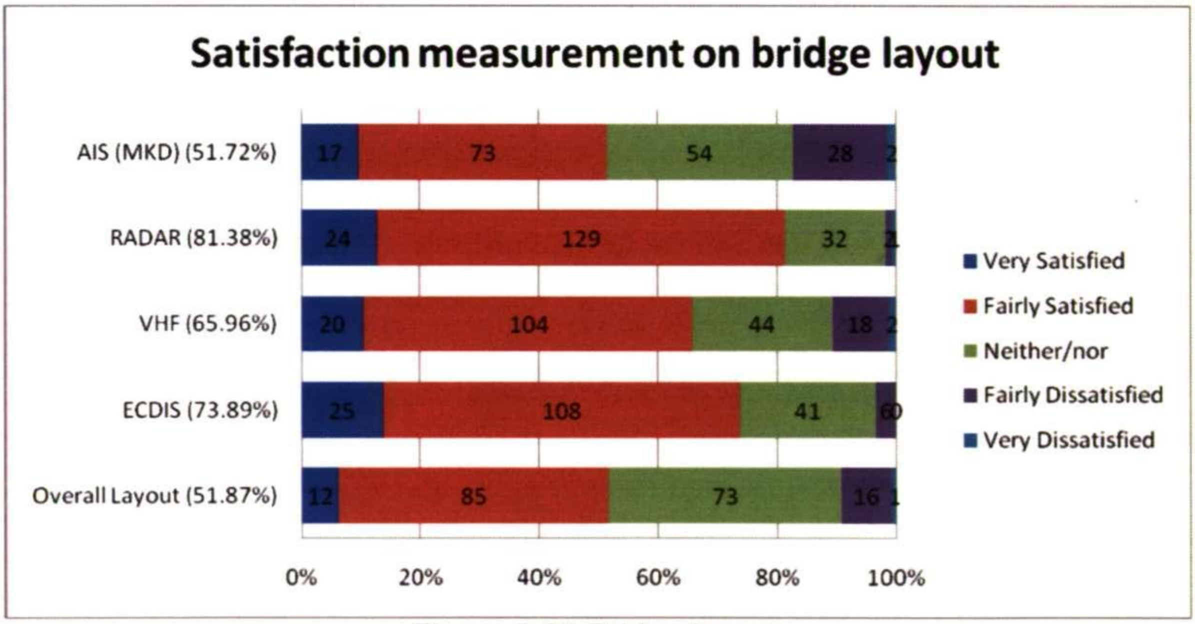

Figure 6-27 Bridge layout

Item (P<0.05)	Occupation groups	Ship Types
Q21_1 AIS MKD	0.57498	0.57326
Q21_2 RADAR/ARPA	0.97774	0.75443
Q21_3 VHF	0.69672	0.70649
Q21_4 ECDIS	0.67614	0.72858
Q21_5 Overall layout	0.40476	0.46659

Table 6-7 Significance level by KW test for bridge layout

A quarter of the respondents (24.9%) thought that reading data from the AIS MKD influences their decisions on collision avoidance (69.4% no; 5.8% do not know). A similar proportion of the respondents (29.5%) felt that reading information from the MKD could delay decision making in collision avoidance (65.3% no; 5.2% do not know). AIS can provide information based on ground movement, ROT, identity of targets, etc. Most respondents (91.9%) would like to see AIS data integrated with the other electronic devices on board (7.5% no; 0.6% do not know). Among the respondents, integration with ARPA/RADAR (132 votes) and ECDIS (102 votes) was particularly favoured (Figure 6-28).

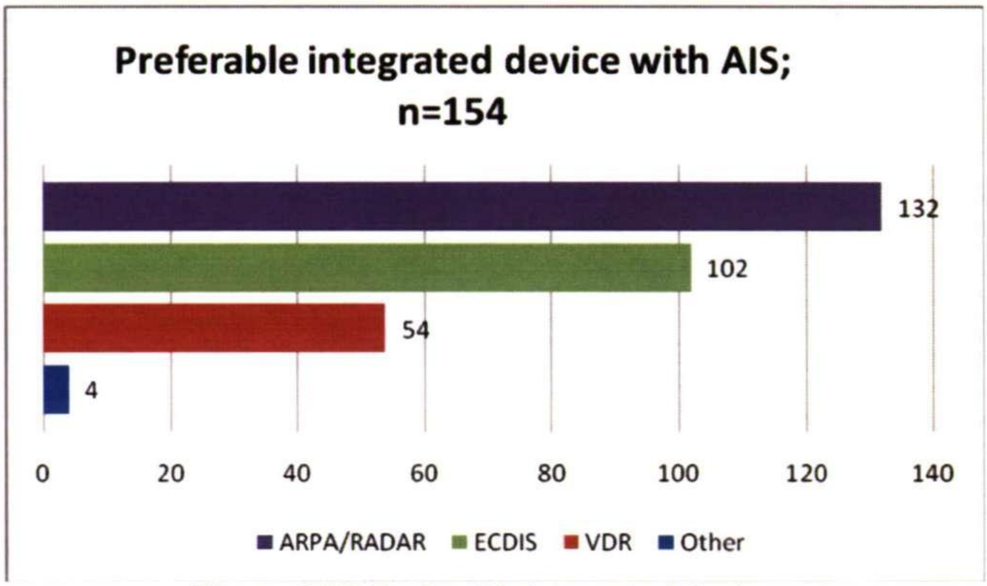

Figure 6-28 Preferable integrated devices

6.4.3.5 AIS implementation issues

In the process of implementing AIS, questions related to training, an implementation scheme and installation were investigated. Firstly, 12.3% had experienced difficulties due to the implementation date being moved forward (69.6% no; 18.1% do not know). Although the result did not have a strong indication about the problem caused by the changed time schedule, nearly four tenths of respondents (39.9%) agreed that the reason for the modified implementation scheme was due more to security measures than improving navigation (34.1% no; 26.0% don't know).

On the issue of a training requirement, over six tenths of respondents (67.4%) knew that there is no training requirement for operating AIS (32.6% did not know). Furthermore, over seven tenths of respondents (71.3%) believed that proper training is needed if AIS is used for collision avoidance (28.7% no). Among the respondents who supported AIS training, most answers favoured an onshore organisation (n=41), onboard self-training (n=42) and a Shipping Company (n=34) as the venues for holding AIS training (Figure 6-29). The remainder were 14 respondents advocating tutorial by technicians whilst calling in at harbour. Additionally, over seven tenths of respondents (73.0%) did not think that there is difficulty in communicating with technicians (13.5 yes; 13.5% don't know).

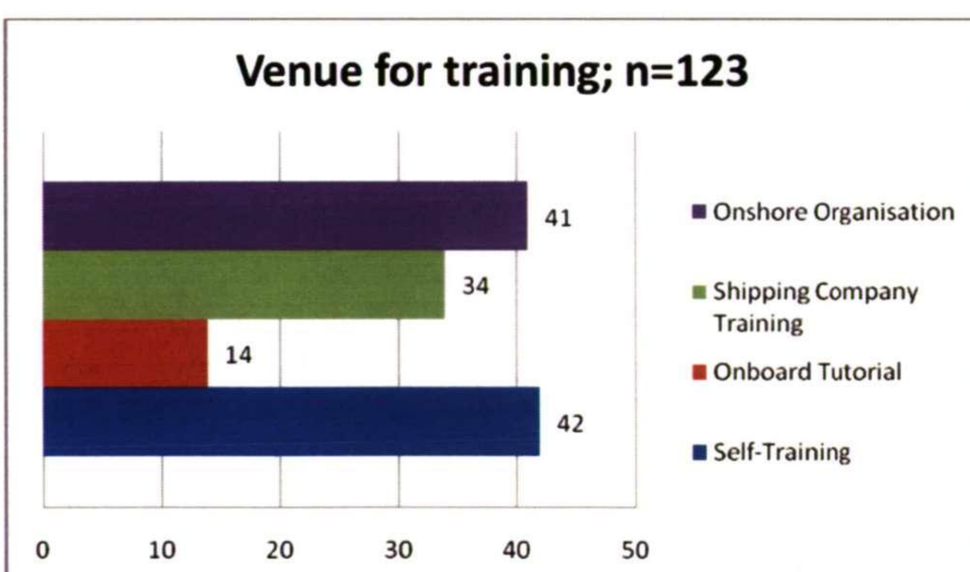

Figure 6-29 The venue to hold AIS training

Inevitably, if there is to be an optional or mandatory requirement for AIS training, the training cost would also be an issue for consideration. Figure 6-30 shows that the most desired authorities who should bear the cost chosen by the respondents are shipping companies (n=91) and the government (n=79). Finally, more than six tenths of respondents (65.5%) are not worried about sharing a ship's details with other people at sea via the AIS broadcasting network in terms of a pirating fear (25.9% yes; 8.6% do not know).[27]

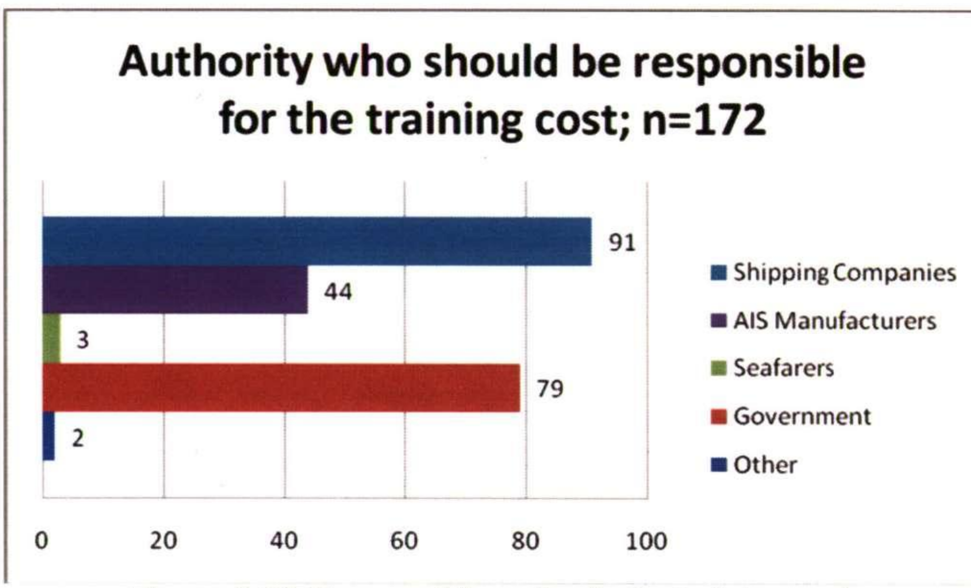

Figure 6-30 Responsible authority for training cost

6.4.3.6 AIS and collision avoidance

From Section 6.4.3.2, nearly six tenths of respondents (57.8%) have experience operating AIS in collision avoidance, and a similar proportion (52.87%; see Figure 6-21) also agreed that AIS is useful as one of the aids to collision avoidance. In addition to the respondents' experiences and opinions, nearly three quarters of the respondents (74.0%) thought that AIS is currently suitable as an aid to collision avoidance (24.9% no; 1.2% do not know). In the opinions about operation, most

[27] The valid number of the respondents for this question is 73.

respondents (96.4%) would not rely fully on AIS data in a decision about collision avoidance (3.0% yes; 0.6% do not know). Hence, cooperation between AIS and other bridge systems will be expected.

According to the opinions on navigation aids for collision avoidance, five navigational devices were presented for respondents to indicate the most important aids to navigation on the bridge (Figure 6-31). ARPA/RADAR and Watchkeeping were deemed to be the top navigational aids, while VHF was seen as an important aid with over eight tenths of respondents' approving. GNSS and AIS were in the last two positions, yet six tenths of respondents still felt that they are important in decision making about collision avoidance.

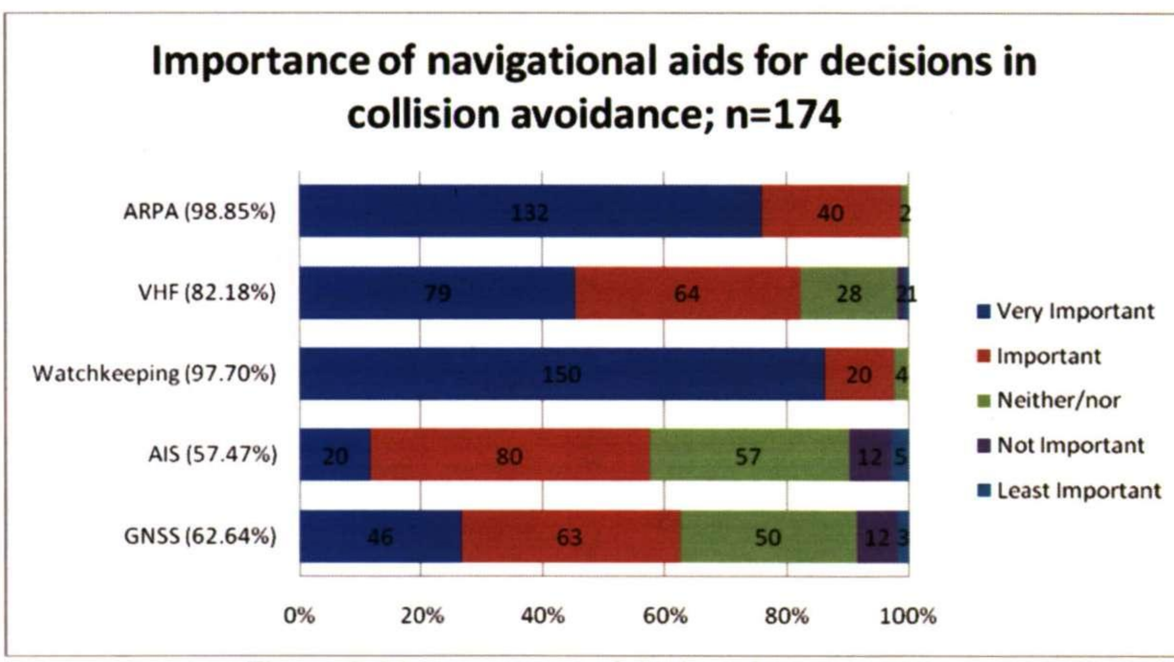

Figure 6-31 Importance of devices for navigation

A significance reflecting differing opinions was found in responses regarding VHF communication/collision avoidance (Table 6-8 and Table 6-9). The groups of masters, chief mates and deck officers all reckoned that VHF communication is important in collision avoidance (see Q30_2, Page K12, Appendix K). However, a generally neutral view was found from the group of pilots.

Item (P<0.05)	Occupation groups	Ship Types
Q30_1 ARPA RADAR	0.90787	0.17805
Q30_2 VHF Communication	**0.00339**	0.05995
Q30_3 Visual Lookout	0.57552	0.72709
Q30_4 AIS	0.88483	0.18522
Q30_5 GNSS	0.05005	0.14476
Key	Bold results are tested significantly	

Table 6-8 Significant level by KW test for important navigational device in collision avoidance

Occupation groups (P<0.0083)	P/M	P/X	P/D	M/X	M/D	X/D
Q30_2 VHF Communication	**0.00065**	**0.00206**	**0.00066**	0.52776	0.85413	0.43620
Key	Bonferroni correction for P value (P<0.0083) represents 0.05 in MW tests P: Pilots; M: Masters; X: Chief officers; D: Deck officers Bold results are tested significantly					

Table 6-9 Significant level by MW test for VHF calling in collision avoidance

In terms of accuracy for position fixing (Figure 6-32), the overall result showed that respondents scored AIS the least accurate device (42.53%). It is not difficult to see why only a quarter of the respondents (26.43%) would use AIS in position fixing (see Figure 6-2, Section 6.4.3.2). Most respondents felt most confident in GNSS (89.66%) and ARPA RADAR (94.83%) in terms of position fixing, while only seven tenths of respondents (71.84%) felt that bearing taking was accurate for position fixing.

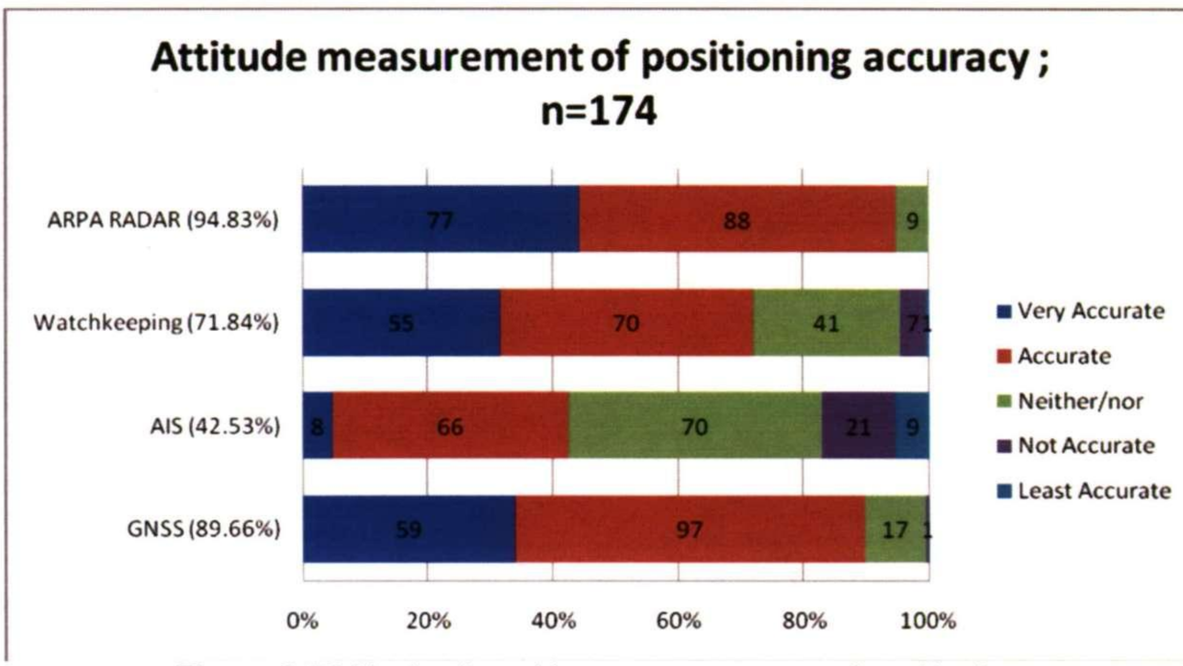

Figure 6-32 Navigation aids versus accuracy of positioning

In terms of opinions on the accuracy of navigation aids for position fixing, there was significance found between the groups of ship types regarding visual lookout (Q31_2) (Table 6-10). Furthermore, a significance was also identified between the group of non container ship and group of sea/land shift (Table 6-11), where the group of non container ship gave a better view on visual positioning than the group of sea/land shift (see page K13, Appendix K).

Item (P<0.05)	Occupation groups	Ship Types
Q31_1 ARPA RADAR	0.19559	0.60310
Q31_2 Visual Lookout	0.17434	**0.00723**
Q31_3 AIS	0.71808	0.12919
Q31_4 GNSS	0.55648	0.29177
Key	Bold results are tested significantly	

Table 6-10 The significance level by KW test for positioning accuracy

Ship Types (P<0.0167)	N/C		N/S		C/S	
Q31_2 Visual Lookout	0.03823		**0.00191**		0.04523	
Key	Bonferroni correction for P value (P<0.0167) represents 0.05 in MW tests N: Bulk Carrier, Tanker and others; C: Container ship; S: Sea/Land shift Bold results are tested significantly					

Table 6-11 The significance level by MW test for Visual Lookout

Apart from the concerns for accuracy, AIS was discussed in terms of its integrity, coverage, reliability and harmonisation. The respondents were asked to give a score for these five attributes. The current aids to navigation (RADAR, GNSS and visual lookout) were also investigated. Generally, the respondents are satisfied with RADAR and GNSS (Table 6-12 and Figure 6-33) in terms of the five gauging attributes. For Radar, over nine tenths of respondents (93.10%) were satisfied with the accuracy and nearly nine tenths of respondents (87.93%) were also satisfied with GNSS for this attribute. The lowest score for RADAR was the concern about detecting coverage (70.69%), while the lowest score for GNSS was harmonisation (76.44%). For visual lookout, coverage was mostly criticised by the respondents. Only nearly half of the respondents thought that AIS is good for accuracy (48.28%) and coverage (47.70%). However, reliability (40.23%) and harmonisation (40.80%) were most worrying for the respondents. Detailed figures for the four individual aids are shown in Question 32~35, Appendix J (pp J20 ~ J26).

Radar	Very Good	Good	Fair	Not Very Good	Poor	n
Accuracy (93.10%)	51	111	12	0	0	174
Integrity (80.46%)	31	109	34	0	0	174
Coverage (70.69%)	16	107	49	2	0	174
Reliability (79.89%)	24	115	35	0	0	174
Harmonisation (75.86%)	12	120	41	1	0	174
AIS	Very Good	Good	Fair	Not Very Good	Poor	n
Accuracy (48.28%)	9	75	63	22	5	174
Integrity (42.53%)	6	68	74	22	4	174
Coverage (47.70%)	12	71	69	20	2	174
Reliability (40.23%)	6	64	67	33	4	174
Harmonisation (40.80%)	8	63	77	23	3	174
GNSS	Very Good	Good	Fair	Not Very Good	Poor	n
Accuracy (87.93%)	48	105	18	3	0	174
Integrity (85.63%)	35	114	22	3	0	174
Coverage (88.51%)	42	112	17	3	0	174
Reliability (79.89%)	37	102	32	3	0	174
Harmonisation (76.44%)	29	104	37	3	1	174
Visual	Very Good	Good	Fair	Not Very Good	Poor	n
Accuracy (69.39%)	41	78	51	4	0	174
Integrity (63.21%)	23	87	56	7	1	174
Coverage (39.08%)	9	59	80	24	2	174
Reliability (73.56%)	49	79	42	4	0	174
Harmonisation (67.82%)	25	93	52	4	0	174

Table 6-12 Overall attributes for four navigational methods

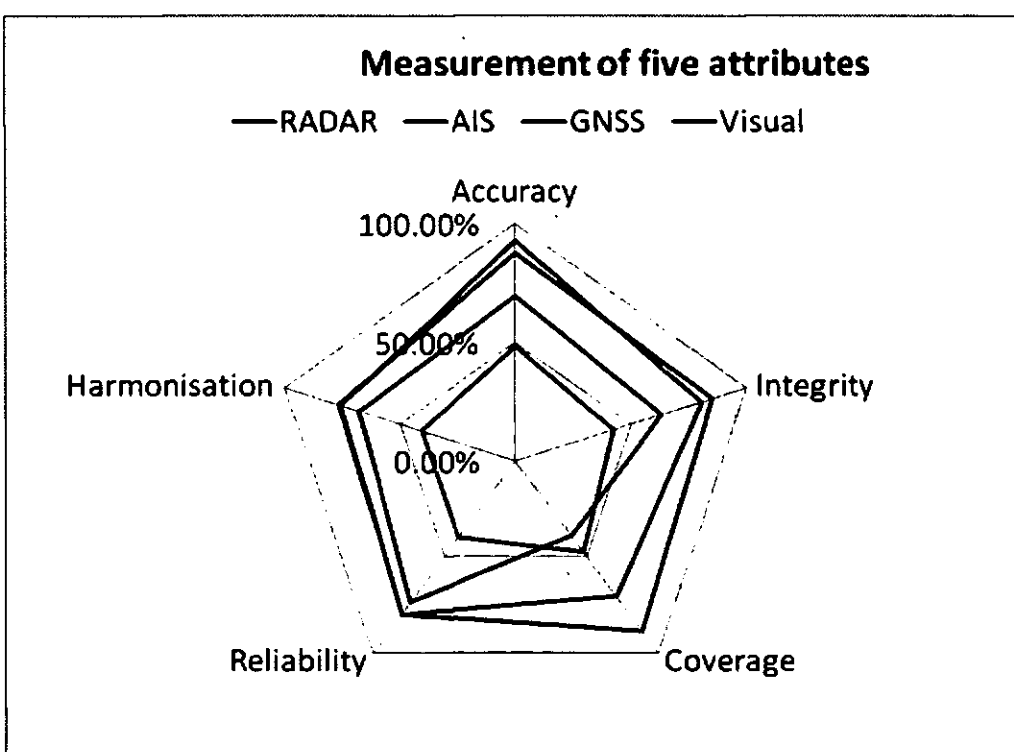

Figure 6-33 Star chart of navigational methods

There were significances found in the opinions on GNSS (accuracy, integrity and coverage) among the ship-type groups (Table 6-13 and Table 6-14). The OOWs who served on container ships presented a different view to those who were on the Sea/Land shift in terms of GNSS accuracy (Q34_1) and GNSS coverage (Q34_3). The group of Sea/Land shift showed a more positive view on GNSS accuracy and coverage than the group of container ship (page K14 & page K16, Appendix K). The group of Non container ships and the group of Container ships had different views on GNSS integrity (Q34_2), with nearly half of the Non-container-ship OOWs reckoning that GNSS is very good in the attribute of system integrity (page K15, Appendix K).

Item (P<0.05)	Occupation groups (n=174)	Ship Types (n=159)
Q34_1 Accuracy GNSS	0.23320	**0.01980**
Q34_2 Integrity GNSS	0.44520	**0.00188**
Q34_3 Coverage GNSS	0.13110	**0.00309**
Q34_4 Reliability GNSS	0.51349	0.05280
Q34_5 Harmonization GNSS	0.54305	0.37650
Key	Bold results are tested significantly	

Table 6-13 Significance level by KW test for GNSS in overall attributes

Ship Types (P<0.0167)	N/C	N/S	C/S
Q34_1 Accuracy GNSS	0.06206	0.67535	**0.01531**
Q34_2 Integrity GNSS	**0.00038**	0.30263	0.13007
Q34_3 Coverage GNSS	0.01870	0.52986	**0.00366**
Key	Bonferroni correction for P value (P<0.0167) represents 0.05 in MW tests N: Bulk Carrier, Tanker and others; C: Container ship; S: Sea/Land shift Bold results are tested significantly		

Table 6-14 Significance level by MW test for GNSS in three testing attributes

As there are a number of results showing a connection between communication and AIS, most respondents (94.3%) think that they will obtain a target's identity via AIS to assist VHF calling in collision avoidance (5.7% no). Put together with the previous findings that 94.7% and 82% of the respondents would use VHF in collision avoidance and in CQS, respectively (See Section 6.4.3.3), it is likely that these respondents will deploy VHF more often to assist in their manoeuvring mainly because prompt target identification is available from the AIS network.

Finally, the involvement of AIS in COLREGs was also addressed in the questionnaire. A hypothetical question was asked, if any rule in COLREGs should be modified by the introduction of AIS in collision avoidance. Three tenths of respondents (36.8%) thought the potential use of AIS would trigger the provisions modification of the COLREGs (54.6% no; 8.6% do not know). Among the respondents who would like to see COLREGs changed (Figure 6-34), Rules 8 Action to avoid collision and Rule 19 Conducts of vessels in restricted visibility were most favoured (n>30).

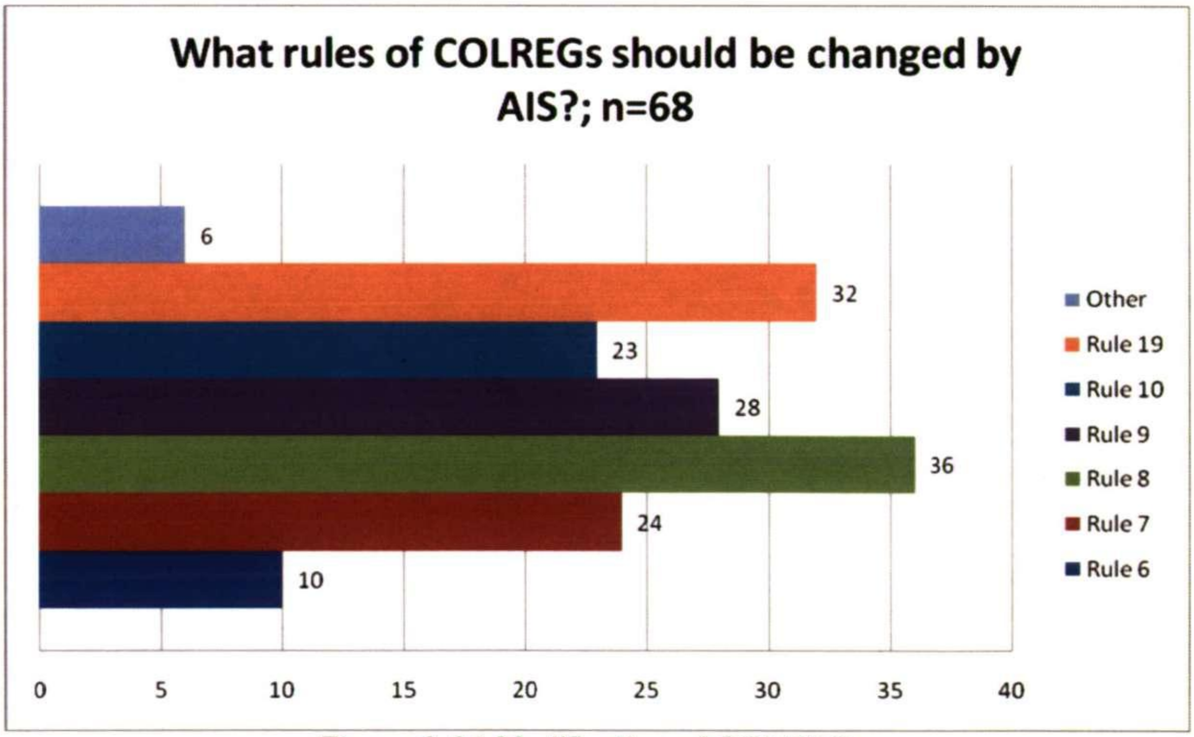

Figure 6-34 Modification of COLREGs

6.4.4 Discussion of Survey II

Survey II was carried out when AIS had become a mandatory carriage requirement onboard SOLAS ships after December 2004. Most respondents had operated AIS and had also used or considered AIS operation in assisting collision avoidance. Apart from the high expectations for anti-collision use, the respondents saw communication as the most useful application currently.

Before considering AIS as part of the lookout operation, most respondents think that there were difficulties when they used VHF calling with another ship. Moreover, respondents also indicated that busy traffic and vessel identification are the two elements that cause concern. Despite the difficulties, most respondents agreed with AIS/VHF communication and are willing to use VHF in ship manoeuvring.

As AIS can identify targets, the encouragement gained from AIS identification could have solved one of the worrying elements of vessel identification when using VHF calling. Secondly, the ARPA/RADAR has been recognised as one of the most important navigation aids in navigation and collision avoidance. However, ARPA/RADAR does have its limitations, and Survey II showed that the majority of respondents do have a concern about detection while sailing on a bend channel as well as meeting a small boat/object at sea. Therefore, the extra identification and confirmation from AIS could act as a backup device for OOWs on lookout.

The majority of ships that the respondents were working on were ships built before the mandatory AIS carriage requirement. MKD was generally found to be the standalone AIS during the survey. Therefore, opinions on the operation of AIS MKD were also discussed in the survey topics. There were around three tenths of respondents felt that reading AIS data from the MKD device delayed and influenced decision for collision avoidance. There were some indications that most respondents might not be taking AIS into account to a certain degree in their operation of collision avoidance. Survey II would suggest that the data from the MKD device may not be compatible with ARPA/RADAR. As a result, ARPA/RADAR and ECDIS were chosen by the majority of respondents as potential devices for AIS fused data.

As the original AIS carriage requirements would not have been accomplished on every SOLAS ship until 2008, the respondents have also taken part in the accelerated time schedule. Initially, the longer time schedule would have left more time for the preparation of AIS fitting onboard, along with any corresponding issues such as training and navigational applications. In fact, the concern for national security regarding the maritime sector became so important that it brought forward the plan for AIS carriage requirement (Batty 2003; Nell 2003). Hence, more respondents believed that the reason to bring AIS in earlier than the previous plan was more due to maritime security measures than application in navigation. Despite the focus on security, most respondents approved the idea of training the OOW in ship manoeuvring and navigation.

Apart from the focus on maritime security and interim MKD displays for AIS data, most respondents still took AIS into account in their daily work when on watch. Most respondents thought that AIS was currently suitable as an aid to navigation and in the operation of collision avoidance. With regard to situation awareness at sea, the external data from AIS was positively approved. In order to precisely identify the degree to which AIS is considered in the navigation and manoeuvre operation, a number of approaches were used to test the respondents. Survey II started with a general view of AIS, along with opinions on the present bridge operation. In the results, the respondents showed familiarity with the characteristics of AIS and also noticed advantages and disadvantages from operating AIS for navigation and manoeuvre.

In theory, AIS can enhance coverage detection and identity detection if the target ships are equipped with AIS. The findings have addressed the concerns of RADAR's detection and coverage. Furthermore, AIS identification can provide the OOWs with the ability to be aware of 'target swapping' on RADAR scanning, which normally occurs when two targets are very close to each other. As a result, there could be a better chance of identifying an ambiguous target at sea with the assistance of the AIS network. Currently, the lack of harmonisation of AIS into the bridge system was criticised by the respondents; this might become obvious in the short term regarding the use of AIS MKD and affect the outcome of these results.

In general, higher percentages of results reflect answer consistency among the surveyed respondents. Regardless of the ranking (no significance found), respondents were holding similar opinions (attitudes) toward the asked questions. Conversely, significances were found in a few items based on the examined ranking difference. The opinions and attitudes were then highly related to the difference of the respondent's ranking. For example, the group of pilots were found particularly holding a few different opinions (attitudes) with the rest of ranking groups.

6.5 Comparison between the two surveys

Survey I and Survey II were planned and took place at different times, while the respondents for both were mainly interviewed in Taiwanese based shipping lines and organisations. Survey I took place in 2004, when AIS became a mandatory carriage requirement on board every SOLAS ship. One of the survey's objectives was to look for general opinions of the impact that AIS might have on their daily operations on the bridge. Survey II took place in the third season of 2005.

In Survey II, nine tenths of respondents (92.6%; n=190) had operated AIS on the bridge, which was higher in comparison with Survey I (78.6%; n=103). Based on the degree of involvement of AIS in the bridge operation, the respondents from Survey I put collision avoidance at the top of the list of applications (collision avoidance, VHF, position fixing and security). The view of AIS had changed by Survey II, when communication became the top choice above the other three methods (security, collision avoidance and position fixing). Furthermore, there were fewer respondents (39.9%; n=174) in Survey II who felt that AIS was more about security than aids to navigation (66% in Survey I; n=103). With regards to the source of training costs, the top three choices by the two surveys were shipping companies, governments and AIS Manufacturers. For the training venue, in Survey II, opinions were divided evenly between onboard training, shipping company training and onshore organisation training. However, Survey I showed that majority of the respondents (59.2%) supported onboard training.

In Survey I, over half of the respondents (53.4%; n=103) thought that AIS is suitable for assisting ship manoeuvring, while nearly three quarters of the respondents (74%; n=169) agreed in Survey II. In addition, over eight tenths of respondents from both Survey I and Survey II would not fully rely on a single information resource from AIS in making an anti-collision decision. As a result, a similar percentage of respondents from both surveys strongly agree (more than seven tenths of respondents from both surveys) that non-SOLAS vessels should also carry AIS for identification. In addition to collision avoidance, nearly nine tenths of respondents from both surveys (87.3% Survey I; 89.2% Survey II) used VHF to assist with manoeuvres. The respondents from both surveys also gave a strong impression (more than three quarters of respondents from both surveys) that they would not use the AIS function of text messaging as a means or a substitute for communication. To sum up, AIS identified target information could be used to assist VHF calling in collision avoidance.

In order to gauge the importance of the role of AIS in navigation, a comparison of AIS with a few navigational aids was undertaken on both Survey I and Survey II, with the visual lookout and RADAR remaining the priority for consideration when an officer is on watch, whereas AIS and VHF are left behind. AIS has advantages and disadvantages in assisting navigation and ship manoeuvres. Over half of the respondents from the two surveys recognised the performance that AIS can provide and they also would like to see whether AIS will be seriously considered in the modification of COLREGs in the future.

6.6 Conclusions

There were 293 views collected in total from the two questionnaire surveys, Survey I and Survey II. Views on AIS development, concerns for shipborne AIS operation and the role of AIS in bridge lookout were investigated. In short, the views on AIS and the early development of AIS was the main focus in Survey I, and the users' perspectives on AIS/bridge operation were assessed in Survey II. The opinions from the interviewed deck officers revealed the current status of AIS operation on the bridge and showed support by the majority for the use of shipborne AIS.

For current bridge lookout, several navigational devices were discussed along with AIS. Survey II particularly tested five attributes – accuracy, integrity, coverage, reliability, harmonisation – of these navigational aids. On average, assessment of AIS operation was less optimistic than for the other devices. Nevertheless, three quarters of the respondents agreed that AIS is currently suitable as an aid to collision avoidance.

Satisfaction analysis revealed worries over some types of ship in obeying COLREGs. Fishing boats and leisure boats are the most criticised groups for keeping COLREGs during their transits. The findings also reflected that most respondents agreed that non-SOLAS vessels should also have the function of ship identification.

There were more respondents who had operated shipborne AIS in Survey II (92%) than in Survey I (78%). Moreover, more respondents in Survey II (74%) than in

Survey I (53%) agreed that AIS is currently suitable as an aid to collision avoidance. In fact, over nine tenths of respondents from Survey I agreed that every OOW should be able to use AIS for collision avoidance after AIS was fully implemented.

A change in perception was discovered, with most respondents from Survey II choosing security concerns as the reasons for shipborne over navigational approval. The opposite view was discovered in Survey I. Despite the interest in AIS as a VTS tool and navigational device, the concern for costal security measures became dominant. The survey results therefore suggest that more development is needed for AIS in ship manoeuvring.

Most of the respondents used VHF calling to assist in collision avoidance. Furthermore, Survey II found that AIS/VHF communication in collision avoidance was favoured by most of those surveyed. Frequent use of VHF assistance in ship manoeuvring is therefore highly likely to happen. Concerns for training were also raised by the two surveys. From the users' point of view, training could mean extra work if onshore training is the only option. More respondents were in favour of self-training or on-the-job training. Until today, training for AIS operation in bridge lookout is not mandatory. The results of AIS assistance in ship manoeuvring will be varied by the different commitment users make of AIS in their decision-making process.

Chapter 7

Ship Simulation and Evaluation

7.1 Introduction

This research aims to examine the effect on end users operating AIS as one of the navigation aids on the bridge. In the literature, AIS is designed to give users early warning of potential collision risks by its designed functions in target detection, target tracking and target classification. Therefore, a better situation awareness of the surrounding traffic could be expected. In Chapter 6, lack of system harmonisation was criticised by the surveyed mariners where information transmitted via AIS might be compromised. In short, integrated AIS into the bridge system was not yet compulsory. It would be difficult to measure how much AIS can actually enhance the overall bridge lookout by the surveys. As a result, a simulator experiment with a fused AIS bridge operation was adopted.

This research concentrates on the function of AIS providing addition information into the current bridge operation in ship manoeuvring. Providing AIS can automatically support the OOWs' information with a VTS like traffic situation. AIS is also able to assist RADAR with the independent function of target detection. Furthermore, AIS's precise target detection is available with positioning accuracy and real-time updated data. With a number of advantages ready to assist users at sea, this chapter will look at the impact of bringing AIS information into the bridge control in ship manoeuvring. The added effects from operating AIS will be measured by means of a range of analyses. The users' behaviours will also be considered in the light of COLREGs.

7.2 Simulation experiment

There were five pairs of simulator exercises run by two groups of mariners (Group A and Group B). Group A was asked to read AIS information before the exercises started and throughout the exercises. Group B did not have access to AIS information throughout the exercises. Each one of the participants undertook the five exercises individually in a random order. The participants' own-ship tracks were shown in five different scenarios (see Appendix L).

The data collected (see Section 5.3.6) from the five scenarios were analysed by:

- Range from the encountered vessel at which action was taken;
- TCPA from the encountered vessel at which action was taken;
- Collision avoidance manoeuvres;
- Actual CPA or passing distance to the encountered vessel; and
- Off-track distance.

MW pair tests were carried out to test the two designated groups (Group A and Group B) in terms of TCPA at which action was taken and off-track distance.

7.3 Simulation results

Participants were obtained for the study through the support of the South West Branch, Nautical Institute (NI), and Marine Training, Plymouth (MTP). The ranking detail of the participants is shown in Figure 7-1 and the number of the groups is shown in Figure 7-2. Participants were evenly grouped in terms of their ranking into 2 experimental groups. The results from the simulation trials will now be discussed separately for the five exercises.

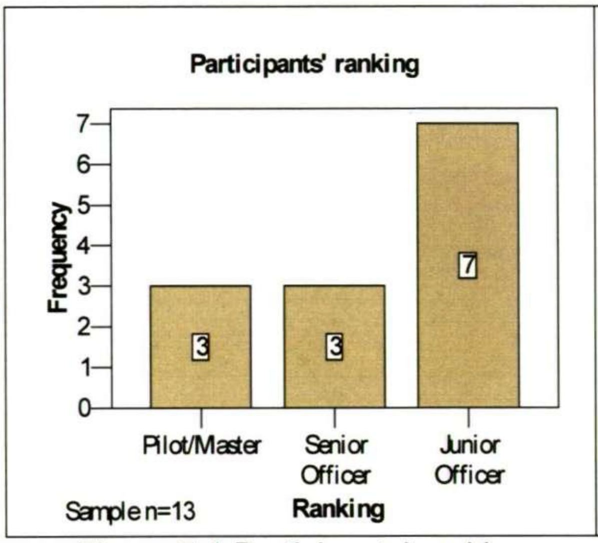

Figure 7-1 Participants' ranking

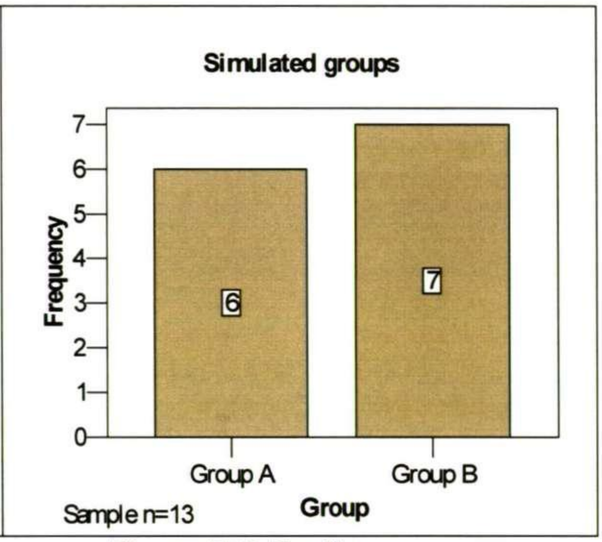

Figure 7-2 Testing groups

7.3.1 Target ship in reciprocal course (Ex-A/B)

Ex-A/B puts the own ship's track (code: OS) with a target vessel (code: TG3) in a head-on situation if the two vessels meet in visual range before altering courses (Figure 7-3). The OS and TG3 would have a CPA/TCPA 0.1 nm/18.55 minutes after the start if the OS did not take any action (engine and course alteration).

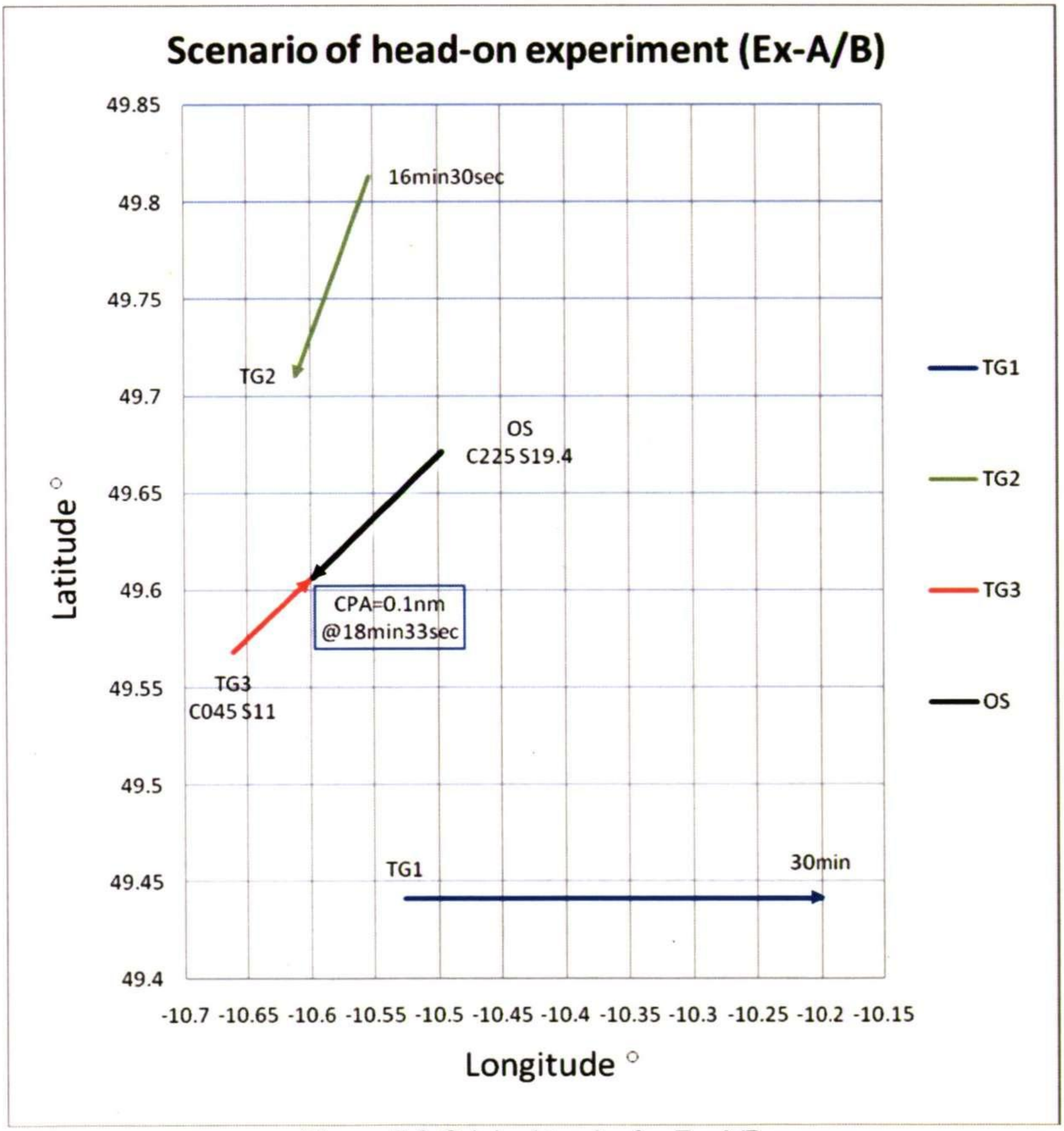

Figure 7-3 Original tracks for Ex-A/B

The TG3 was set up as a comparably smaller target at a range of 9 nm from the start of the exercise. Hence, difficulties in detecting vessels, especially the small target, were emphasised in this exercise. Due to the help obtained from AIS, information about the TG3 was clearly shown on all three AIS displays (RADAR, ECDIS and MKD) at the beginning. TG3 was displayed as a fishing boat under way using engine and travelling at 11 knots on a reciprocal course with the OS. As the visibility was only 3 nm, TG3 was not visible until 12.6 minutes after the exercise starts. The TCPA would be 5.96 minutes if no action was taken onboard OS.

In Ex-A/B, all participants decided to take action before meeting the oncoming TG3 in visual contact. Hence, situation involving the coming TG3 was studied by the electronic equipment. According to the COLREGs, Rule 19 suggests not to alter course to port if the approaching vessel is forward of its beam (except in an overtaking situation). While TG3 kept a steady speed and reciprocal course to the OS, all actions taken by the participants were to alter course to starboard (see Ex-A/B, Appendix L).

In Figure 7-4 and Figure 7-5, participants' exercises are displayed respectively for two groups.

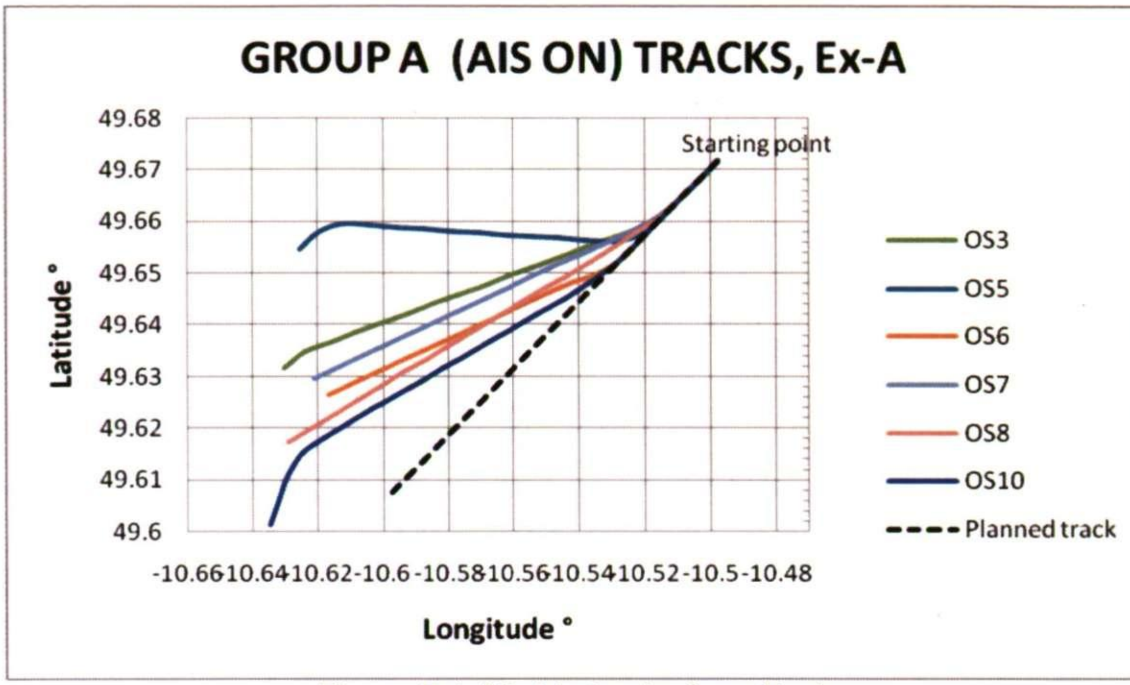

Figure 7-4 All ship tracks from Ex-A

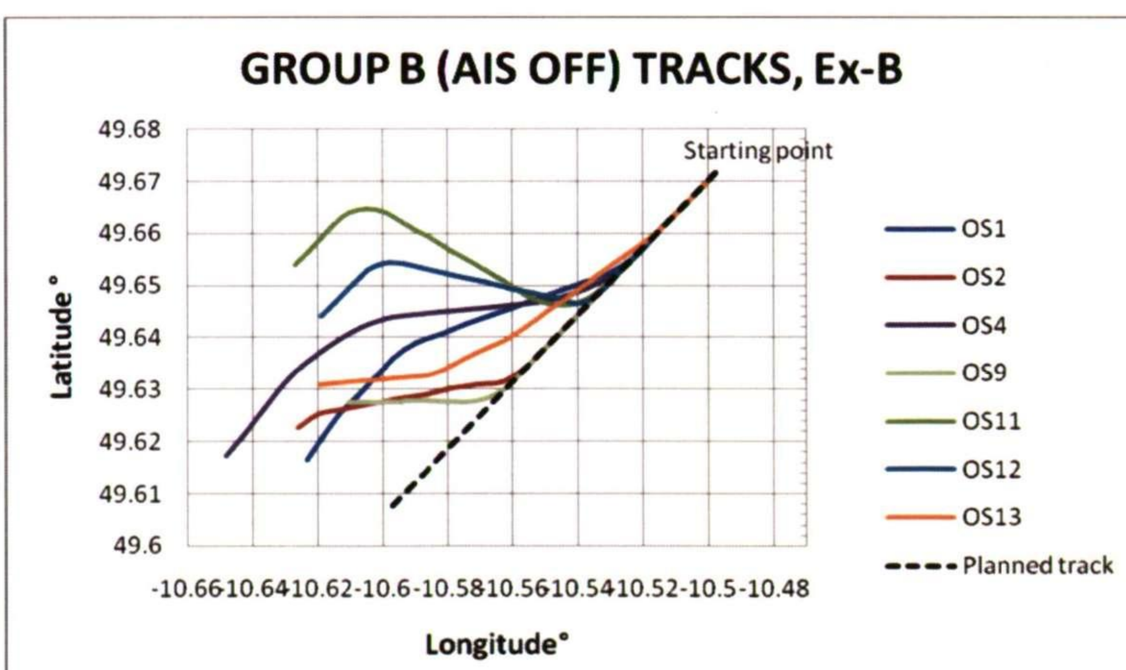

Figure 7-5 All ship tracks from Ex-B

Table 7-1 shows the data collected regarding the action taken by the participants. Among the 13 participants, the range at which action was taken was 6.55 nm from the TG3 (TCPA: 13.42 min.). Respectively, Group A took action at 7.57 nm from TG3 (TCPA: 15.03 min.), while Group B did it at 6.05 nm (TCPA: 12.05 min.). Overall, Group A took earlier action than Group B by 2.98 minutes of the TCPA.

Group	A (Ex-A)						B (Ex-B)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Action range (nm)	7.74	7.4	6.47	7.9	7.74	6.51	6.87	4.12	6.56	3.63	6.05	5.89	7.61
Median (SD)	7.57 (0.64) nm						6.05 (1.45) nm						
Total Median (SD)	6.55 (1.34) nm												
Action	A/S						A/S						
TCPA (min.)	15.36	14.7	12.9	15.7	15.4	13.4	13.6	8.18	13.0	7.18	12.0	11.6	15.1
Median (SD)	15.03 (1.15) min.						12.05 (2.89) min.						
Total Median (SD)	13.42 (2.68) min.												
Key	A/S: Altered course to Starboard; SD: Standard Deviation;												

Table 7-1 Action from Ex-A/B

Table 7-2 shows the data collected regarding the actual CPA to the TG3 and off-track distance taken by the participants. Among the 13 participants, the actual CPA achieved was 1.41 nm. Group B took closer CPA to the TG3 than Group A by 0.15 nm. An alteration of course back to the planned track indicates that a threat of collision from the TG3 no longer exists. The distance off the planned track by the all participants was 1.61 nm. Group A took 1.5 nm off the planned track before heading back, whereas Group B took 1.66 nm off the track.

Group	A (Ex-A)						B (Ex-B)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Actual CPA (nm)	1.889	2.46	1.41	1.63	1.16	0.98	1.11	1.33	1.89	1.38	2.78	2.14	1.35
Median (SD)	1.53 (0.53) nm						1.38 (0.59) nm						
Total Median (SD)	1.41 (0.55) nm												
Off-track distance (nm)	1.938	2.76	1.38	1.61	1.29	1.15	1.2	1.43	1.84	1.2	2.76	2.12	1.66
Median (SD)	1.50 (0.60) nm						1.66 (0.56) nm						
Total Median (SD)	1.61 (0.55) nm												

Table 7-2 Actual CPA achieved and off-track distance for Ex-A/B

2 participants in Group B took action at comparably late time which 1 participant (OS9) did not take any action until the OS was in a CQS (action taken when the TG3 was less than 4nm from the OS). All participants in Group A accomplished the mission before a CQS developed. In addition, 5 out of 6 Group A participants passed the target with pre-claimed CPA distance (>1 nm).

7.3.2 Meeting with a privileged vessel (Ex-C/D)

Ex-C/D puts the own ship (code: OS) on a crossing situation with two targets (code: TG4 and TG3), with both CPAs less than 2 cables in 13.72 minutes and 17.3 minutes (Figure 7-6). The TG4 altered course (60° starboard) at 3 minutes from the start of the exercise. It became clear that TG4 took action in order to avoid CQS with the OS. As a result, TG3 is of great concern.

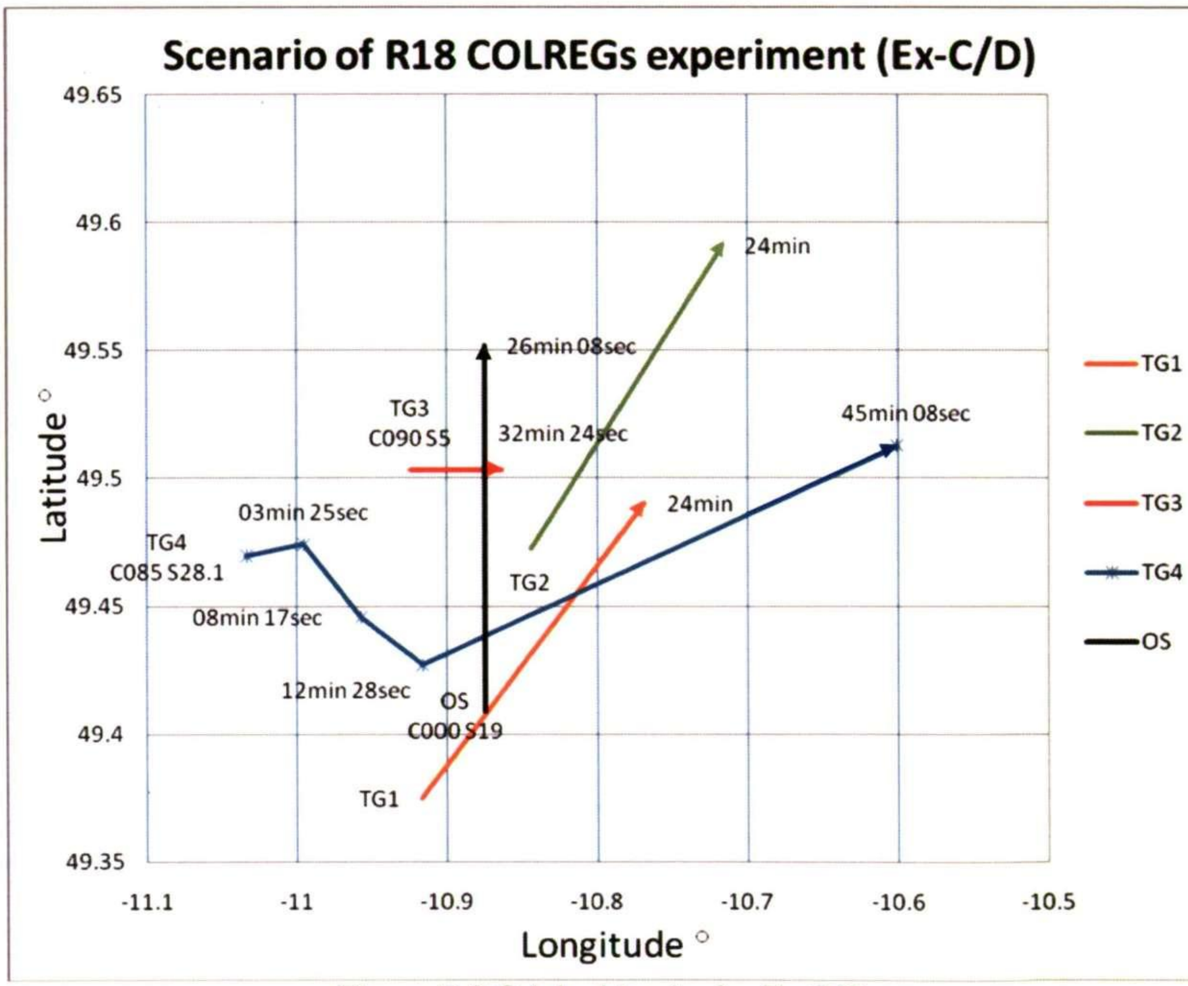

Figure 7-6 Original tracks for Ex-C/D

The only difference between Ex-C (Group A) and Ex-D (Group B) was that Group A could obtain more target information during the simulator exercise. In particular, TG3, initially with two points on her port bow and 6 nm away, was actually in engine failure. A corresponding NUC signal was displayed both by two round-shaped balls and via the AIS data transmission. In fact, it is more difficult to spot 0.6 metre round-shaped balls from a certain distance (see Section 3.5.3). Hence, it is impossible that participants from Group B would be aware of the real situation of TG3 before visual contact.

Rule 18, Responsibilities between vessels, COLREGs, gives privilege to certain vessels that a power-driven vessel should keep out of the way. Furthermore, Rule 18 is in the section dealing with vessels that are in sight of each other. While concerns were raised whether AIS could improve information broadcasting (see Section 3.5.3), difficulties in determining privileged vessels can be eased by AIS information. Although Rule 18 was not applicable in restricted visibility (Section III, COLREGs), AIS information can still show a vessel's condition in restricted visibility, or even if the vessel is out of RADAR detecting range. In short, an early awareness of vessels with concerns about manoeuvrability can be achieved.

Figure 7-7 shows that 5 out of 6 Group A participants altered course to starboard in response to the TG3 (OS 8 altered course to port). In Figure 7-8, all Group B participants altered course to starboard (OS 13 made a round turn).

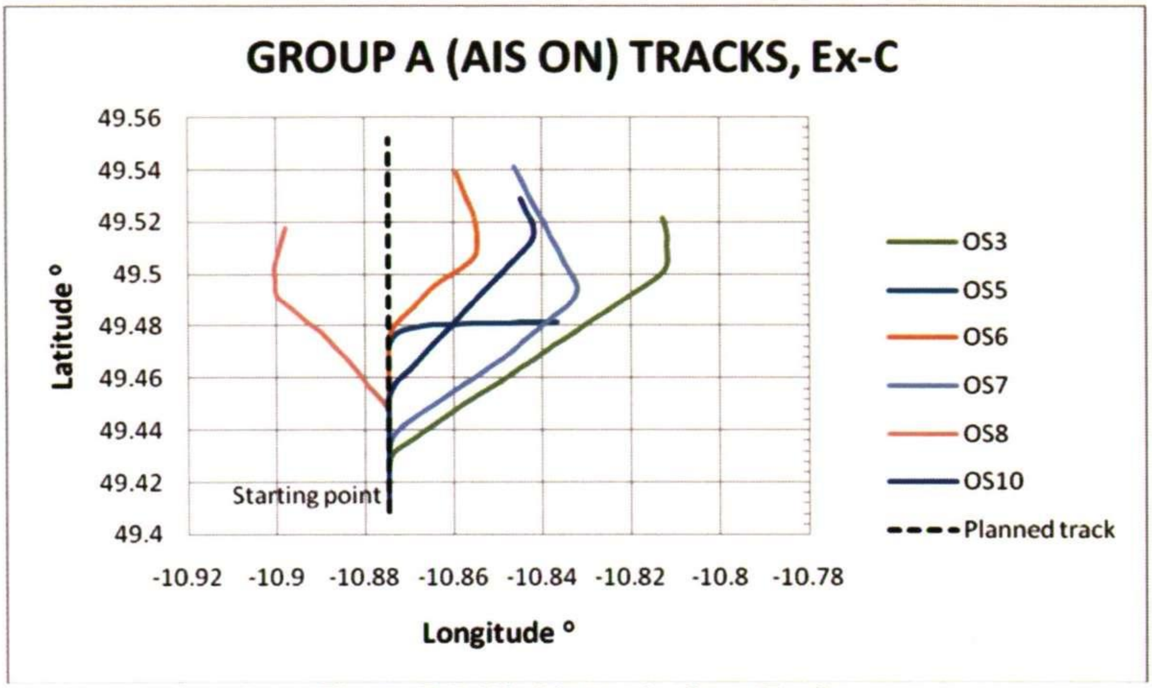

Figure 7-7 All ship tracks from Ex-C

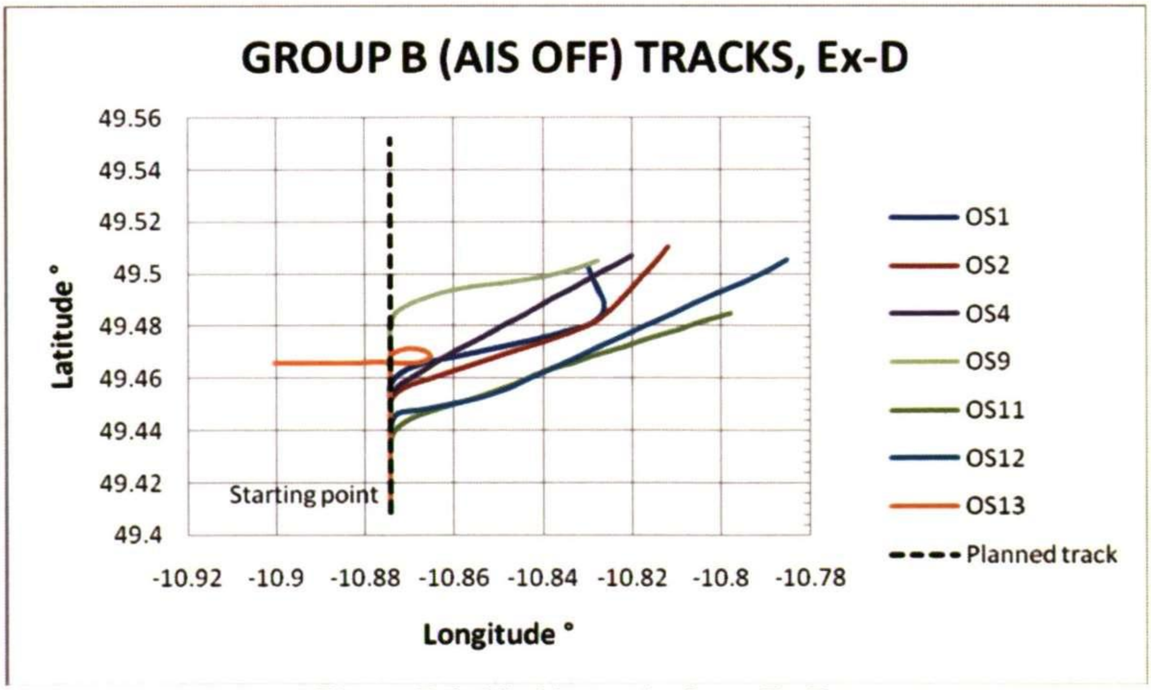

Figure 7-8 All ship tracks from Ex-D

Table 7-3 shows the data collected regarding the action taken by the participants. Among the 13 participants, the range at which action was taken was 3.59 nm from the TG3 (TCPA: 10.33 min.). With a fraction of difference, Group A took action at 3.64 nm from TG3 (TCPA: 10.17 min.), while Group B did it at 3.41 nm (TCPA: 10.33 min.).

Group	A (Ex-C)						B (Ex-D)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Action range (nm)	4.89	3.59	2.9	4.49	3.69	3.3	3.08	3.41	3.37	1.54	4.33	3.93	4.04
Median (SD)	3.64 (0.74) nm						3.41 (0.92) nm						
Total Median (SD)	3.59 (0.84) nm												
Action	A/S	E(-); A/S	E(-); A/S	A/S	A/P	A/S	A/S	A/S	A/S	A/S	A/S	A/S	E(-); R
TCPA (min.)	14.33	8.36	8.61	13.1	10.6	9.66	9.15	10.0	10.3	4.53	12.6	11.4	11.8
Median (SD)	10.17 (2.45) min.						10.33 (2.69) min.						
Total Median (SD)	10.33 (2.51) min.												
Key	A/S: Altered course to Starboard; E(-): Engine reduction; A/P: Altered course to port; R: Round turn;												

Table 7-3 Action from Ex-C/D

Table 7-4 shows the data collected regarding the passed distance to the TG3 and off-track distance taken by the participants. Among the 13 participants, the passed distance achieved was 1.39 nm. Group A took closer passed distance to the TG3 than Group B by 0.84 nm. An alteration of course back to the planned track indicates that the threat of collision from the TG3 no longer exists. Group A took 1.45 nm off the planned track before heading back, while Group B took 2.19 nm off the course.

Group	A (Ex-C)						B (Ex-D)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Passed distance (nm)	2.127	1.43	0.54	1.27	0.95	1.03	1.2	1.98	1.39	0.89	2.62	2.66	2.19
Median (SD)	1.15 (0.53) nm						1.99 (0.70) nm						
Total Median (SD)	1.39 (0.68) nm												
Off-track distance (nm)	2.562	1.56	0.81	1.71	1.06	1.34	1.93	2.5	2.18	1.93	3.12	3.62	1.43
Median (SD)	1.45 (0.61) nm						2.19 (0.76) nm						
Total Median (SD)	1.94 (0.81) nm												

Table 7-4 Passed distance achieved and off-track distance for Ex-C/D

7.3.3 Overtaking and course alteration (Ex-E/F)

Ex-E/F has one of the targets (code: TG1) altering course toward the own ship (code: OS). The initial configuration is given in Figure 7-9, where the OS has TG1 at a relative bearing of 115°, 6 nm in distance. At one point (11m20s from the start), TG3 altered course to port in consideration of a group of fishing boats on her bow and intended to cross the OS ahead. After the steady course achieved by TG3, CPA/TCPA was reduced to 0.264 nm/11.65 min. At the time, TG3 was 5 nm on 3 points on the own ship's starboard side.

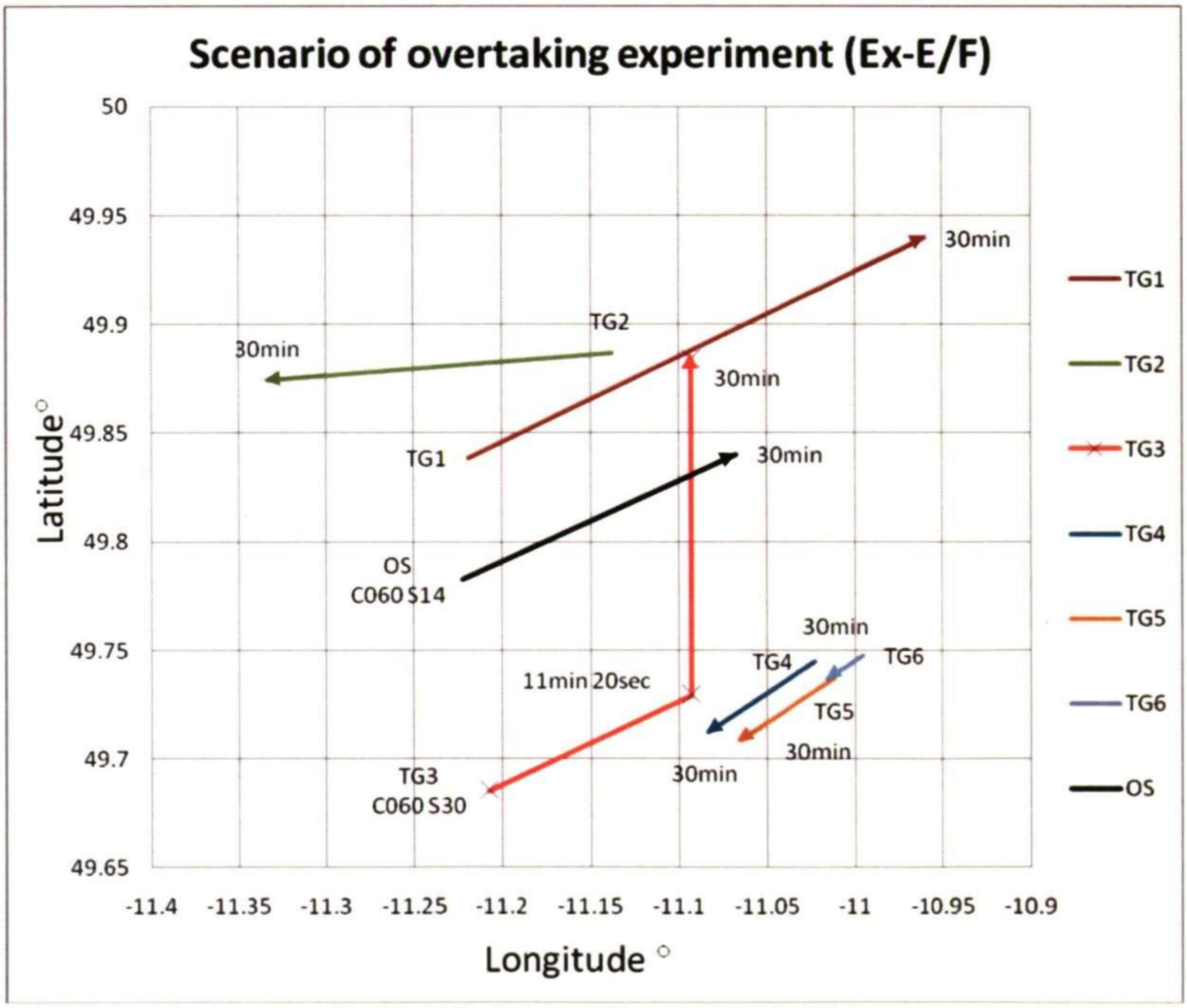

Figure 7-9 Original Tracks for Ex-E/F

Figure 7-10 shows that 4 Group A participants gave notice to the engine room and reduced speed after the TG3 altered course to port, while the other participants altered course to starboard (OS 3 made a round turn). In Group B, 3 participants altered course to starboard, 2 to port (with engine slowed down), 1 made a round turn to port and 1 slowed the engine (Figure 7-11).

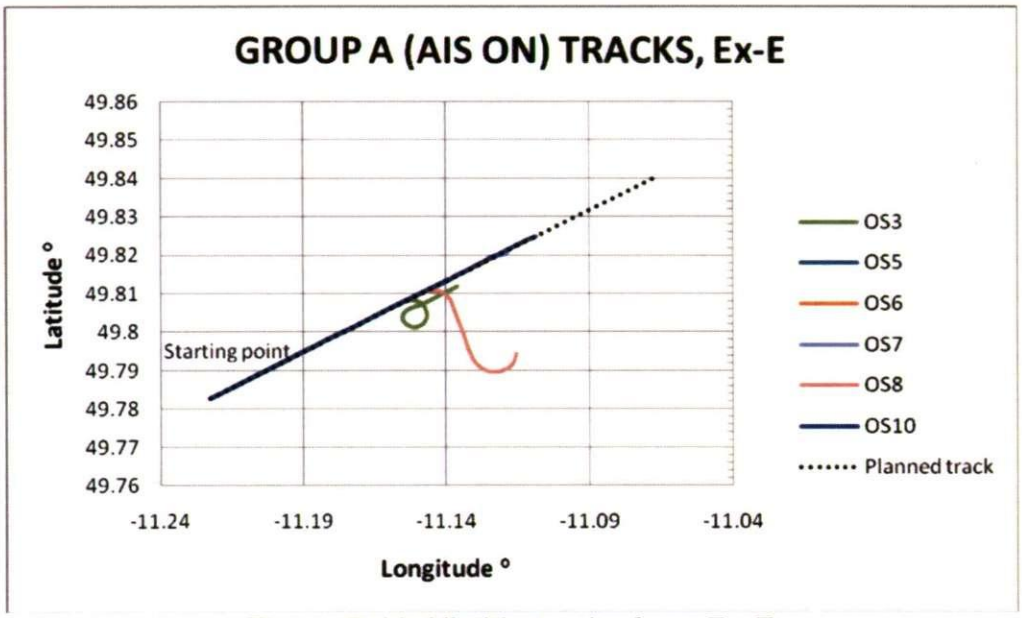

Figure 7-10 All ship tracks from Ex-E

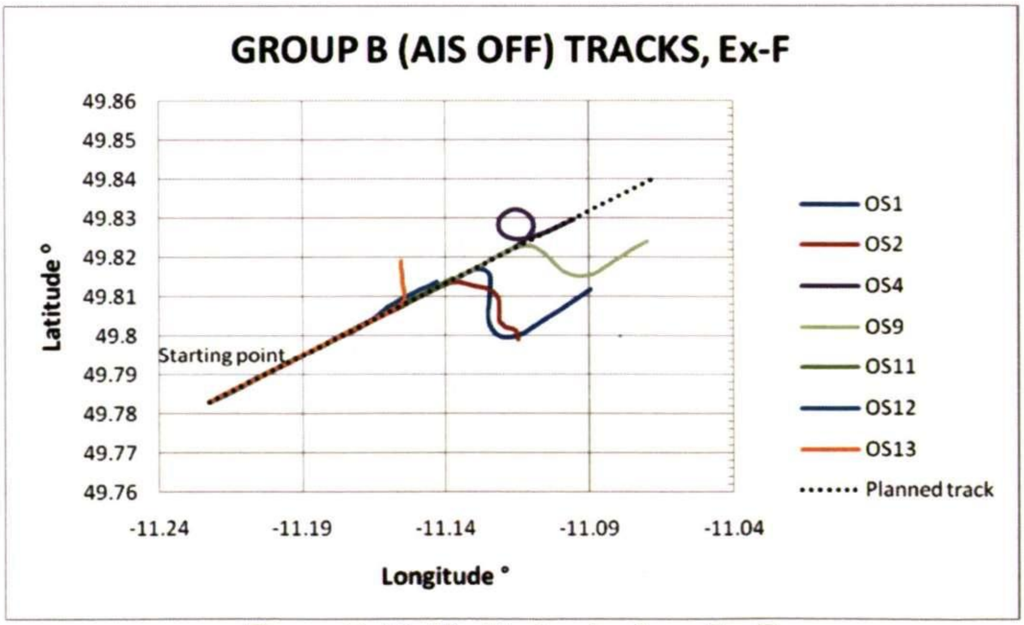

Figure 7-11 All ship tracks from Ex-F

Table 7-5 shows the data collected regarding the action taken by the participants. Among the 13 participants, the range at which action was taken was 4.24 nm from the TG3 (TCPA: 9.17 min.). Group A took action at 4.35 nm from TG3 (TCPA: 10.59 min.), while Group B did it at 3.85 nm (TCPA: 7.93 min.). Overall, Group A took earlier action than Group B by 2.66 minutes of the TCPA.

Group	A (Ex-E)						B (Ex-F)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Action range (nm)	4.86	3.17	2.43	4.86	4.44	4.25	3.7	4.24	1.81	1.88	4.72	4.47	3.85
Median (SD)	4.35 (0.99) nm						3.85 (1.20) nm						
Total Median (SD)	4.24 (1.09) nm												
Action	R	E(-)	E(-)	E(-); A/S	A/S	E(-)	A/S	A/S	R	A/S	E(-)	A/P; E(-)	A/P; E(-)
TCPA (min.)	11.98	7.8	5.96	12.0	10.8	10.3	7.83	9.16	4.45	4.7	11.4	9.56	7.93
Median (SD)	10.59 (2.44) min.						7.93 (2.55) min.						
Total Median (SD)	9.17 (2.60) min.												
Key	A/S: Altered course to Starboard; A/P: Altered course to port; E(-): Engine reduction; R: Round turn;												

Table 7-5 Action from Ex-E/F

Table 7-6 shows the data collected regarding the passed distance to the TG3 and off-track distance taken by the participants. Among the 13 participants, the passed distance achieved was 1.15 nm. With a fraction of difference, Group A took closer passed distance to the TG3 than Group B by 0.06 nm. An alteration of course back to the planned track indicates that the threat of collision from the TG3 no longer exists. Group A took 0.03 nm off the planned track before heading back, while Group B took 0.51 nm off the course.

Group	A (Ex-E)						B (Ex-F)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Passed distance (nm)	2.183	1.10	0.71	1.15	1.54	0.96	1.18	1.04	0.83	0.42	1.77	2.00	2.42
Median (SD)	1.13 (0.52) nm						1.18 (0.71) nm						
Total Median (SD)	1.15 (0.60) nm												
Off-track distance (nm)	0.34	0	0	0.06	1.2	0	0.97	1.03	0.46	0.71	0	0.11	0.51
Median (SD)	0.03 (0.48) nm						0.51 (0.39) nm						
Total Median (SD)	0.34 (0.44) nm												

Table 7-6 Passed distance achieved and off-track distance for Ex-E/F

The majority (7 out of 13) indicated that the visibility was the main concern meaning that Rule 19 should apply. Two participants pointed out that the distance to the TG3 at the beginning (6nm) means that it would not be considered as an overtaking ship to the own ship. These opinions were confirmed by Cockcroft (see Section 5.3.4.3). In contrast, 3 participants stated that it would have been an overtaking situation if the TG3 was in visual contact at the beginning. Although Group A took action to the oncoming TG3 a little earlier than Group B, there was little evidence to suggest that participants with ROT information from AIS acted differently to the other group (ARPA/RADAR only).

7.3.4 Course alteration in TSS area (Ex-G/H)

Based on the findings from Redfern's study (1993) in Dover Strait (see Section 5.3.4.4), a meeting between a cargo ship on the Southwest bound TSS lane and a passenger ferry intending to cross the channel (see Figure 5.6) was adopted. From a modification of Redfern's findings, the planned scenario was created for Ex-G/H (Figure 7-12). As the scenario was in a TSS channel, the engine was on standby initially.

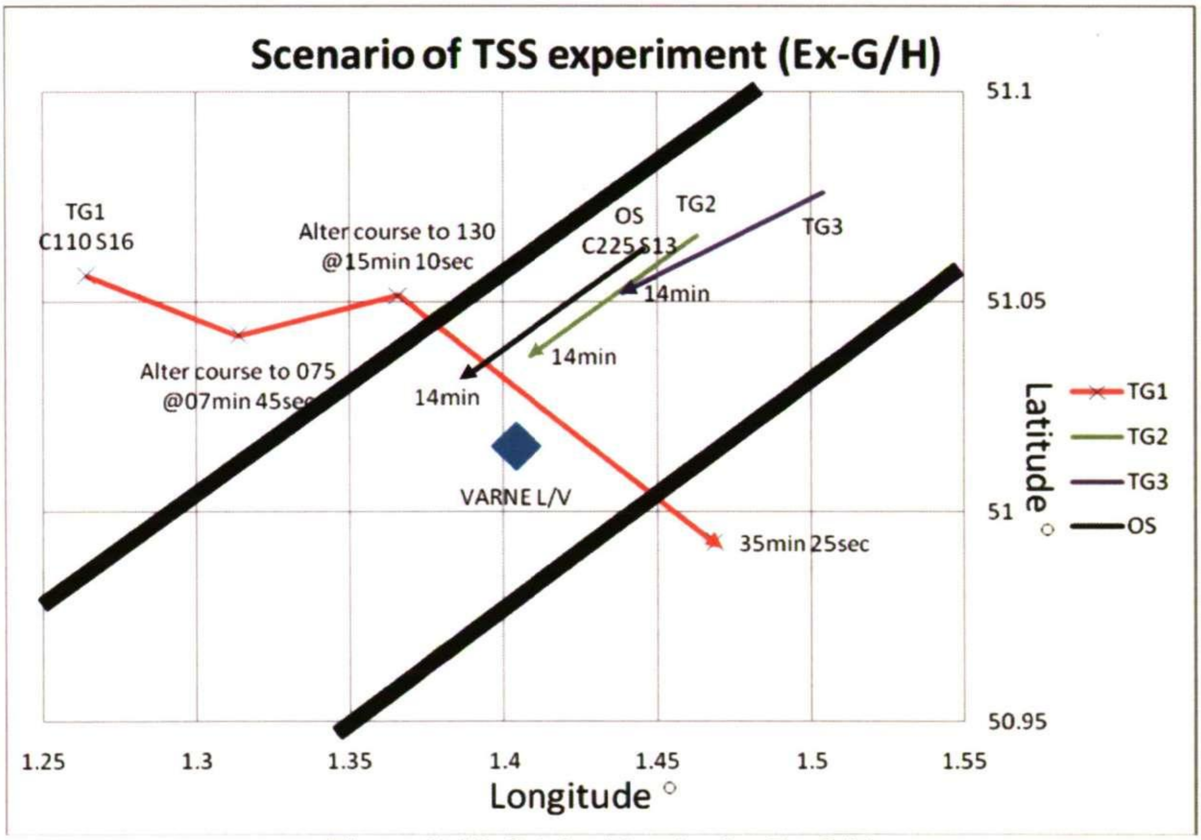

Figure 7-12 Original tracks for Ex-G/H

In Figure 7-13, 4 out of 6 Group A participants altered course to starboard (OS 3 and OS 8 also changed speed to assist the developing CQS). OS 6 only slowed down the engine. OS 10 did not take any action leaving, TG1 at CPA/TCPA 0.021nm/16m45s, 6.7nm on the own ship's starboard bow. After TG1 changed her course to port, the CPA/TCPA to the own ship was 1.478 nm/ 5m49s at the range of 3nm off the starboard bow. The same result applied to OS 2 (Group B), who did not take any action during the exercise (Figure 7-14). 4 Group B participants altered course to starboard (OS 1 made a round turn). Another 2 participants decided to adjust the engine.

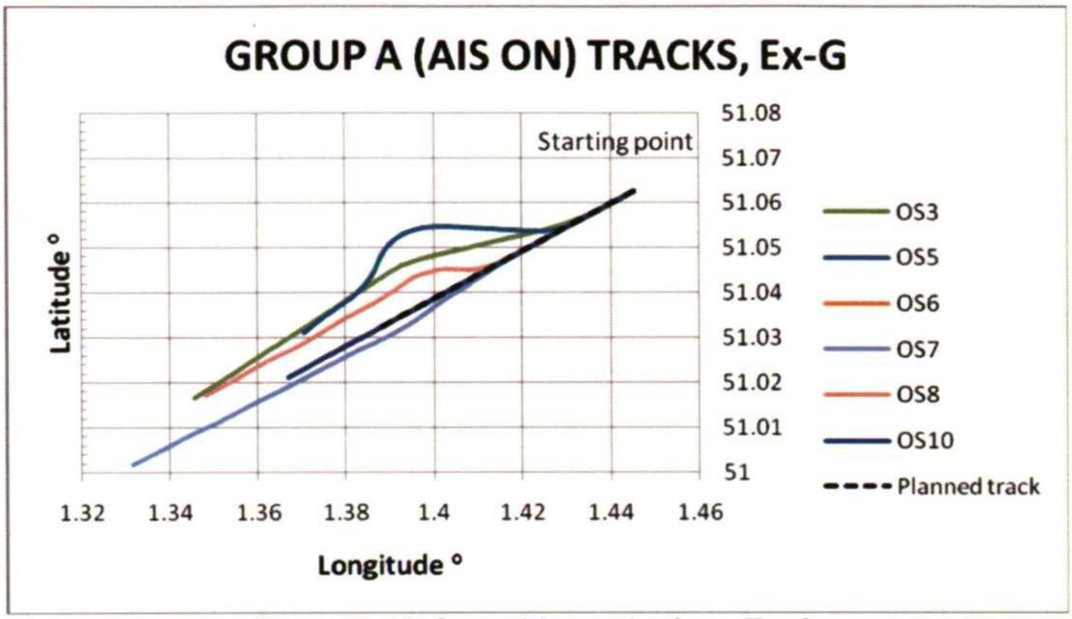

Figure 7-13 Own ship tracks from Ex-G

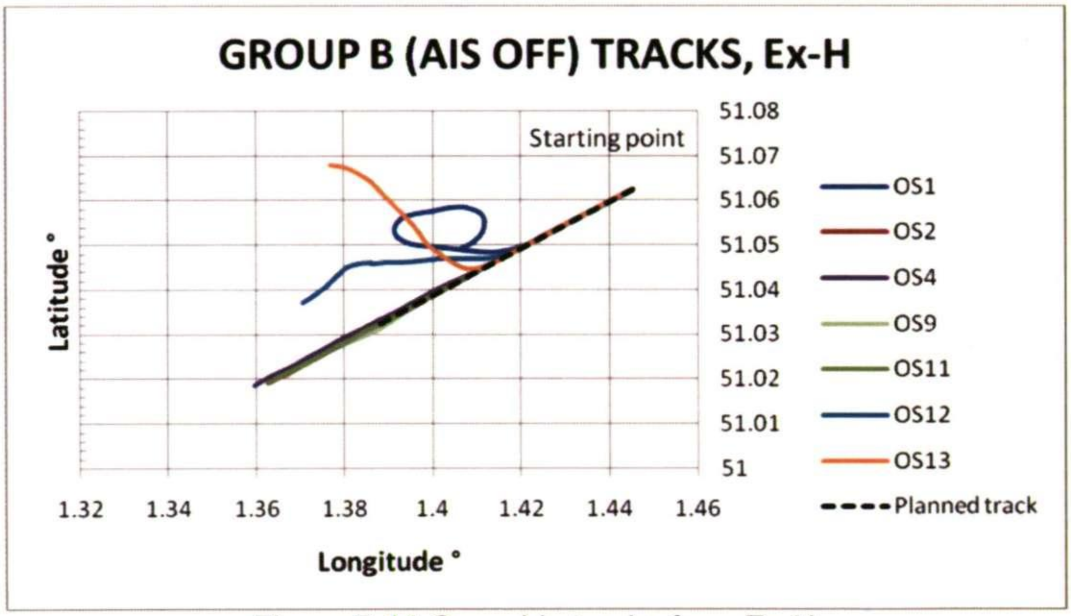

Figure 7-14 Own ship tracks from Ex-H

Table 7-7 shows the data collected regarding the action taken by the participants. Among the 13 participants, the distance at which action was taken was 4.69 nm from the TG1 (TCPA: 11.60 min.). Group A took action at 5.31 nm from TG1 (TCPA: 11.60 min.), while Group B did it at 4.31 nm (TCPA: 11.1 min.). Overall, Group A took earlier action than Group B by 0.50 minutes of the TCPA.

Group	A (Ex-G)						B (Ex-H)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Action range (nm)	6.16	5.83	4.49	5.31	4.31	*	4.89	*	3.63	3.15	4.89	4.69	3.92
Median (SD)	5.31 (0.81) nm (exempt OS10)						4.31 (0.73) nm (exempt OS2)						
Total Median (SD)	4.69 (0.90) nm (exempt OS2 & OS10)												
Action	A/S; E(+)	A/S	E(-)	A/S	A/S; E(-)	*	R	*	A/S	E(+); A/P	E(-)	A/S	A/S
TCPA (min.)	15.4	14.5	11.6	11.2	10.8	*	12.2	*	7.13	5.12	12.2	11.6	10.6
Median (SD)	11.60 (2.09) min. (exempt OS10)						11.10 (2.98) min. (exempt OS2)						
Total Median (SD)	11.60 (2.91) min. (exempt OS2 and OS10)												
Key	A/S: Altered course to Starboard; A/P: Altered course to port; E(-): Engine reduction; E(+): Speed up; R: Round turn;*:No action												

Table 7-7 Action from Ex-G/H

Table 7-8 shows the data collected regarding the passed distance to the TG1 and off-track distance taken by the participants. Among the 13 participants, the passed distance achieved was 1.13 nm. Group A took closer passed distance to the TG1 than Group B by 0.09 nm. An alteration of course back to the planned track indicates that the threat of collision from the TG1 no longer exists. Group A took 0.24 nm off the planned track before heading back, while Group B took 0.06 nm off the course. In terms of off-track distance, Group B spent less distance off the original course (0.18nm) when considering the collision threat coming from TG1.

Group	A (Ex-G)						B (Ex-H)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Passed distance (nm)	1.132	0.59	1.03	1.84	0.80	1.47	1.17	1.26	1.17	1.62	1.06	0.17	1.00
Median (SD)	1.08 (0.45) nm						1.17 (0.44) nm						
Total Median (SD)	1.13 (0.43) nm												
Off-track distance (nm)	0.514	0.85	0	0.14	0.34	0	1.02	0	0.05	0.05	0	0.8	2.00
Median (SD)	0.24 (0.34) nm						0.06 (0.76) nm						
Total Median (SD)	0.14 (0.60) nm												

Table 7-8 Passed distance achieved and off-track distance for Ex-G/H

Ex-G/H was also testing participants' behaviours concerning a target ship (TG1 here) altering course. In contrast to Ex-E/F, the own ship was travelling in a TSS channel. From Redfern's study, mariners act differently in a constrained traffic area. Table 7-7 shows that Group A took action earlier than Group B. Group A had gathered extra information, that the crossing TG1 was identified as a channel crossing ferry en-route to Calais travelling at 16 knots. Once the course alteration had been made by the TG1, 4 participants from Group A all altered course back to the planned track (see Figure 7-13). Group B participants could only see TG1 as a crossing target at the beginning and later TG1 changed its course to port. In average, Group B took action when TCPA was 11.1 minutes. Subsequently, 2 participants in Group B (OS1 & OS13) left the TSS channel.

7.3.5 Detection of speed change (Ex-I/J)

Ex-I/J original track (Figure 7-15) has one target vessel (code: TG1) slowing down her speed in order to keep clear of the own ship (code: OS).

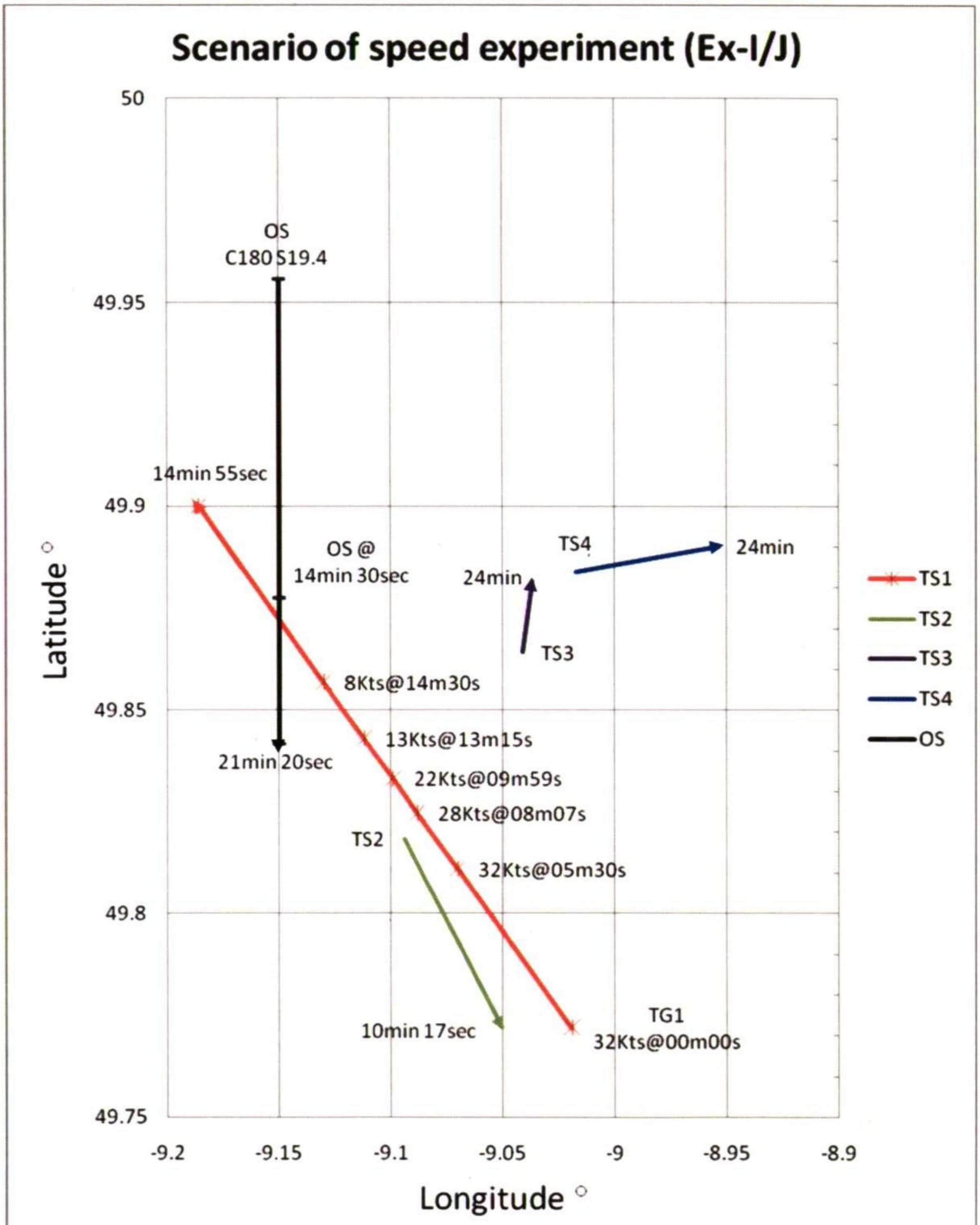

Figure 7-15 Original Tracks for Ex-I/J

In the AIS dynamic information, a speed change can be obtained which could give confirmed information to OOWs relating to an opponent's intentions. In the initial configuration, the TG1 and OS would be in a crossing situation if both ships had each other in visual contact. Initially at 32 knots, TG1 was three points off the own ship's port bow at a range of 12.14nm. Table 7-9 showed the observed speed, CPA/TCPA and distance of TG1. The CPA increased once the TG1 had reached her 8 knots speed at 14m30s.

TG1 / Time	Displayed speed	CPA (nm)	TCPA	Distance (nm)
00min00sec	32kts steady	-	-	12.14
05min30sec	<32kts	0.05	09min16sec	7.45
08min07sec	<28kts	0.18	08min00sec	5.7
09min59sec	<22kts	0.43	07min25sec	4.5
13min15sec	<13kts	0.78	05min28sec	2.8

Table 7-9 Observation of TG1

12 out of the 13 participants altered course to starboard in the Ex I/J. In Rule 19 COLREGs, two vessels in a potential encounter shall act together (Lewison 1978; IMO 2003b). Group A and Group B decided to take action (except OS10) when the oncoming TG1 was not yet in visual range. More information was fed to the participants from Group A, where TG1's ship type (HSC), dynamic information and destination were all available on the bridge. In order to keep clear of the OS, the TG1 eventually slowed its speed from 32 knots to 8 knots.

In Figure 7-16 and Figure 7-17, participants' exercises are displayed respectively for two groups. 12 out of 13 participants altered course to starboard, while only one (OS 10) did not take any action.

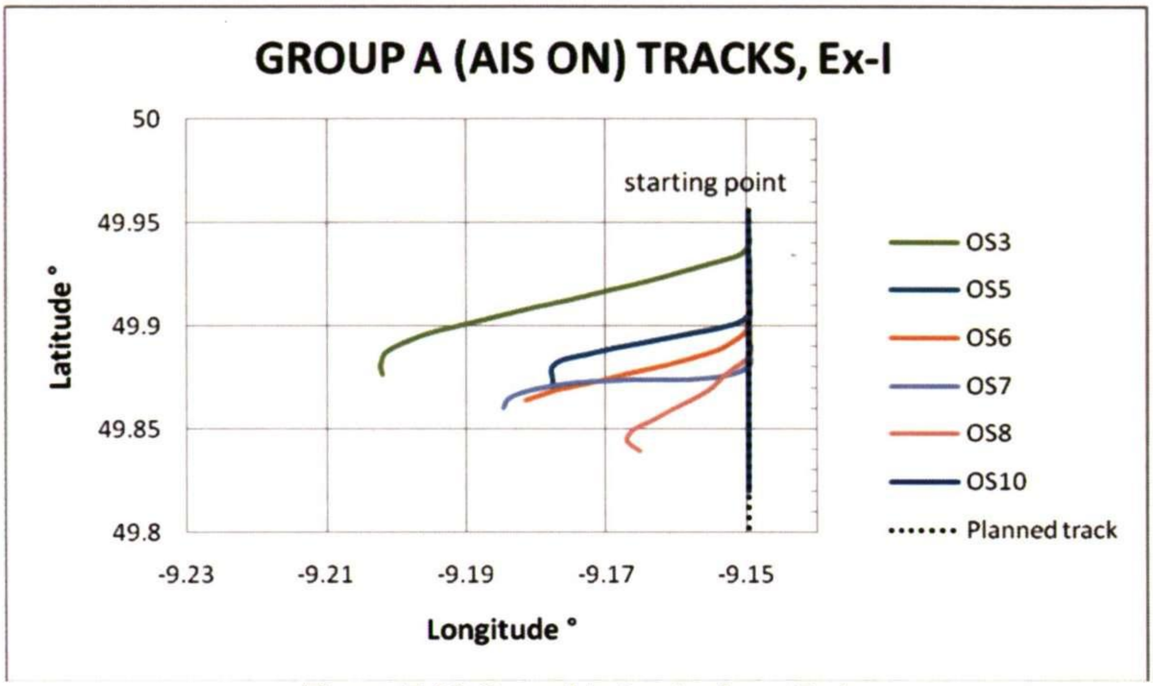

Figure 7-16 Own ship tracks from Ex-I

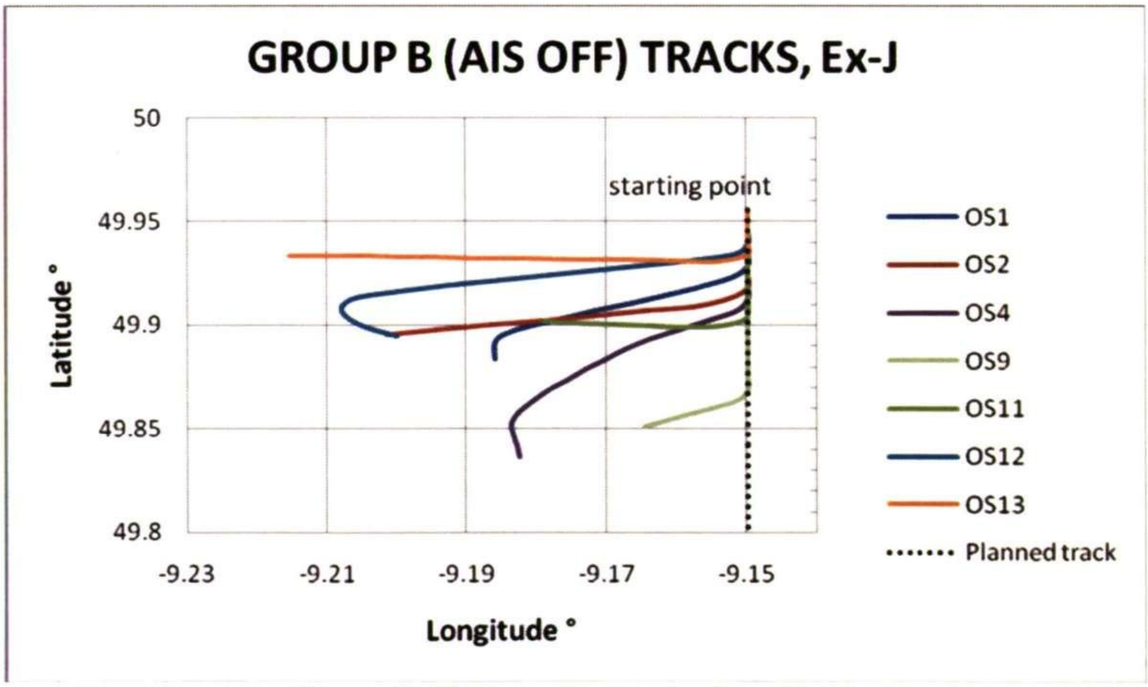

Figure 7-17 Own ship tracks from Ex-J

Table 7-10 shows the data collected regarding the action taken by the participants. Among the 12 participants, the distance at which action was taken was 8.09 nm from the TG1 (TCPA: 9.98 min.). Group A took action at 8.36 nm from TG1 (TCPA: 10.37 min.), while Group B did it at 7.82 nm (TCPA: 9.63 min.). Group A took earlier action than Group B by 0.74 minutes of the TCPA.

Group	A (Ex I)						B (Ex J)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Action range (nm)	9.71	7.29	8.36	10.3	4.3	*	8.36	6.92	5.92	1.8	7.82	9.71	9.2
Median (SD)	8.36 (2.37) nm (exempt OS10)						7.82 (2.68) nm						
Total Median (SD)	8.09 (2.49) nm												
Action	A/S	E(-); A/S	E(-); A/S	E(-); A/S	A/S	*	A/S	A/S	A/S	A/S	E(-); A/S	A/S	A/S
TCPA (min.)	12.1	8.28	10.3	12.8	8.05	*	10.3	9.33	7.88	3.51	9.63	12.0	11
Median (SD)	10.37 (2.17) min. (exempt OS10)						9.63 (2.86) min.						
Total Median (SD)	9.98 (2.55) min.												
Key	A/S: Altered course to Starboard; E(-): Engine reduction; *:No action												

Table 7-10 Action time for Ex-I/J

Table 7-11 shows the data collected regarding the passed distance to the TG1 and off-track distance taken by the participants. Among the 13 participants, the passed distance achieved was 2.21 nm. Group A took closer passed distance to the TG1 than Group B by 1.41 nm. An alteration of course back to the planned track indicates that the threat of collision from the TG1 no longer exists. Group A took 1.25 nm off the planned track before heading back, while Group B took 1.53 nm off the course. In terms of off-track distance, Group A spent less distance off the original course (0.28 nm less) when considering the collision threat coming from TG1.

Group	A (Ex-I)						B (Ex-J)						
OS	3	5	6	7	8	10	1	2	4	9	11	12	13
Passed distance (nm)	2.739	1.61	2.08	2.20	1.48	0.95	3.25	4.36	2.16	1.34	3.93	2.48	5.65
Median (SD)	1.85 (0.63) nm						3.26 (1.46) nm						
Total Median (SD)	2.21 (1.35) nm												
Off-track distance (nm)	2.189	1.17	1.32	1.47	0.71	0	1.52	2.18	1.42	0.66	1.22	2.18	2.74
Median (SD)	1.25 (0.74) nm						1.53 (0.71) nm						
Total Median (SD)	1.43 (0.75) nm												

Table 7-11 Passed distance achieved and off-track distance for Ex I/J

Ex-I/J was also testing participants' behaviours concerning a target ship (TG1) slowing down. Compared to Ex-E/F and Ex-G/H (see Section 7.3.3 and Section 7.3.4), the own ship was quickly given way by the oncoming TG1 by means of engine reduction. For Group A participants, act made by TG1 cannot only be obtained from ARPA/RADAR but AIS dynamic data can reflect the use of engine from TG1.

7.4 Evaluation and assessment

The differing designs of the five simulation trials can be classified by the collision avoidance geometries and actions taken by the target vessels. In terms of collision avoidance geometries, the five scenarios embrace head-on, crossing and overtaking situations at the initial time of meeting. In the actions taken by the target vessels, some target vessels give way to the own ship, while other target vessels do not take any action despite a developing small CPA. With access to AIS functions, participants in Group A were able to obtain further details about the traffic, including ROT information, engine-change information, voyage data and navigational status. The evaluation and assessment will cross-check the time of collision avoidance action, the collision avoidance behaviour and the off-track distance taken.

7.4.1 Action time evaluation

The average time for mariners taking anti-collision action in the 5 scenarios indicates that those in Group A tended to act earlier than Group B (Table 7-12). A considerable time difference in action taking was found in Ex-A/B, Ex-E/F and Ex-G/H. The use of a non-parametric test in paired populations is intended to assess the significance of the impact of the controlled variable. The controlled variable in this experiment is the availability of AIS information (see Section 5.3.7).

Descriptive & Statistical results / Exercises		Ex-A/B	Ex-C/D	Ex-E/F	Ex-G/H	Ex-I/J
TCPA results	Group A (min.)	**14.59**	10.81	9.83	12.73	10.33
	Group B (min.)	**11.55**	10.01	7.87	9.84	9.18
	Subtraction (min.)	**3.04**	0.8	1.96	2.89	1.15
	$\left\| \frac{A - B}{B} \right\|$	**26.32%**	7.99%	24.90%	29.37%	12.53%
Statistical results	Group A Median (min.)	**15.03**	10.17	10.59	11.67	10.37
	Group B Median (min.)	**12.05**	10.33	7.93	11.15	9.63
	Mann Whitney U	**6.000**	20.000	12.000	8.500	12.000
	p-value (5%)	**0.032**	0.886	0.199	0.234	0.372
Key	U: a statistic reflects the smaller total of ranks; Bold results are tested significantly; Degree of freedom is 1 for the 5 pairs of exercises.					

Table 7-12 Average action time and MW test results

In Ex-A/B, the Group B participants only had a returned echo that, through a calculation from ARPA, showed a target vessel with a reciprocal course to the OS. Not only was there a 26.32% time difference in TCPA/action time, but a significant difference was also found in Ex-A/B (head-on situation). The null hypothesis (*Ho*) was then rejected. Therefore, the two populations (AIS and non-AIS groups) were not identical in terms of the TCPA at which action was taken. The results mean that, in the Head-on situation (Ex-A/B), Group A participants (Median = 15.03 minutes; AIS available) were significantly quicker in taking anti-collision action than Group B participants (Median = 12.05 minutes; AIS not available), MW U=6.000, $p<0.05$.

In Ex-E/F, a target ship (TG3) initially behind beam overtook the OS and altered course towards the OS, with a small CPA as a consequence. Both groups of participants took action after the TG3 became a bow-crossing rogue. Although, Group A participants took action 24.9% earlier than the Group B participants (see Table 7-11), the result was not sufficient to report a significant difference between the two testing groups. Statistically, Group A participants (Median = 10.59 minutes) did not seem to differ greatly in action time to Group B participants (Median = 7.93 minutes), with a MW U=12.0 and p>0.05.

In Ex-G/H, a target ship (TG1) that displayed herself as a ferry crossing the channel by showing her heading and destination (only available for Group A) altered course to port. On average, Group A took action earlier than Group B by 29.37% when considering the TG1 (see Table 7-11). However, the statistical result was again not sufficient to report a significant difference between the two testing groups. Group A participants (Median = 11.67 minutes) did not differ to a great extent in their action time when compared to Group B participants (Median = 11.15 minutes), with a MW U=8.5 and p>0.05.

Because Group A took action over 20% earlier, AIS did have an impact on the action time of participants, especially in the Head-on situation (Ex-A/B), the Overtaking scenario (Ex-E/F) and the TSS meeting (Ex-G/H). In the MW test, Group A participants took action significantly earlier than Group B participants regarding the approaching target in Ex-A/B (Head-on situation).

7.4.2 Collision avoidance behaviour

The participants took action in the simulation trials before the concerned vessel came into an 'In sight' situation. Rule 19 of COLREGs was commonly considered in this. In summary, the Rule advises not altering course to port if the encountered target is forward of the ship's beam. All 5 scenarios involved encountering target vessels when the developing collision risks with the own ship were ahead of the own ship's beam.

In meeting with a head-on fishing boat (Ex-A/B, Head-on meeting), both groups of participants altered course to starboard. In Ex-C/D (R18 meeting), one Group A (AIS on) participant decided to alter course to port after an acknowledgment of the privileged vessel. A concern was also raised by presence of developing traffic on his starboard side. In Ex-E/F (overtaking scenario), none of the group A participants altered course to port, whereas 2 out of 7 Group B participants did. The lack of an operating area on the own ship's starboard side was mentioned, with the target coming from the starboard. In Ex-G/H (TSS meeting), only 1 Group B participant altered course to port. In Ex-I/J (Speed meeting), no member of the two groups altered course to port. Generally, there were greater differences in collision avoidance manoeuvring in Group B. However, Rule 19 was not intended to prevent OOWs altering course to port when a potential target is ahead of beam. The situation regarding emergency and traffic patterns might also influence an OOW's decision (see Rule 2 (b), COLREGs).

The actions being taken by the participants showed little confusion about compliance with COLREGs in the five pairs of exercises. Hence, the 'potential encounter' situation, where two ships would pass within half a mile of each other in the absence of avoiding action (Lewison 1978), was generally achieved. Finally, the 'actual encounter' situation, where two ships eventually pass within half a mile of each other, was well avoided. According to R19 COLREGs, action should be taken before being in sight by two vessels in a potential encounter situation. The Rule emphasises that CQS can be avoided by action taken by two meeting vessels not in sight (Table 7-13). Overall, Group A with AIS information needed less time to pass the threat. The recognition that the vessel encountered was taking action and a knowledge of its identity was found useful in situation awareness for collision avoidance.

Vessel 2 \ Vessel 1	Action taken	Action not taken
Action taken	R19 applied	Risk may exist
Action not taken	Risk may exist	CQS

Table 7-13 Action taken before 'in sight'

7.4.3 Off-track distance

According to the standing order (see Section 5.3.6) on the simulator bridge, the participants should alter course back to the planned track after the risk of collision is cleared. The off-track distances for the five pairs of exercises are shown in Table 7-14. Considerable range differences in off-track distance were found in Ex-C/D, Ex-E/F, Ex-G/H and Ex-I/J.

Descriptive & Statistical results \ Exercises		Ex-A/B	**Ex-C/D**	Ex-E/F	Ex-G/H	Ex-I/J
Descriptive results	Group A (nm)	1.69231	**1.51042**	0.26667	0.30952	1.145455
	Group B (nm)	1.74725	**2.39286**	0.54142	0.56327	1.709091
	Subtraction (nm)	-0.05494	-0.88244	-0.27475	-0.25375	-0.56364
	$\left\lvert \frac{A-B}{B} \right\rvert$	3.14%	**36.87%**	50.74%	45.04%	32.98%
Statistical results	Median (Group A)	1.50 nm	**1.45 nm**	0.03 nm	0.24 nm	1.25 nm
	Median (Group B)	1.66 nm	**2.19 nm**	0.51 nm	0.06 nm	1.53 nm
	Mann Whitney U	18.500	**7.000**	11.500	19.000	12.000
	p-value (5%)	0.72024	**0.04520**	0.16876	0.77171	0.19606
Key	U: a statistic reflects the smaller total of ranks; Bold results are tested significantly; Degree of freedom is 1 for the 5 pairs of exercises.					

Table 7-14 Average off-track distances and MW test results

In Ex-C/D (crossing a privileged ship), Group A participants obtained the status of the encountered target ship (TG3) as a NUC cargo ship. After the course alteration to the TG3, Group A participants decided to head back to the planned track much quicker than those in Group B. Furthermore, a significant difference was found in this scenario. The null hypothesis (*Ho*) (see Section 5.3.7), that the two populations (Group A and Group B) with a control on the given AIS information would be identical in their off-track distance performance, was then rejected. Group B (Median = 2.19 nm; AIS off) was taking a significantly wider off-track distance than Group A (Median = 1.45 nm; AIS on), with MW U=7.000 and $P<0.05$. On average, nearly 9 cables difference (36.87%) was measured between the two groups.

In Ex-E/F, the encountered ship (TG3) altered course towards the own ship and intended to cross the own ship ahead. The only advantage that Group A participants had was the ability to obtain TG3's information from AIS in terms of ship type, COG/SOG and ROT during the course alteration. As a result, half of the participants in Group A slowed down the own ship's engine without leaving the planned track. On average, over 2 cables difference (50.74%) was measured between the 2 groups in terms of off-track distance. Nevertheless, the statistical result was not sufficient to report a significant difference between the two testing groups. Group A participants (Median = 0.03 nm) did not seem to differ in off-track distance when compared to Group B participants (Median = 0.51 nm) with a MW U=11.5 and $p>0.05$.

In Ex-G/H, the own ship initially encountered a channel crossing target ship (TG1). As opposed to the scenario in Ex-E/F, the TG1 in Ex-G/H altered course to give way to the own ship (a TSS transit vessel). Both groups could obtain target tracking on their ARPA/RADAR. In addition, Group A participants could obtain TG1's information via AIS regarding destination (heading for Calais), ship type (ferry) and near real-time dynamic data. With TG1's voyage (destination) and static information (ship type), Group A was able to positively identify TG1 as a channel crossing ferry. Hence, Group A took earlier action to TG1 than Group B in terms of the TCPA. Later, TG1 altered course to port, and the marginal difference could be obtained by Group A participants because AIS is able to report TG1's dynamic information (mainly the ROT data). Apart from the participants slowing their engine down, some participants in Group A altered course back to the planned track soon after the course alteration of TG1 was noticed. On average, over 2 cables difference (45.04%) was measured between the 2 groups in terms of off-track distance. Nevertheless, the statistical result was again not sufficient to report a significant difference between the two testing groups. Group A participants (Median = 0.24 nm) did not seem to differ in off-track distance to Group B participants (Median = 0.06 nm), with MW U=19.0 and $p>0.05$.

In Ex-I/J, the own ship encountered a fast approaching target ship (TG1) in a crossing situation. Similar to the Ex-G/H, where the encountered target ship gives way to the own ship, the TG1 in Ex-I/J also gives way by slowing down its speed. In comparison to Group B, Group A participants were able to notice the TG1's ship type as an HSC and a near real-time engine change. It is supposed that Group A would have a clear message via AIS revealing that the TG1 is actually slowing down compared to the own ship. On average, over 5 cables difference (32.98%) was measured between the 2 groups in terms of off-track distance. Nevertheless, the statistical result was not sufficient to report a significant difference between the two testing groups. Group A participants (Median = 1.25 nm) did not seem to differ in off-track distance to Group B participants (Median = 1.53 nm), with MW U=12.0 and p>0.05.

Although significant differences were not found in Ex-E/F, Ex-G/H and Ex-I/J, a range difference of over 30% was measured between the two groups. On average, Group A participants did spend less time completing a collision avoidance manoeuvre. According to the MW test, Group A participants were significantly quicker than Group B participants in tackling the approaching threat in Ex-C/D (R18 meeting).

7.5 Conclusions

The simulator trials assumed that every vessel (target ships and own ship) in the experiment would send associated information and accurate movement data promptly. Although it is not the case in reality, the potential bias for the trials in terms of human factors, limitations of electronic systems, and reality environmental elements, were exempted. According to the proposed trials, the only controlled variable was the AIS information in between the two testing mariner groups. It is aimed to measure the marginal effect of AIS operation for the bridge lookout operation.

The simulation trials provided an insight into how OOWs behave when additional information of AIS was available on the bridge. The research used the TCPA at which action was taken as well as off-track distance to evaluate the impact of AIS assisted RADAR operation. On the whole, Group A took action quicker than Group B when considering the encountered target ship, with a difference of over 20% in three of the simulated scenarios. In terms of the time spent on collision avoidance manoeuvring, Group A spent less time/off-track distance before heading back to the planned track, with over 30% difference in four of the simulated scenarios. Statistically, significant differences were found in Ex-A/B (Head-on meeting) for by action time and in Ex-C/D (R18 meeting) for off-track distance.

The hypothesis regarding AIS data was rejected by the controlling variable, i.e. AIS information. As a result, the added AIS information did affect the decision making result for collision avoidance by the comparison between the two groups. The group with AIS assisted bridge system, under the guidance of COLREGs, represent more promptly action toward the approaching targets. Furthermore, the significant difference in the discipline of off-track distance reflected the group with AIS information did spend less time in clearing approaching collision risks. The overall situation awareness by the assistance of AIS information has been improved. As proposed idea that AIS assisted bridge operation provides OOWs a VTS-like image added into the current bridge system, subjects were able to take on this additional information and make a collision avoidance decision upon it.

Chapter 8

Conclusions

8.1 Introduction

The AIS is recognised by a number of reputable international organisations as a potential aid to navigation. With its unique working function, AIS does not only establish a self-determining communication network among the Class A vessels, but it enables data fusion among the bridge systems. A new string of data is available to the users. In particular, additional navigational data is presented to the OOWs. Nevertheless, AIS itself is not mature enough to be taken for a full-scale collision avoidance. For example, SOLAS vessels that were built before the AIS carriage requirement were allowed to carry an interim and basic AIS display (i.e. MKD) onboard. Only new-built SOLAS vessels after July 2008 will have to carry an integrated AIS into the bridge system. This has resulted in the majority of the OOWs being left with compromised display of AIS information in terms of links to other bridge systems and functional display. In addition, there has not been any compulsory training for operating AIS in collision avoidance.

The purpose of this research has been to examine issues relevant to operating shipborne AIS in bridge lookout. By studying collision cases, lessons from AIS involved cases were learnt to indicate caution in operation AIS on the bridge. By carrying out two consecutive surveys before and after the official AIS carriage requirement, OOWs' perspectives on current AIS bridge operation were collected and analysed. By running a simulator experiment, AIS/bridge lookout operation was examined to study collision avoidance behaviour based on a full-scale bridge system fused with AIS information.

8.2 Research questions and hypothesis

The raised research question was, 'can AIS be useful in bridge lookout operation?' The aim of the research is to evaluate the effectiveness of AIS operation in the application of collision avoidance. The objectives of this research were:

1. To investigate the current status of shipborne AIS;
2. To investigate the issues related to bridge lookout;
3. And to evaluate OOWs' behaviours when using RADAR and AIS for bridge lookout.

The strategy for accomplishing the aim and objectives has been presented in Figure 1-1 and is reiterated in Figure 8-1.

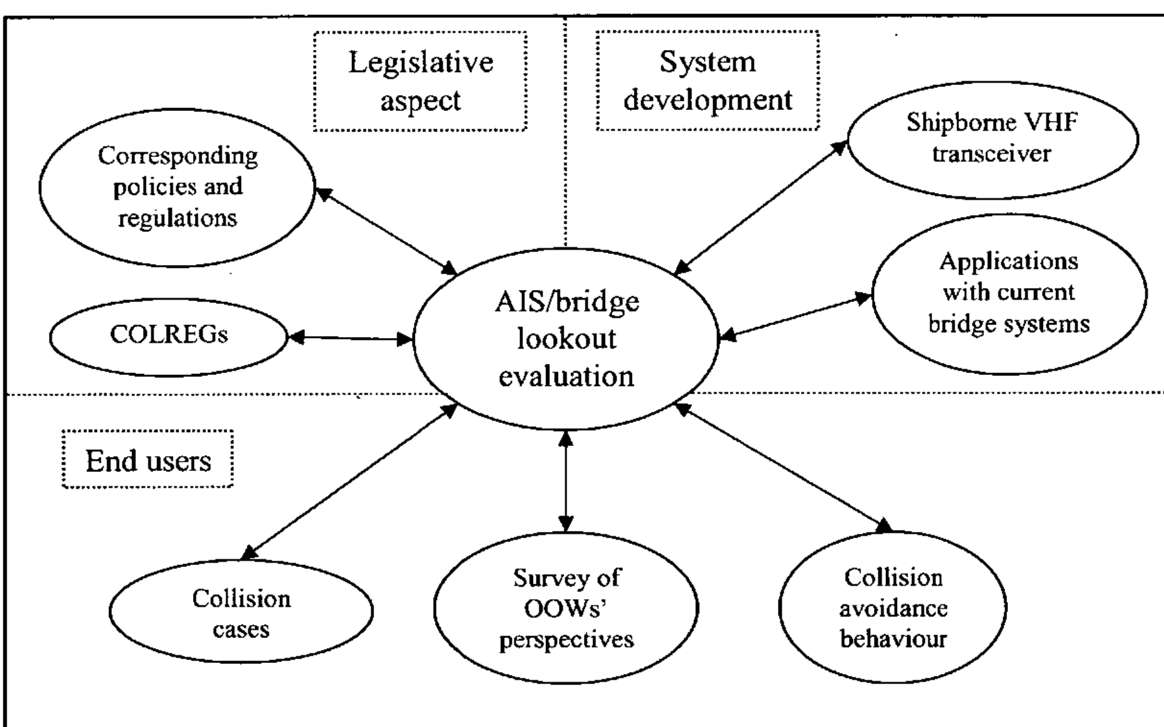

Figure 8-1 Strategy for AIS bridge operation evaluation

By addressing these objectives, the present study has made the following contributions to the existing literature (legislative aspect and system development) on AIS/collision avoidance operation. Firstly, the AIS assisted collision cases have indicated the danger of AIS/VHF operation in ship manoeuvring. From the OOW surveys, there was positive feedback supporting the use of AIS in collision avoidance operation. However, a concern about short-term underdevelopment was also raised by the same respondents. For example, the display by AIS MKD was criticised for the distance to the decision maker (mainly the OOWs) and a lack of interaction with other navigational aids. Next, collision avoidance behaviour was observed among the participating OOWs by carrying out the simulation trials. In this comparison, those participants with access to AIS information took collision action and completed collision avoidance manoeuvres quicker than the participants who did not have access to AIS.

8.2.1 Pre and post carriage requirement surveys

The AIS carriage requirement for SOLAS vessels was moved forward to an earlier time schedule (See Section 2.4.1.1). Recently, AIS-assisted collision cases have taken place before and after the official date. Without an associated training requirement and consensus for AIS bridge operation applications, the Class A end users were left alone in operating the newly introduced equipment. From the survey findings, the respondents showed neutral opinions toward the changed timescale of AIS carriage requirement as indicating the act was mainly for improving security measure from the sea. Nevertheless, opinions on the application for AIS bridge operation was shifted from collision avoidance in Survey I (pre carriage requirement) to Communication in Survey II (post carriage requirement). The follow-up research was carried out to investigate the concern for AIS communication application (see Section 8.2.3).

8.2.2 Ranking and ship type hypothesis for Survey II

Survey II not only revealed the attitude of the respondents, but the degree of this attitude was also studied under two distinct variables: respondents' ranking and the serving types of ships. A number of points were raised as the surveyed respondents did hold different point of view toward a few questions by their ranking and ship types. It is believed that ranking reflected sea experience and corresponding qualification. The variable of ship types showed opinions may differ onboard different type of ships or between onboard and onshore.

8.2.2.1 Null hypothesis testing: ranking

The null hypothesis was tested in two demographic variables in Survey II. The demographic variables (ranking and ship types) were tested in order to give a cross-sectional analysis. The assumption made for the hypothesis was that a difference in the attitude level given by the respondents was a matter of random error. The null hypothesis could be rejected unless a significant p value (less than 5%) was determined.

In this research, the null hypothesis relating to respondents' rankings was rejected in 8 items. In 7 of these items, the degree of attitude from the group of pilots was strongly different to that the other 3 groups (Master, Chief officer and Deck officer). In all but 2 of these 7 items, the pilots seemed to have strongly positive opinions compared to the other three groups in their view of:

- AIS in positioning application (Q11_2, Page K2, Appendix K);
- Cargo ships obeying COLREGs (Q20_1, Page K4, Appendix K);
- Naval ships obeying COLREGs (Q20_4, Page K6, Appendix K);
- HSC obeying COLREGs (Q20_5, Page K7, Appendix K);
- And ferry obeying COLREGs (Q20_7, Page K11, Appendix K).

In addition, the group of pilots also had a strongly positive view compared to the group of chief officers in VLCC obeying COLREGs (Q20_2, Page K5, Appendix K). The only item that the group of pilots were found to be significantly more pessimistic than the other three groups was the importance of VHF calling in collision avoidance operation (Q30_2, Page K12, Appendix K). The question of whether the different degree of attitude measured in the group of pilots was due to their ranking position or their serving area has been raised. This will lead to a further study identifying the significance of the view from the group of pilots.

The first hypothesis in Survey II assumed the difference found in the data collected among different ranking officers was due to random error. As a significant difference was found in a number of items, the research suggests that there is a significant difference in terms of respondents' rankings. In short, the ranking systems must refer to different qualification levels and the career of time spent at sea. The greatest significance was found between the group of pilots and the rest of the OOW groups.

8.2.2.2 Null hypothesis testing: serving ship types

The second hypothesis in Survey II was assumed the differences found in the data collected from OOWs' serving types of ships was due to random error. As significance was found in a number of items, the research suggests that mariners who work for different types of ships may hold different points of view on certain questions.

In this research, the null hypothesis relating to respondents' serving types of ships was rejected in 7 items. The significant event is intended to indicate the difference in the attitude levels. Three null hypotheses were rejected in items of COLREGs compliance:

- Fishing boat obeying COLREGs (Q20_3, Page K9, Appendix K): respondents working on container ships are more optimistic about a fishing boat following COLREGs than respondents who were working ashore.
- Naval ship obeying COLREGs (Q20_4, Page K10, Appendix K): with a more positive view than non-container ship respondents and a more negative view than sea/land shift respondents, respondents who working on container ships held neutral opinions on Naval ships/COLREGs.
- Ferry obeying COLREGs (Q20_7, Page K11, Appendix K): respondents working on non-container ships were more optimistic about a ferry following COLREGs than respondents who were working ashore.

There were three items that rejected the null hypotheses in terms of GNSS system attributes. Firstly, the respondents who were working on container ships had a more pessimistic view of GPS system accuracy (Q34_1, Page K14, Appendix K) and GPS coverage (Q34_3, Page K16, Appendix K) than respondents who were working ashore. Secondly, the respondents who were on container ships had a more pessimistic view of GPS system integrity (Q34_2, Page K15, Appendix K) than the respondents who were working on non-container ships.

The only item on which the null hypothesis was rejected with a significant difference between non-container ships and sea/land shift respondents related to the views on the positioning accuracy of a visual lookout (Q31_2, Appendix K). The respondents working on non-container ships were more optimistic about this than respondents who were working ashore.

Significant events were found among the selected variable (ship types). Different points of view existed in the survey regarding COLREGs compliance and GNSS performance.

8.2.3 The use of VHF in ship manoeuvring

In Section 3.4.3, it was shown that the introduction of AIS could reduce the time spent on the air as ship identification would no longer an issue for most SOLAS ships. Nevertheless, an increased usage of AIS-assisted VHF calling for collision avoidance was identified by the recent AIS-assisted collision cases (see Section 4.2). Firstly, an inadequate procedure for taking VHF communication existed. Secondly, the danger of misunderstanding between two or more ships' OOWs in exchanging intention of ship manoeuvring cannot be ignored (See Section 3.4 & Appendix A).

In this research, the VHF-assisted ship manoeuvring was broadly discussed in the literature review and a few mistakes were discussed in the collision case study. As an extended study from Survey I, Survey II revealed a distinct finding on this issue. An alarming result was raised by the research as 60% of the respondents agreed that there are difficulties in making communication contact with another vessel by VHF, yet 180 out of 190 deep sea deck officers still use VHF in collision avoidance (82% will use VHF in CQS). Moreover, there were indications that AIS would encourage these respondents to use VHF in collision avoidance manoeuvre because of the prompt target identification. A further study should be made monitoring the convenience of VHF calling when assisted by AIS, to see if this would increase the amount of VHF calling in ship manoeuvring, or whether this might cause infringements of the COLREGs.

8.2.4 AIS enhanced bridge lookout operation

AIS was defined as an assistance to the current bridge system (See Section 2.4.1.3). In terms of electronic aids in collision avoidance, AIS is designed to support extra information to RADAR in terms of its unique GNSS based manoeuvring data and VHF information link. In terms of adding information to the bridge operation, AIS is designed to support OOWs with independent information that is different to RADAR. As a result, the comparison of bridge simulation between RADAR bridge operation and AIS added RADAR bridge operation was completed.

The simulator experiment aimed to discover the effects on behaviour when AIS was added to the bridge lookout operation. The hypothesis assumed that any difference in both the TCPA at which anti-collision action was taken and off-track distance was due to a random error.

8.2.4.1 Target Detection

In Section 3.2, RADAR and visual lookout have raised issues that the coverage for targets at sea is not perfect. With additional traffic detection from AIS, it is believed the OOWs can have a better target detection if three methods are used (based on the illustration of Figure 3-9). To be able to measure the adding effect, the simulator trials have placed a comparably small fishing trawler as a potential encounter target (see Section 7.3.1). A significant result was found between the two groups in terms of action time. Compared to having small target on Group B's RADAR screen, Group A did not have any delay in detecting the target in terms of its position, navigational data and ship types. A prompt action was followed since Group A participants realised the approaching target becomes a potential encounter risk.

8.2.4.2 Target classification

In Section 3.5.3, privileged status can be obtained by 'AIS navigational data' much earlier than any other methods on the bridge. A significant result was found in meeting a privileged vessel. The simulator group with AIS information spent less time in avoiding the coming collision risk (the privileged vessel) in terms of the off-track distance (see Section 7.3.2 & Section 7.4.3). As the other group did not have any information regarding the navigational status on the crossing vessel, AIS was proved significantly effective where early situation awareness was achieved by the group of AIS equipped bridge.

8.2.4.3 Target Tracking

Based on the Figure 3-8 in Section 3.3.2.2, a robust detection of course and speed change can be obtained via AIS dynamic data. The simulator experiments undertook three tests of dynamic data performance: Test of ROT information (see Section 7.3.3 & Section 7.3.4) and Test of Speed Change (see Section 7.3.5). In between the two testing groups, Group A (AIS assisted bridge operation) took collision avoidance action quicker than Group B (RADAR only) by 25% in ROT test and 12% in Speed change. Nevertheless, the results were not tested significantly. As a result, although the controlled variable was the availability of AIS information, the hypothesis was not rejected. It is assumed that any difference in the TCPA at which anti-collision action was taken was due to a random error.

8.3 Research contribution

The contribution of the research can be listed as follows:

- Current opinions of usage, expectation and concerns on the Class A AIS;
- A bridge operation survey based on the Far Eastern deep sea deck officers;
- A collision behaviour study based on an AIS-assisted bridge operation;
- The impact of AIS for future integrated bridge lookout operation.

8.4 Implications for theory

The survey of mariners showed support for AIS functions in bridge lookout, and the simulator trials also showed greater effectiveness over a traditional ARPA/RADAR ship manoeuvring operation. Early warning and positive intention awareness of a potential encounter target by AIS can contribute positively to decision making under the roof of COLREGs. In terms of a system's aspect, a redundancy check should be applied to benefit OOWs' decision making, while workload and over-reliance on electronic aids should be considered in an attempt to achieve a balance between man and machine. Mariners ought to study the balance between conventional navigational skills and advanced navigational aids.

8.5 Concern for further guidance and regulations

The research has identified the danger of AIS-assisted VHF communication in collision avoidance. The guidance for such cooperated usage shall be made related to both VHF-assisted collision avoidance and AIS-assisted ship identification with VHF calling.

The simulator results have shown significant results between the bridge equipped with AIS and the one without it. It could raise several concerns for AIS/collision avoidance, training guidance and COLREGs. Recommendations are made based on the research findings:

1. A full scale AIS carriage requirement including non SOLAS vessels;
2. Guidance for sub standard AIS (Class B) users for collision avoidance if a full scale AIS carriage requirement is not the case;
3. An standard display for AIS information on the bridge;
4. A sustainable training scheme to be developed for AIS ship manoeuvring;
5. A VHF calling procedure with regard to the access to the AIS information; and
6. Rule 18 COLREGs, to be considered in the condition of a restricted visibility.

8.6 Research limitations

A world-wide survey and simulator experiments for international deep sea deck officers were not carried out as the scale of the research would exceed the scope of this research.

The research was mainly carried out to the Class A AIS and the OOWs who are qualified to work on vessels under SOLAS Convention. As the opinions were collected unilaterally from the group of merchant navy officers, it is understandable that opinions may differ from the groups of naval officers, leisure craft users and fishing boat skippers. Nevertheless, a consensus interpreting the COLREGS was not reached between the merchant mariners and fishing vessels.

The simulator trials were tested on a full scale bridge with AIS fusion. It is acknowledged that it is still under progress for all SOLAS vessels to reach such higher standard of bridge integration. The simulator trials also assumed all vessels (SOLAS and non SOLAS vessels) to be fully registered in the AIS network although it is not the case in reality. For a full carriage requirement of AIS, the non SOLAS vessels may need to be considered either with an extended capacity for VHF radio transmission or a compulsory Class B carriage requirement is fulfilled among the sub standard vessels.

8.7 Further research

Due to the limitations of time and research conditions, a further research is planned to include more detail in the analysis and findings. This will include:

1. Samples reconsiderations:

   A total of 13 samples were collected, which was acceptable for the paired non-parametric test. Although the participants' ranking varied from junior officers to senior officers and pilot, a further analysis in terms of the ranking could not proceed. Future analysis should invite more OOWs in order to enable a further analysis of these variables.

2. A survey on an AIS fused RADAR operation:

   The AIS fused RADAR operation in collision avoidance has already been on trial for half of the simulator participants. SOLAS ships built after July 2008 will have an integrated display for both RADAR and AIS. Thus, increasing numbers of AIS enhanced RADARs should be expected. As the surveys showed support for training in AIS operation and the simulator experiments discovered significant of AIS enhanced bridge operation, a field survey upon AIS fused bridge operation would be essential to carry out in the near future.

3. Industry development:

   The simulator findings showed the impact of AIS operation in collision avoidance manoeuvring. Hence, an approved training curriculum and a standard AIS display/device with an international consensus should be developed. The aim of this training should be to achieve an international standardised procedure for shipborne AIS bridge lookout operation.

4. Non-human control of the ship bridge:

   In the system for aviation mid-air collision avoidance, the Traffic-alert and Collision Avoidance System (TCAS), two airplanes encountering a collision risk can be kept apart and directed by the TCAS. A prototype Collision Avoidance Advice System (CAAS) already takes into account the desired course of a sea vessel, the COLREGs, the ENCs and the handling characteristics of the vessel (Norris 1998). AIS provides an information platform that can be shared by all AIS users. Automated anti-collision manoeuvring could be carried out under a system that is able to take encounter targets into its calculations regarding COLREGs and come out with a best solution for collision avoidance. In applying TCAS, the key benefit for bridge lookout would be that intentional movement could be easily monitored. Two vessels with a potential encounter risk can obtain information about whether any collision avoidance manoeuvre has been taken by the other vessel. As a challenge to the conventional bridge lookout, this will need more thorough study in the near future.

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Appendix A

The regulations regarding the use of VHF in Collision Avoidance in the USA and UK

USCG RADIO WATCHKEEPING REGULATIONS

Regulations Requiring Monitoring and Listening to VHF Marine Radios

A charter boat whose radio was not tuned to the proper channel missed a severe storm warning. By the time the captain learned of the storm, it was too late to return to shore. The ship sank and a couple of persons died. A yacht in trouble off the west coast of Mexico and far from help saw a passenger ship. What should have been a quick rescue could have turned to disaster when the passenger ship (improperly) had its radio off. The yacht was able to attract the ship's attention, however, and was rescued. Misunderstanding of passing intentions by approaching vessels and near collisions have repeatedly been averted by working radios tuned to the proper channel.

Who regulates whom?

Three U.S. government agencies, the Federal Communications Commission, the National Telecommunications and Information Administration, and the U.S. Coast Guard; and two international organizations, the International Telecommunications Union and the International Maritime Organization; have each established marine radio watch keeping regulations. Regulations on radio watch keeping exist for all boats and ships --commercial, recreational, government and military, domestic and foreign– carrying marine radios.

International Telecommunications Union (ITU). ITU regulates all use of radio spectrum by any person or vessel outside U.S. waters. ITU rules affecting radio, which have treaty status in the U.S. and most other nations, are published in the ITU Radio Regulations. The ITU has established three VHF marine radio channels recognized worldwide for safety purposes:

Channel 16 (156.800 MHz) - Distress, safety and calling

Channel 13 (156.650 MHz) - Internship navigation (bridge-to-bridge)

Channel 70 (156.525 MHz) - Digital Selective Calling

International Maritime Organization (IMO). IMO regulates the outfitting and operation of most vessels engaged on international voyages, except warships. Most IMO radio regulations affect all passenger ships and other ships of 300 gross tonnage and upward. IMO rules affecting radio are promulgated in the Safety of Life at Sea (SOLAS) Convention which has been ratified in the U.S.

Federal Communications Commission (FCC) - the FCC regulates all sales, marketing, and, use of radios in the U.S., including those onboard any recreational, commercial, state and local government, and foreign vessel in U.S. territorial waters. These regulations are contained in Title 47, Code of Federal Regulations.

National Telecommunications and Information Administration (NTIA) - NTIA regulates all use of radio onboard any federal government vessel, including military vessels. NTIA rules do not apply outside the federal government.

U.S. Coast Guard (USCG) - The USCG regulates carriage of radio on most commercial vessels, foreign vessels in U.S. waters, survival craft, and vessels subject to the Bridge-to-Bridge Act (generally all vessels over 20m length) and operating in a Vessel Traffic Service (VTS) area.

Radio Watchkeeping Regulations

In general, any vessel equipped with a VHF marine radiotelephone (whether voluntarily or required to) must maintain a watch on channel 16 (156.800 MHz) whenever the radiotelephone is not being used to communicate.

Source: FCC 47 CFR §§ 80.148, 80.310, NTIA Manual 8.2.29.6.c(2)(e), ITU RR 31.17, 33.18, AP13 §25.2

In addition, every power-driven vessel of 20 meters or over in length or of 100 tons and upwards carrying one or more passengers for hire, or a towing vessel of 26 feet or over in length, as well, as every dredge and floating plant operating near a channel or fairway, must also maintain a watch on channel 13 (156.650 MHz) --channel 67 (156.375 MHz) if operating on the lower Mississippi River-- ; while navigating on U.S. waters (which include the territorial sea, internal waters that are subject to tidal influence, and, those not subject to tidal influence but that are used or are determined to be capable of being used for substantial interstate or foreign commerce). Sequential monitoring techniques (scanners) alone cannot be used to meet this requirement; two radios (including portable radios, i.e. handhelds) or one radio with two receivers, are required. These vessels must also maintain a watch on the designated Vessel Traffic Service (VTS) frequency, in lieu of maintaining watch on channel 16, while transiting within a VTS area. See 33 CFR §§ 2.36, 26, and 161; 47 CFR §§ 80.148, 80.308-309; NTIA: NTIA Manual Chapter 8.2.29.7.

Digital Selective Calling

Ships, where so equipped, shall, while at sea, maintain an automatic digital selective calling watch on the appropriate distress & safety calling frequencies [e.g. channel 70] in the frequency bands in which they are operating. If operating in a GMDSS Sea Area A1 may discontinue their watch on channel 16. However, ships, where so equipped, shall also maintain watch on the appropriate frequencies for the automatic reception of transmissions of meteorological and navigational warnings and other urgent information for ships.

Ship stations complying with these provisions should, where practicable, maintain a watch on the frequency 156.650 MHz for communications related to the safety of navigation.

ITU RR 31.17, 33.18, AP13 §25.2

Maritime and Coastguard Agency

MARINE GUIDANCE NOTE

MGN 324 (M+F)

Radio: Operational Guidance on the Use Of VHF Radio and Automatic Identification Systems (AIS) at Sea

Notice to all Owners, Masters, Officers and Pilots of Merchant Ships, Owners and Skippers of Fishing Vessels and Owners of Yachts and Pleasure Craft.

This notice replaces Marine Guidance Notes MGN 22, 167 & 277

Use of VHF as Collision Avoidance Aid

7. There have been a significant number of collisions where subsequent investigation has found that at some stage before impact, one or both parties were using VHF radio in an attempt to avoid collision. The use of VHF radio in these circumstances is not always helpful and may even prove to be dangerous.

8. At night, in restricted visibility or when there are more than two vessels in the vicinity, the need for positive identification is essential but this can rarely be guaranteed. Uncertainties can arise over the identification of vessels and the interpretation of messages received. Even where positive identification has been achieved there is still the possibility of a misunderstanding due to language difficulties however fluent the parties concerned might be in the language being used. An imprecise or ambiguously expressed message could have serious consequences.

9. Valuable time can be wasted whilst mariners on vessels approaching each other try to make contact on VHF radio instead of complying with the Collision Regulations. There is the further danger that even if contact and identification is achieved and no difficulties over the language of communication or message content arise, a course of action might still be chosen that does not comply with the Collision Regulations. This may lead to the collision it was intended to prevent.

10. In 1995, the judge in a collision case said "It is very probable that the use of VHF radio for conversation between these ships was a contributory cause of this collision, if only because it distracted the officers on watch from paying careful attention to their radar. I must repeat, in the hope that it will achieve some publicity, what I have said on previous occasions that any attempt to use VHF to agree the manner of passing is fraught with the danger of misunderstanding. Marine Superintendents would be well advised to prohibit such use of VHF radio and to instruct their officers to comply with the Collision Regulations."

11. In a case published in 2002 one of two vessels, approaching each other in fog, used the VHF radio to call for a red to red (port to port) passing. The call was acknowledged by the other vessel but unfortunately, due to the command of English on the calling vessel, what the caller intended was a green to green (starboard to starboard) passing. The actions were not effectively monitored by either of the vessels and collision followed.

12. Again in a case published in 2006 one of two vessels, approaching one another to involve a close quarter's situation, agreed to a starboard to starboard passing arrangement with a

person on board another, unidentified ship, but not the approaching vessel. Furthermore, the passing agreement required one of the vessels to make an alteration of course, contrary to the requirements of the applicable Rule in the COLREGS. Had the vessel agreed to a passing arrangement requiring her to manoeuvre in compliance with the COLREGS, the ships would have passed clear, despite the misidentification of ships on the VHF radio. Unfortunately by the time both vessels realised that the ships had turned towards each other the distance between them had further reduced to the extent that the last minute avoiding action taken by both ships was unable to prevent a collision.

13. Although the practice of using VHF radio as a collision avoidance aid may be resorted to on occasion, for example in pilotage waters, the risks described in this note should be clearly understood and the Collision Regulations complied with.

Appendix B

Simulator configuration and results of crossing situation in Dover Strait

1. Initial configuration on board channel crossing ferry

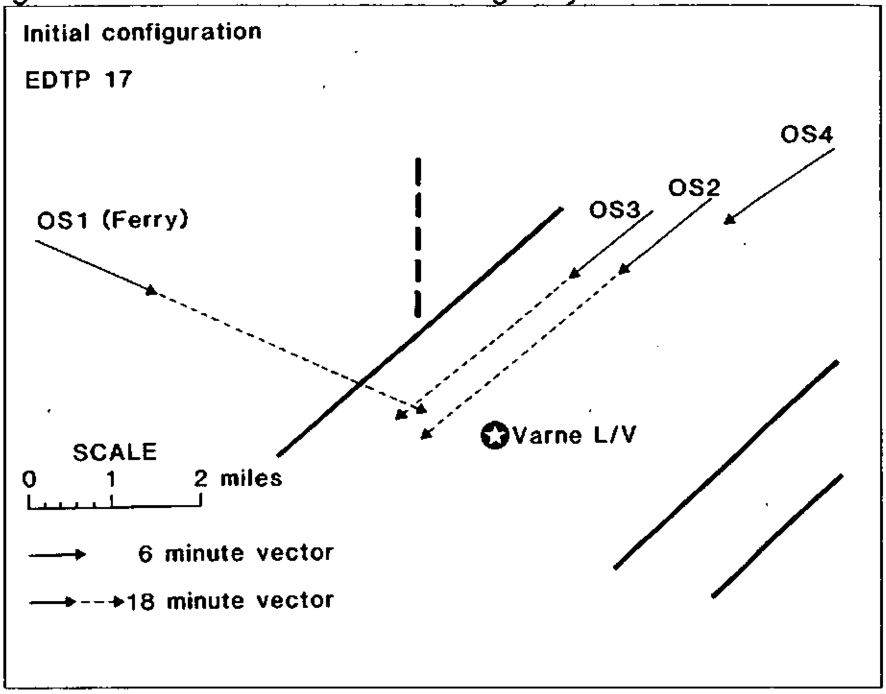

Figure B-1 Initial configuration on board channel crossing ferry (Redfern 1993)

2. Simulator results on board channel crossing ferry

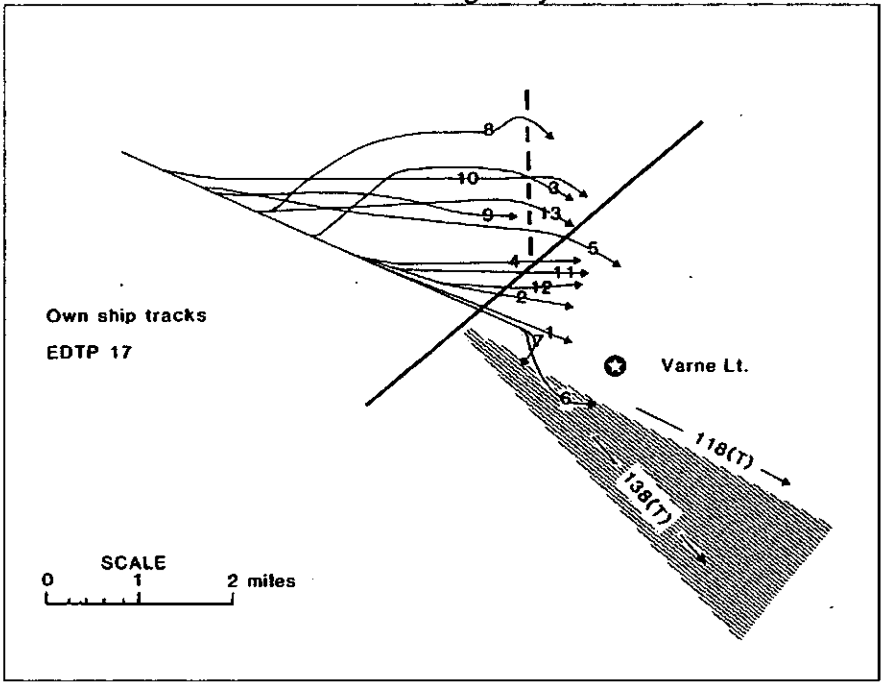

Figure B-2 Simulator results on board channel crossing ferry (Redfern 1993)

3. Initial configuration on board channel transit coaster

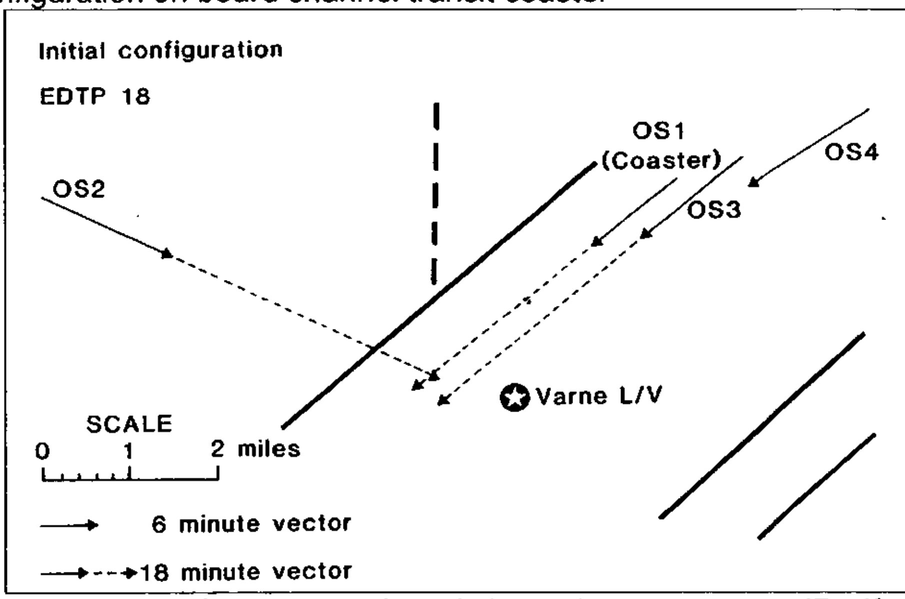

Figure B-3 Initial configuration on board channel transit coaster (Redfern 1993)

4. Simulator results on board channel-transit coaster

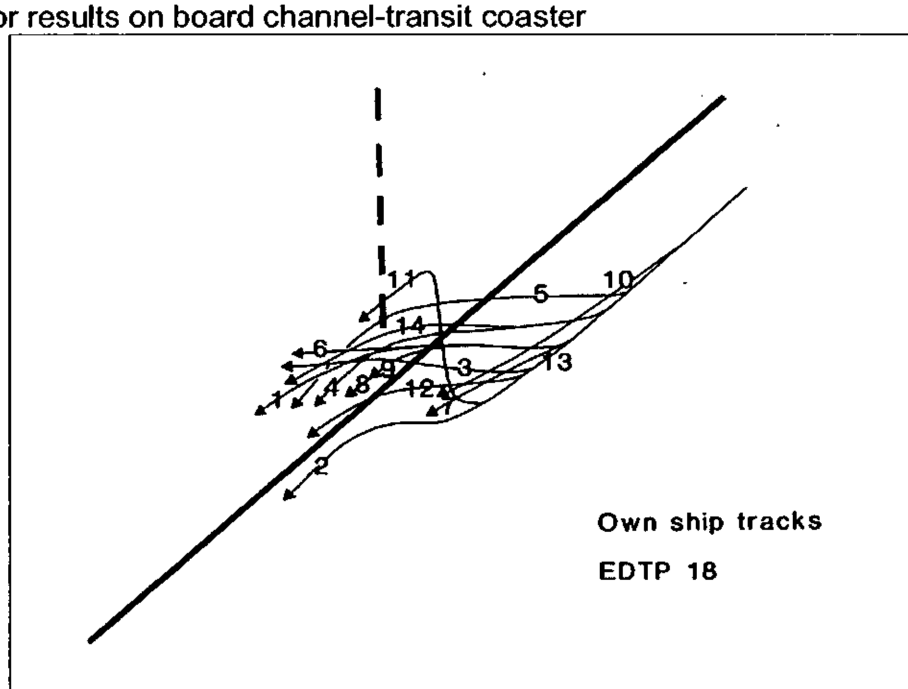

Figure B-4 Simulator results on board channel transit coaster (Redfern 1993)

5. Analysis of the simulated results
   In EDTP 17, 10 out 13 subjects (77%) on channel crossing ferry altered course to port (contrary to Rule 17(c) COLREGs) where four subjects had a late turn to port. The implication of keeping clear to the TSS transit vessels was discussed.

   In the absence of any constraint to starboard, the own ship was already to the right hand side of the TSS lane and the majority action in EDTP 18 was found an alteration of course to starboard (79%; 21% reduced the speed).

   The risk taken by subjects in EDTP 17 is apparent when compared with the positive action taken in EDTP 18. An extreme risk was suggested in altering course to port at close range in EDTP 17 when meeting ships gave way to the crossing ferry in EDTP 18.

Appendix C

The documents for simulator briefing

AIS the user's perspective

We would like to assure you that all replies will be treated in confidence and answers will be anonymous if used for research publication and thesis. We would like to illustrate seafarers' general views on AIS operation and how seafarers can benefit from the newly introduced bridge device. In theory, AIS aims to improve the safety of navigation at sea and also give better traffic efficiency without adding to the workload of officers on watch. The research project is to gather the opinions and experiences of users (mainly the Officer On Watch) regarding the operation of AIS in bridge operations.

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PL4 8AA
United Kingdom

Tel +44 (0) 1752 232977 or +44 (0) 777 1576903
Email hhsu@plymouth.ac.uk or hsuinuk@yahoo.com

1. Participant number: ....

2. Participant's initial: ....

3. What is your professional rank? (Please tick one)

   Master ❑ / 1st Mate ❑ / 2nd Mate ❑ / 3rd Mate ❑ / Cadet ❑ /

   Other (please specify) ❑ ....

4. Are You: Male ❑ / Female ❑

5. How many years have you been serving at sea? (Please tick one)

   Less than one year ❑ / 1 year to 5 years ❑ / 6 years to 10 years ❑ / 11 years to 15 years ❑ /More than 15 years ❑ / No experience ❑

6. What types of ships have you worked on in the past? (Please select all that apply)

   Bulk carrier ❑ / Tanker ❑ / Container ship ❑ /

   Cruise ship or Ferry ❑ / Naval ship ❑ / No experience❑ /

   Other (please specify) ❑ ....

<u>Thank you for taking time to participate in this simulator exercise.</u>

UNIVERSITY OF PLYMOUTH

FACULTY OF SCIENCE

Human Ethics Committee Consent Form

CONSENT TO PARICIPATE IN RESEARCH PROJECT / PRACTICAL STUDY

Name of Principal Investigator

Hua-Zhi HSU

Title of Research
Watchkeeper operation behaviour in ship collision avoidance

Brief statement of purpose of work

An observation on watchkeepers with potential electronic aids to navigation under the Collision Regulations

---

The objectives of this research have been explained to me.

I understand that I am free to withdraw from the research at any stage, and ask for my data to be destroyed if I wish.

I understand that my anonymity is guaranteed, unless I expressly state otherwise.

I understand that the Principal Investigator of this work will have attempted, as far as possible, to avoid any risks, and that safety and health risks will have been separately assessed by appropriate authorities (e.g. under COSSH regulations)

Under these circumstances, I agree to participate in the research.

Name: ....

Signature: .... Date: ....

UNIVERSITY OF PLYMOUTH

FACULTY OF SCIENCE

RESEARCH INFORMATION SHEET

Name of Principal Investigator

Hua-Zhi HSU

Title of Research

Watchkeeper operation behaviour in ship collision avoidance

Aim of research

To observe watchkeeper behaviour on the bridge operation when an action of collision avoidance takes place

Description of procedure

There will be 5 to 6 simulator trails after the briefing and a simulator warm-up session. Each session lasts 15-20 minutes and there will be short breaks between sessions.

Description of risks

A stress or distress may occur when a simulated risk of collision or near-miss situation develops.

Benefits of proposed research

Relationship between bridge operation and the Rules of the Roads can be identified.
Potential aids to navigation by Automatic Identification System can be tested.

Right to withdraw

Participants have every right to withdraw as his/her wish from the simulator trails at any time.

If you are dissatisfied with the way the research is conducted, please contact the principal investigator in the first instance: telephone number *[07771576903]*. If you feel the problem has not been resolved please contact the secretary to the Faculty of Science Human Ethics Committee: Ms Christine Brown 01752 232762.

Log Book

- Exercise.........:

- Exercise.........:

- Exercise..........:

- Exercise..........:

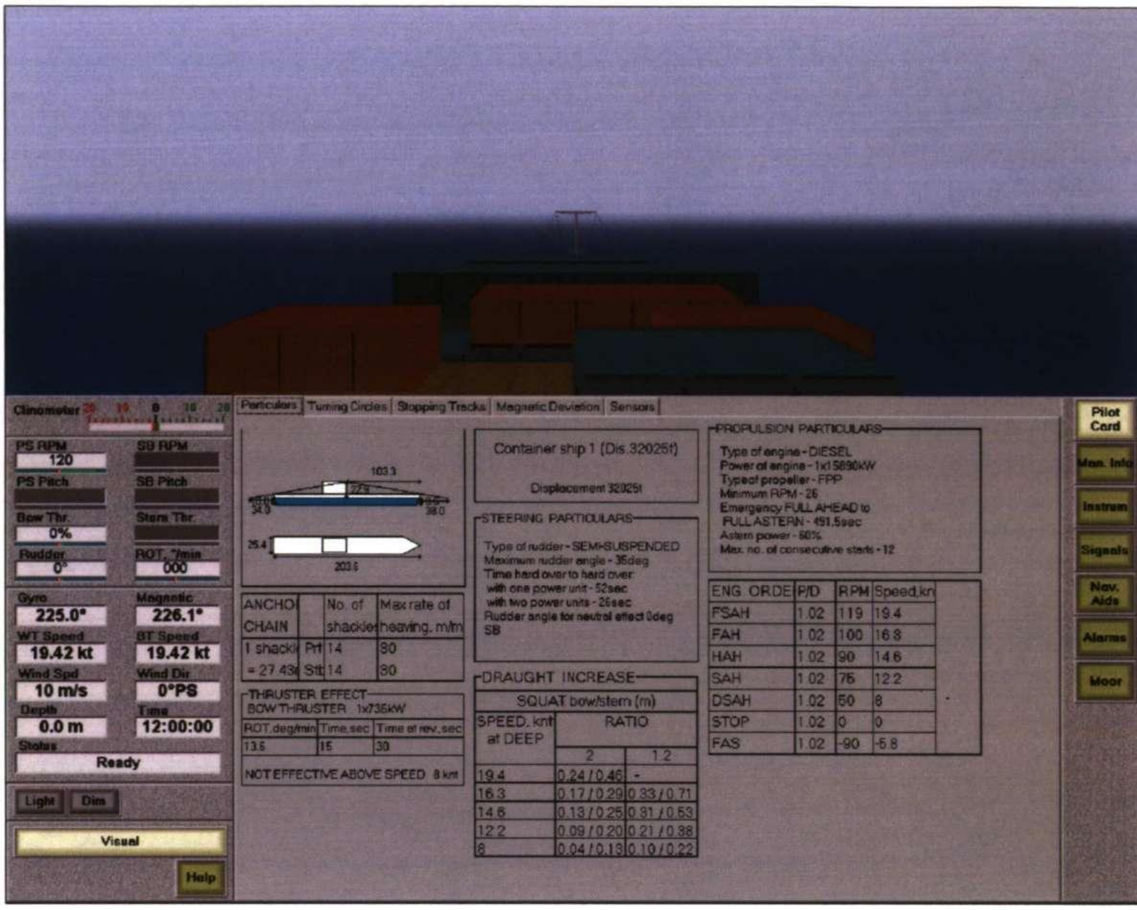
- Exercise..........:

Remark:

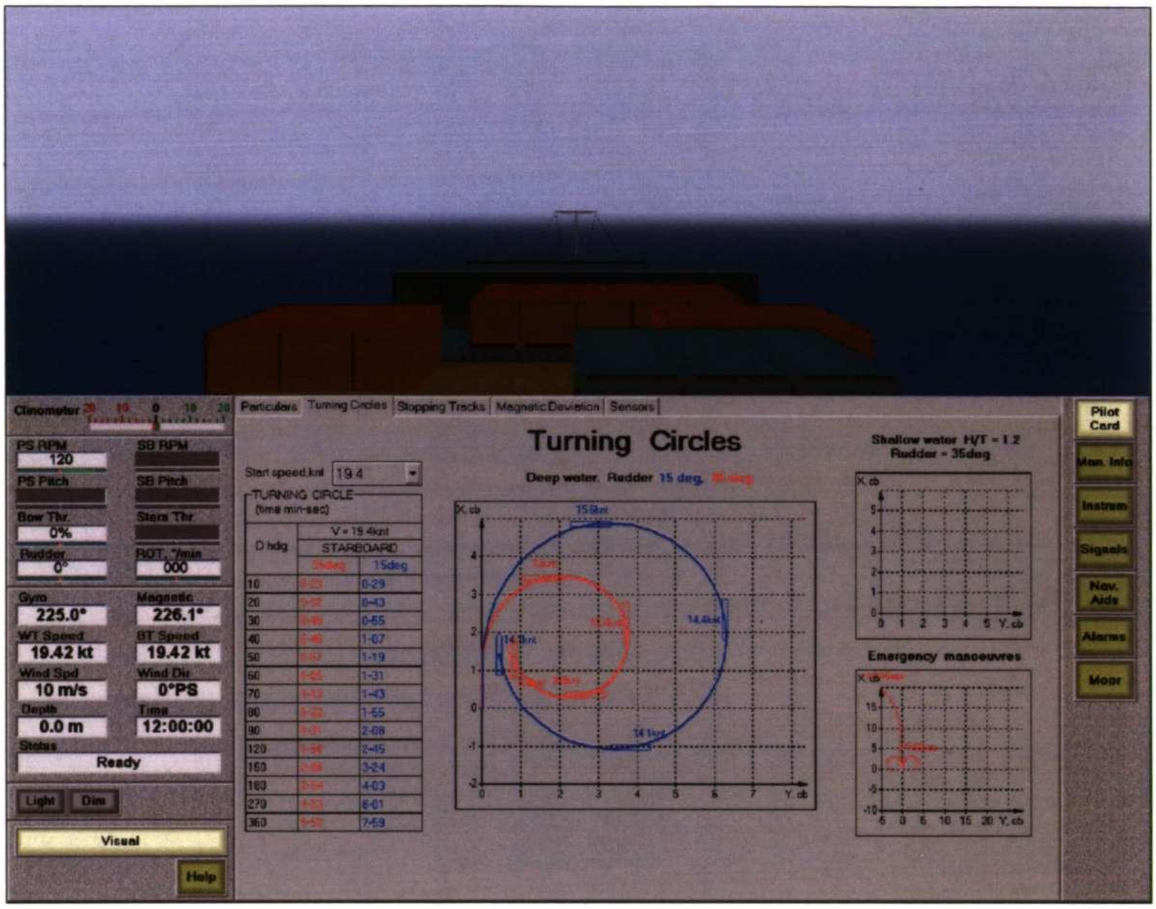
Appendix D

Simulator own ship's specifications

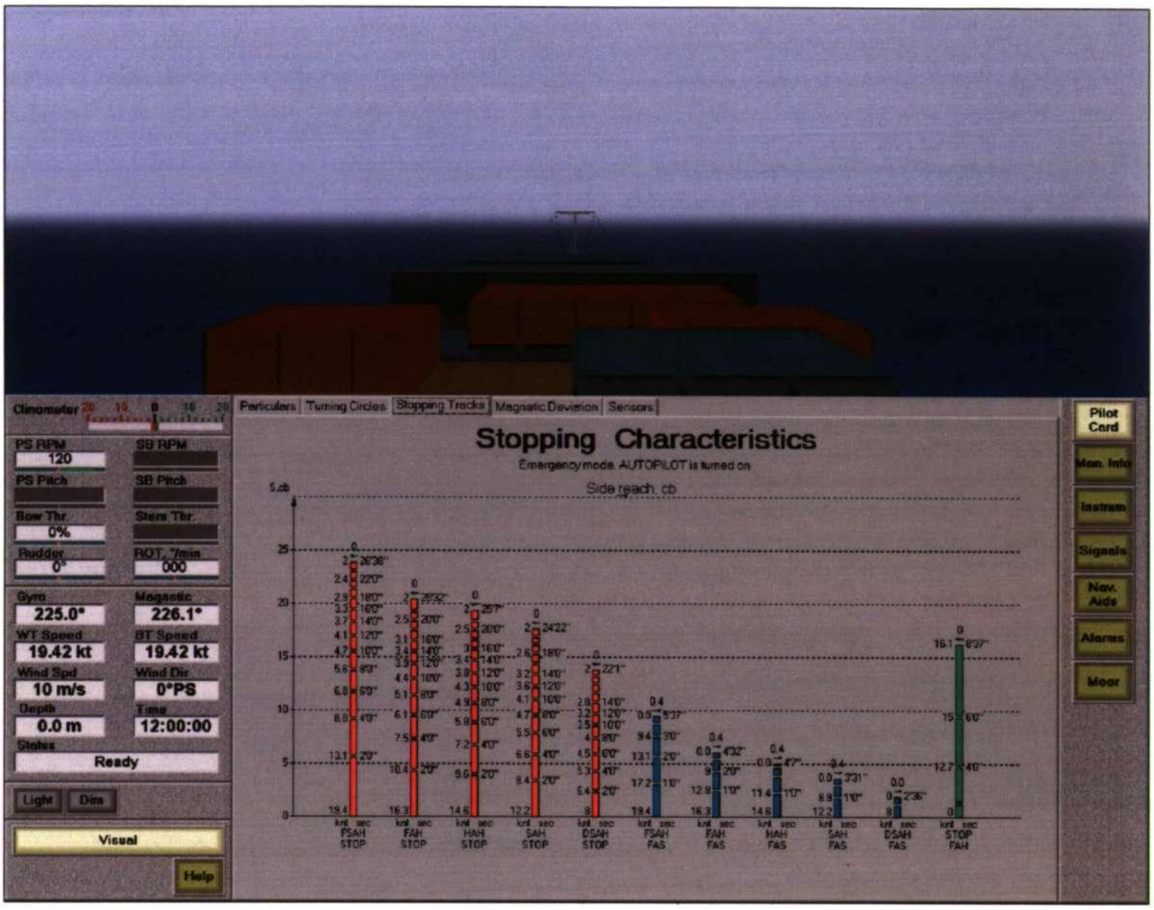
1. Ship particulars



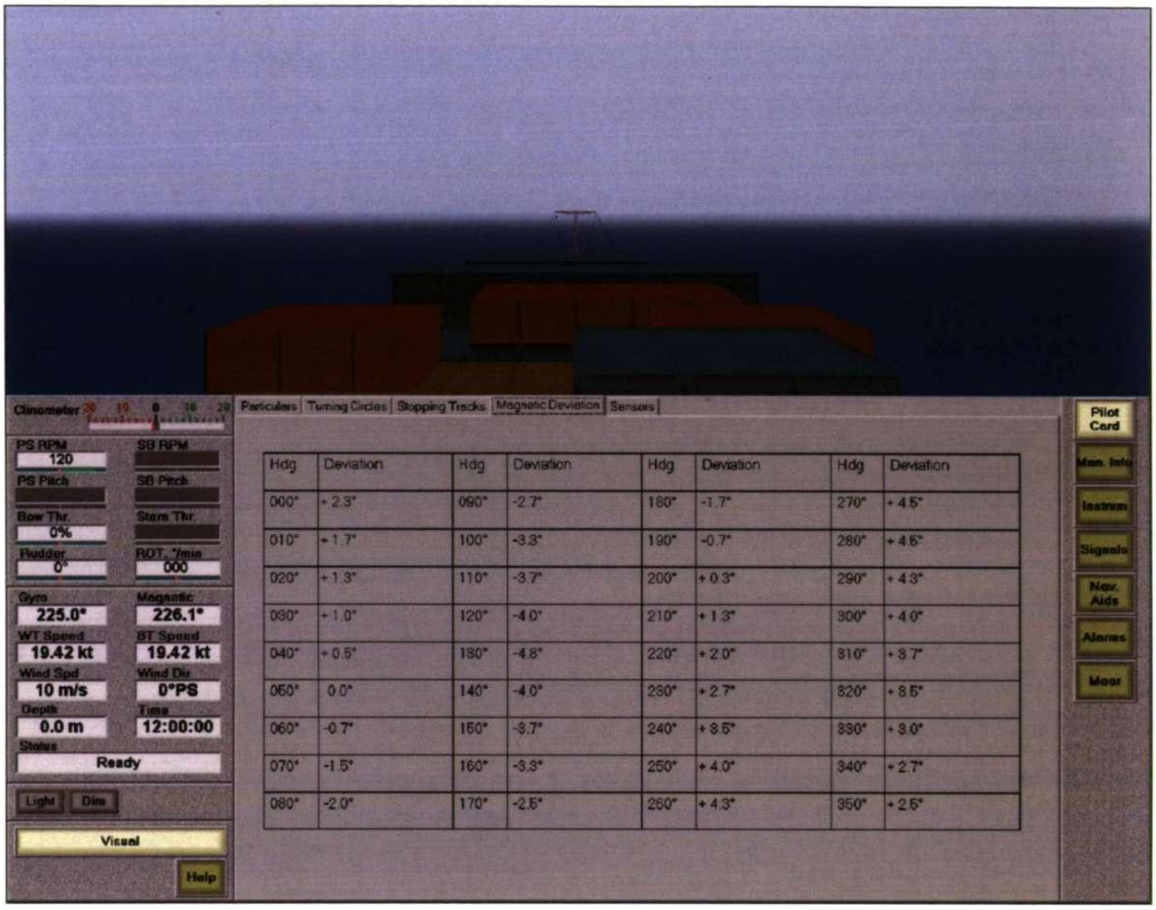
2. Ship turning circles at full sea speed



3. Own ship's stopping characteristics

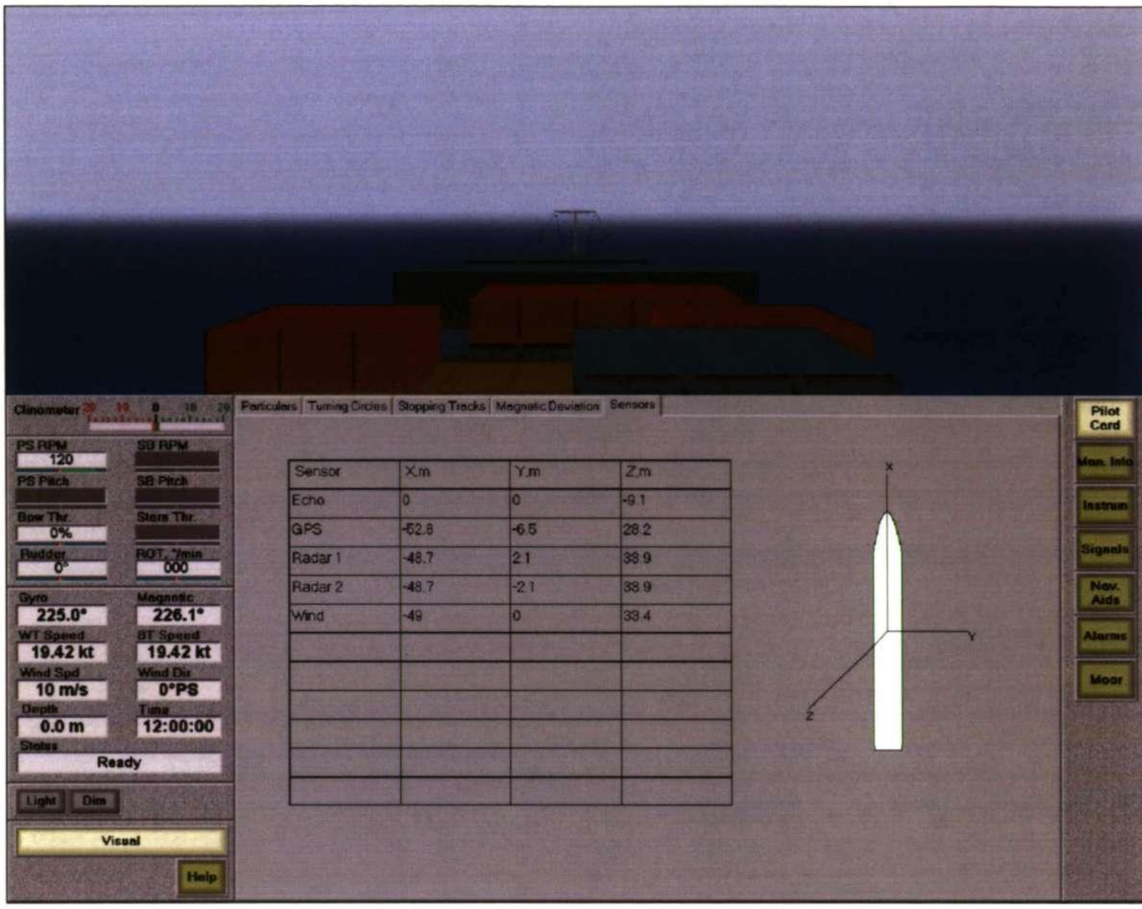


4. Magnetic deviation



Hdg	Deviation	Hdg	Deviation	Hdg	Deviation	Hdg	Deviation
000°	+ 2.3°	090°	-2.7°	180°	-1.7°	270°	+ 4.5°
010°	+ 1.7°	100°	-3.3°	190°	-0.7°	280°	+ 4.5°
020°	+ 1.3°	110°	-3.7°	200°	+ 0.3°	290°	+ 4.3°
030°	+ 1.0°	120°	-4.0°	210°	+ 1.3°	300°	+ 4.0°
040°	+ 0.5°	130°	-4.8°	220°	+ 2.0°	310°	+ 3.7°
050°	0.0°	140°	-4.0°	230°	+ 2.7°	320°	+ 3.5°
060°	-0.7°	150°	-3.7°	240°	+ 3.5°	330°	+ 3.0°
070°	-1.5°	160°	-3.3°	250°	+ 4.0°	340°	+ 2.7°
080°	-2.0°	170°	-2.5°	260°	+ 4.3°	350°	+ 2.5°

5. Sensors


Clinometer
PS RPM
120
SB RPM
PS Pitch
SB Pitch
Bow Thr.
0%
Stern Thr.
Rudder
0°
ROT, °/min
000
Gyro
225.0°
Magnetic
226.1°
WT Speed
19.42 kt
BT Speed
19.42 kt
Wind Spd
10 m/s
Wind Dir
0°PS
Depth
0.0 m
Time
12:00:00
Status
Ready
Light
Dim
Visual
Help
Particulars
Turning Circles
Stopping Tracks
Magnetic Deviation
Sensors
Sensor | X,m | Y,m | Z,m
Echo | 0 | 0 | -9.1
GPS | -52.8 | -6.5 | 28.2
Radar 1 | -48.7 | 2.1 | 38.9
Radar 2 | -48.7 | -2.1 | 38.9
Wind | -49 | 0 | 33.4
X
Y
Z
Pilot Card
Man. Info
Instrum
Signals
Nav. Aids
Alarms
Moor

Appendix E

Pilot-Study Questionnaire

AIS the user's perspective

Automatic Identification System (AIS) has been a carriage requirement for newly built ships, passenger vessels and tankers since 2002. This research project aims to gather the opinions and experiences of users (including the OOW) related to the operation of AIS.

Personal working experience:

1. What is your current rank? (please select)
- Master ❑; 1st Mate ❑; 2nd Mate ❑; 3rd Mate ❑; Cadet ❑ Other (please specify)....

2. How many years have you been serving at sea? ....

3. What type of ship have you been worked on? (please select all that apply)
- Bulk carrier ❑; Tanker ❑; Container ship ❑; Passenger ship ❑; Ferry ❑; Naval vessel ❑; LNG/LPG ❑; Other (please specify) ....

4. What has been your area of operation? (please select all that apply)
- Open sea ❑; Short sea vessel ❑; Inland water ❑ Other (please specify) ....

5. Could you specify the voyages you have/ had been working on?(please select all that apply)
- Asia -> Australia ❑; Asia -> Europe ❑; Asia -> North America ❑; Asia -> South Africa, South America ❑; Inter-Asia, Persian gulf ❑; Other (please specify) ......

6. Do you have any experience of working for the military navy?
- YES ❑; NO ❑; If yes, for how long years? ....

AIS implementation issues

General view of AIS

7. Have you heard about AIS?
- YES ❑; NO ❑

8. Do you think AIS is one of the key devices dealing with navigational operation?
- YES ❑; NO ❑

9. Do you have any experience of using AIS?
- YES ❑; NO ❑

10. Apart from navigational purpose, do you think AIS can be used for other purposes?
- YES ❑; NO ❑

11. What other function to you think AIS could be used for?
- Communication aids ❑; Security approval ❑; Traffic management ❑; Other (please specify)..................

12. What are the costs associated with equipping a ship with AIS?
- Less than $500 ❑; $500 - $999 ❑; $1000 -£2000 ❑; over $2000 ❑

There has been some debate related to changing the time-scale of fitting AIS onboard earlier than it was planned. What is your opinion about the changing the schedule of AIS carriage requirements?

13. What do you think about the changed timescale? (please select one)
- Too early ❑; Early ❑; Late ❑; Too late ❑; No opinion ❑

14. Do you think the change of implementation date will cause any problems?
- YES ❑; NO ❑

15. If you have selected YES to question 14 please explain what problems changing the implementation timescale may cause.

    ....

16. Do you believe that the issue is considering more about the security reasons for the littoral countries rather than safety at sea?
- YES ❑ (Please go to question 17); NO ❑ (Please go to question 18)

17. Do you think it is too early to use AIS as an aid of collision avoidance?
- YES ❑; NO ❑

18. Do you still think it would be appropriate to adhere to the original plan rather than the revised time schedule of AIS carriage requirement?
- YES ❑; NO ❑

What do you think about the effect on navigation by AIS?

19. For what degree will you use AIS as a navigational aid? (please select all that apply
- Fully operated(i.e. as the function of Radar) ❑; Half/ Medium operated (as ECDIS which might be used in some users only) ❑; Less operated (i.e. VHF with general use but not better performance) ❑; least operated (i.e. NAVTEX with criticized usage) ❑

Training Issues

20. Should the master captain be trained properly in order to use AIS under company's scheme supervised by IMO?
- YES ❑; NO ❑

21. Should anyone else on board be trained in order to use AIS under company's scheme supervised by IMO?
- YES ❑; NO ❑

22. If you have answered YES to question 21 who else should be trained?
- 1st Mate ❑; 2nd Mate ❑; 3rd Mate ❑; Cadet ❑ Other (please specify) ....

23. What rank of OOW should be allowed to operate the AIS?
- Master ❑; 1st Mate ❑; 2nd Mate ❑; 3rd Mate ❑; Cadet ❑; Other (please specify)...

24. Who should be responsible for paying for training?
- Shipping companies ❑; Manufacturers ❑; Seafarers ❑; Government ❑; Other (please specify) ....

25. Is it necessary to be trained off the bridge?
- YES ; NO ❑

26. If you answered YES to question 25 please state why you think it is necessary to be trained off the bridge...

   ....

27. Do you think it is suitable to undertake training on board?
- YES ❑; NO ❑

28. If you have answered YES in question 27, please state who is the person should be in charge of the training?
- Master ❑; Mates with experience of AIS ❑; Other (please specify)....................

29. Is it necessary to train cadets regarding the use of AIS?
- YES ❑; NO ❑

30. Should the AIS be brought into the STCW standard?
- YES ❑; NO ❑

AIS and Collision Avoidance

31. Do you think captain should be responsible to the use of AIS on board while operating Collision Avoidance?
- YES ❑; NO ❑

32. With the possibility that other ships (mainly non-SOLAS vessels) might not install AIS on board; will you still consider to fully relying on AIS for collision avoidance?
- YES ❑ (Please go to question 33); NO ❑ (Please go to question 35)

33. Could you explain why AIS is appropriate for collision avoidance?

   ....

34. Could you explain how you use AIS as a main function in the Aids-to-Navigation?
    ....

35. Will you use AIS in order to reduce the verbal communication while operating collision avoidance with another ship?
- YES ❑; NO ❑

36. In what order (1-6) do you consider the necessity of navigate at sea by the following on board equipment?(Radar, ARPA, VHF, AIS, Visual navigation, etc)
- AIS ❑; ARPA ❑; Radar ❑; VHF ❑; Visual navigation ❑; Other (please specify)❑

37. How do you see the role of AIS compared with other navigation devices on bridge?
- Take higher priority than the equipment, such as NAVTEX ❑
- Cooperation for better working facility among the others ❑
- Independent operation for adding extra information ❑
- Workload impact of disturbing the working load of mariners ❑
- Other explanation (please specify) .... ❑

38. Will you use AIS as part of your navigation operation?
- YES ❑; NO ❑

39. What do you expect the function of AIS to be? (Select all that apply)
- To work alone (only provides information one way) ❑
- Work partially with other Aids to Navigation ❑
- Integration between other navigation equipment on board ❑
- Only carried to meet statutory requirements ❑

Legal considerations

40. Is it important to involve AIS into maritime regulation at sea?
- YES ❑; NO ❑

41. What role will AIS have among the other equipment in terms of COLREGs? (For example, the use of Radar has been brought into COLREGs)
    ....

<u>Long term study: assuming all SOLAS-ships are carrying AIS on board.</u>

42. Do you agree with the following statements
- Non-SOLAS vessels should give way to SOLAS ship except emergency situation. YES ❑; NO ❑

- Non-SOLAS vessels should be exempt from the compulsory carriage of AIS. YES ❑; NO ❑

- Non-SOLAS vessels should be forced to install AIS.
  YES ❑;NO ❑

- There should be no-go zones for non-SOLAS vessels in an specific waters
  YES ❑;NO ❑

43. Do you agree with the following statements

- After AIS is fully implemented every OOW should be capable of using AIS in terms of collision avoidance.
  YES ❑; NO❑

- After AIS is fully implemented AIS should be taking place of the use of verbal communication.
  YES ❑; NO ❑

- After AIS is fully implemented every ship should be operated under the AIS system in order to interact between themselves, and between them and VTS controller.
  YES ❑; NO❑

44. What functions are you willing to use AIS in order to aid navigation? (select all that apply)

- Manage traffic with other users ❑
- Proper communication in an area ❑
- Security consideration ❑
- Environmental concerns ❑
- Other (please specify) ....

45. Will you support AIS training on land?

- YES ❑; NO ❑

46. Do you think AIS should be involved into COLREGS or other relative provisions?

- YES ❑; NO ❑

47. If you support that AIS can do anything better than aiding navigation, what will you consider and determine the role of AIS on bridge even it is operated on every SOLAS-ship? (If you support the idea of using AIS in enhancing navigation, please ignore this question)

- Communication improvement ❑; Identification ❑; Business efficiency ❑; Security enhancement ❑; Other (please specify).................................

<u>The future of AIS network</u>

48. Do you think it's necessary to have non-SOLAS ships to be identified by AIS?
- YES ❑; NO ❑

49. If all the vessels are carrying AIS, do you think there might not be enough capacity on VHF channels for operating the AIS network?
- YES ❑; NO ❑

50. Do you think merchant navy should have a priority to use the AIS VHF channel over the leisure users?
- YES ❑; NO ❑

51. If you selected YES to question 50 please state your reasons
....

52. With the introduction of AIS, do you think there will be a tendency of reduce time on physical lookout on the bridge?
- YES ❑; NO ❑

53. If you selected YES to question 52 please state your reasons
....

Thank you for taking part of this survey.

Appendix F

Deck officers' Certificate Structure in the UK and Taiwan

- **Certification Structures in the UK and Taiwan based on STCW 95**

Capacity	STCW 95 Regulation	Tonnage Limitation and/or Area Limitation
OOW	**A-II/1**	Mandatory minimum requirements for certification of officers in charge of a navigational watch on ships of 500 gross tonnage or more.
Master & Chief Mate	**A-II/2**	Mandatory minimum requirements for certification of masters and chief mates on ships of 500 gross tonnage or more.
Master & OOW	**A-II/3**	Mandatory minimum requirements for certification of officers in charge of a navigational watch and of masters on ships of less than 500 gross tonnage engaged on near-coastal voyages.

Table F-1 IMO STCW 95 certification of deck officers (IMO 1997)

Capacity	Area Limitation	Tonnage Limitation	STCW 95 Regulation	Taiwan system
OOW	Domestic	less than 500gt	II/3	3rd Class Mate
	Domestic	500-10,000gt	II/1	2nd Class Mate
	International	500-3,000gt	II/1	2nd Class Mate
	International	**none**	**II/1**	**1st Class Mate**
Chief Mate	Domestic	500-10,000gt	II/2	2nd Class Chief Mate
	International	500-3,000gt	II/2	2nd Class Chief Mate
	International	**none**	**II/2**	**1st Class Chief Mate**
Master	Domestic	less than 500gt	II/3	3rd Class Master
	Domestic	500-10,000gt	II/2	2nd Class Master
	International	500-3,000gt	II/2	2nd Class Master
	International	**none**	**II/2**	**1st Class Master**
Notes	1. The phrase '1st Class Deck Officer' refers to deck personnel qualified to work on board a vessel of more than 3,000 gross tonnage that is engaged on an international voyage or a vessel of more than 10,000 gross tonnage that is engaged on a domestic voyage. 2. The phrase '2nd Class Deck Officer' refers to deck personnel qualified to work on board a vessel of more than 3,000 gross tonnage but less than 8,000 gross tonnage that is engaged on an international voyage, or a vessel of more than 500 gross tonnage but less than 10,000 gross tonnage that is engaged on a domestic voyage. The phrase '2nd Class Deck Officer' also applies to deck personnel qualified to work on board a vessel of more than 3,000 gross tonnage but less than 8,000 gross tonnage that is engaged on a voyage in the seas encompassed in the area east of 90°E longitude and west of 150°W longitude, and north of 10°S latitude and south of 45°N latitude. 3. The phase '3rd Class Deck Officer' refers to deck personnel qualified to work on board a vessel of more than 50 gross tonnage but less than 500 gross tonnage that is engaged on a domestic voyage.			

Table F-2 Taiwan certification of deck officers
(The Examination Yuan 1991; IMO 1997)

Capacity	Area Limitation	Tonnage Limitation	STCW 95 Regulation
OOW	near-coastal	less than 500gt	II/3
	none	none	II/1
Chief Mate	near-coastal	less than 3,000gt	II/2
	near-coastal	none	II/2
	none	less than 3,000gt	II/2
	none	none	II/2
Master	near-coastal	less than 500gt	II/3
	near-coastal	less than 3,000gt local domestic passenger vessels	II/3
	near-coastal	none	II/2
	none	less than 3,000gt	II/2
	none	none	II/2

Table F-3 UK certification of masters and deck officers (IMO 1997; MCA 2000)

Appendix G

Survey I Questionnaire

AIS the user's perspective (May 2004)

Automatic Identification System (AIS) has been a carriage requirement for newly built ships, passenger vessels and tankers since 2002. This research project aims to gather the opinions and experiences of users (including the OOW) related to the operation of AIS.

Personal working experience

1. What is your current rank? (Please tick one)
   - Master ☐
   - 1st Mate ☐
   - 2nd Mate ☐
   - 3rd Mate ☐
   - Cadet ☐
   - Other ☐ (please specify) ....

2. How many years have you been serving at sea? (Please tick one)
   - Less than one year ☐
   - 1 year to 5 years ☐
   - 5 years to 10 years ☐
   - More then 10 years ☐

3. What type of ship have you been worked on? (Please select all that apply)
   - Bulk carrier ☐
   - Tanker ☐
   - Container ship ☐
   - Passenger ship ☐
   - Ferry ☐
   - Naval vessel ☐
   - LNG/LPG ☐
   - Other ☐ (please specify) ....

4. What type of ship are you working on? (Please select all that apply)
   - Recently working on land ☐ (including sea/land shift)
   - Bulk carrier ☐
   - Tanker ☐
   - Container ship ☐
   - Passenger ship ☐
   - Ferry ☐
   - Naval vessel ☐
   - LNG/LPG ☐
   - Other ☐ (please specify) ....

5. Which areas have you been served? (Please select all that apply)
   - Open sea ❑
   - Short sea vessel ❑
   - Inland water ❑
   - Other ❑ (please specify) ....

6. What is the area of your service? (Please select all that apply)
   - Recently working on land ❑ (including sea/land shift)
   - Open sea ❑
   - Short sea vessel ❑
   - Inland water ❑
   - Other ❑ (please specify) ....

7. Could you specify the voyages you have/ had been working on? (Please select all that apply)
   - Asia -> Australia ❑
   - Asia -> Europe ❑
   - Asia -> North America ❑
   - Asia -> South Africa, South America ❑
   - Inter-Asia, Persian Gulf ❑
   - Other ❑ (please specify) ....

AIS implementation issues

General view of AIS

8. Have you heard about AIS? (Please tick one)
   - YES ❑
   - NO ❑

9. Do you have any experience of using AIS? (Please tick one)
   - YES ❑
   - NO ❑

10. Do you think AIS is one of the key devices dealing with navigational operation? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

11. To What degree will you use AIS as a navigational aid? (Please tick one)
    - Fully integrated for positioning and collision avoidance ❑
    - Half/Medium integrated as a positioning use ❑
    - Less integrated as a communication use ❑
    - Least integrated as a security identification ❑

12. Apart from bridge-to-bridge usage, do you think AIS can be used for other purposes? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

    If the answer is YES, what other function to you think AIS could be used for? (Please select all that apply)
    - Communication aids ☐
    - Security approval ☐
    - Traffic management ☐
    - Other ☐ (please specify) ....

There has been some debate related to changing the time-scale of fitting AIS onboard earlier than it was planned. What is your opinion about the changing the schedule of AIS carriage requirements?

13. What do you think about the changed timescale? (Please tick one)
    - Too early ☐
    - Early ☐
    - Neither/nor ☐
    - Late ☐
    - Too late ☐

14. Do you think the change of implementation date will cause any considerations? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

    If you have selected **YES**, please explain what problems changing the implementation timescale may cause.

    ....

15. Do you believe that the issue is considering more about the security reasons for the littoral countries rather than safety at sea? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

16. Do you still think it would be appropriate to adhere to the original plan rather than the revised time schedule of AIS carriage requirement? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

Training Issues

17. Should the master be trained properly in order to use AIS? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

18. Should anyone else on board be trained in order to use AIS? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

    If you answered **YES**, who else should be trained? (Please select all that apply)
    - 1st Mate ❑
    - 2nd Mate ❑
    - 3rd Mate ❑
    - Cadet ❑
    - Other ❑ (please specify) ....

19. What rank of OOW should be allowed to operate the AIS during collision avoidance? (Please select all that apply)
    - Master ❑
    - 1st Mate ❑
    - 2nd Mate ❑
    - 3rd Mate ❑
    - Cadet ❑
    - Other ❑ (please specify) ....

20. Who should be responsible for paying for training? (Please select all that apply)
    - Shipping companies ❑
    - Manufacturers ❑
    - Seafarers ❑
    - Government ❑
    - Other ❑ (please specify) ....

21. Where do you think is the best place to hold the AIS training? (Please tick one)
    - Special organisation onshore ❑ (Please go to Q23)
    - Self-training course at the shipping company, ashore ❑ (Please go to Q23)
    - Self-training on the bridge ❑ (Please go to Q22)
    - Other ❑ (Please specify) ....(Please go to Q23)

22. Please State that who should be in charge of the AIS training on the bridge? (Please select all that apply)
    - Master ❑
    - Mates with experience of using AIS ❑
    - Other ❑ (Please specify) ....

23. Is it necessary to train all users on watch regarding the use of AIS? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

24. Should the AIS be brought into the STCW standard? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

<u>AIS and Collision Avoidance</u>

25. Do you think that AIS is currently suitable as an aid to collision avoidance? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

26. With the possibility that other ships (e.g. non-SOLAS ships) might not install AIS on board; will you still consider fully relying on AIS for collision avoidance? (Please tick one)
    - YES ❑ (Please go to question 27)
    - NO ❑ (Please go to question 29)

27. Please explain why AIS is appropriate for collision avoidance? ....

28. Please explain how you use AIS as a main function in the Aids-to-Navigation? (Please go to question 31)

    ....

29. Will you use AIS in order to reduce verbal communication while operating collision avoidance with another ship? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

30. Please explain why AIS is appropriate for collision avoidance?
    ....
    ....

31. Do you use VHF while carrying out collision avoidance at sea? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

32. In what order (1-6) do you consider the importance to collision avoidance of the following onboard equipment? (Radar, ARPA, VHF, AIS, Visual navigation, etc)
    - AIS ☐
    - ARPA ☐
    - Radar ☐
    - VHF ☐
    - Visual navigation ☐
    - Other ☐ (please specify) ....

33. How do you see the impact of AIS on the bridge? (Please tick one)
    - To provide better integration between navigation equipment ☐
    - Independent operation for adding extra information ☐
    - Other explanation ☐ (please specify) ....

34. Do you think AIS will increase the workload on the bridge? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

35. Will you use AIS as part of your navigation operation? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

36. Do you think the recent ISPS Code meant AIS is only to meet statutory requirements? (Please tick one)
    - YES ☐
    - NO ☐
    - DON'T KNOW ☐

37. What do you expect the usage of AIS to be? (Please tick one)
    - Stand-alone operation ☐
    - Work partially with other Aids to Navigation ☐
    - Integration between other navigation equipment on board ☐

Long term expectation on AIS: if all SOLAS-ships have already installed AIS.

38. Do you agree with the following statements?
    - Non-SOLAS vessels should give way to SOLAS ship except in emergency situations.
      YES ❑ NO ❑ DON'T KNOW ❑
    - Non-SOLAS vessels should be exempt from the compulsory carriage requirement of AIS.
      YES ❑ NO ❑ DON'T KNOW ❑
    - Non-SOLAS vessels should be compelled to install AIS.
      YES ❑ NO ❑ DON'T KNOW ❑
    - There should be no-go zones for non-SOLAS vessels in specific waters.
      YES ❑ NO ❑ DON'T KNOW ❑

39. Do you agree with the following statements?
    - After AIS is fully implemented every OOW should be capable of using AIS for collision avoidance.
      YES ❑ NO ❑ DON'T KNOW ❑
    - After AIS is fully implemented AIS should be replacing the use of verbal communication for collision avoidance.
      YES ❑ NO ❑ DON'T KNOW ❑
    - After AIS is fully implemented every ship should be operated under the AIS system in order to interact between themselves, and between them and VTS controller.
      YES ❑ NO ❑ DON'T KNOW ❑

40. For what functions are you willing to use AIS in order to aid navigation? (select all that apply)
    - Manage traffic with other users ❑
    - Proper communication in an area ❑
    - Security consideration ❑
    - Environmental concerns ❑
    - Other ❑ (please specify) ....

41. Do you think the use of AIS will trigger the modification to COLREGS? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

42. Do you think AIS can be used to enhance the navigation? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

43. If you think AIS can do more than aiding navigation, how would you describe the other purpose(s)? (Select all that apply)
    - Communication improvement ❑
    - Identification ❑
    - Business efficiency ❑
    - Security enhancement ❑
    - Other ❑ (please specify) ....

Other topics on AIS

44. If all the vessels are carrying AIS, do you think there might not be enough capacity on VHF channels for operating the AIS network? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

45. Do you think merchant vessels should have a priority over leisure users in using the AIS VHF channel? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

46. With the introduction of AIS, do you think there will be a tendency to reduce time on physical lookout on the bridge? (Please tick one)
    - YES ❑
    - NO ❑
    - DON'T KNOW ❑

Thank you for taking part of this questionnaire.

Appendix H

Results of Survey I

A. Personal detail

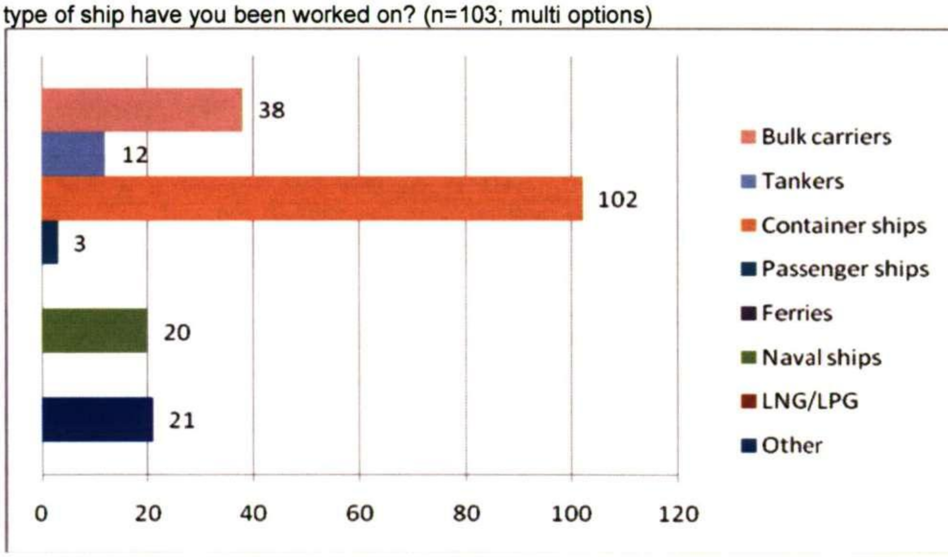
1. What is your current rank? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Master	17	16.5	16.5	16.5
	C/O	21	20.4	20.4	36.9
	2/O	25	24.3	24.3	61.2
	3/O	30	29.1	29.1	90.3
	Cadet	7	6.8	6.8	97.1
	Other	3	2.9	2.9	100.0
	Total	103	100.0	100.0	

2. How many years have you been serving at sea? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than 1 year	11	10.7	10.7	10.7
	1 to 5 years	48	46.6	46.6	57.3
	6 to 10 years	21	20.4	20.4	77.7
	more than 10 years	23	22.3	22.3	100.0
	Total	103	100.0	100.0	

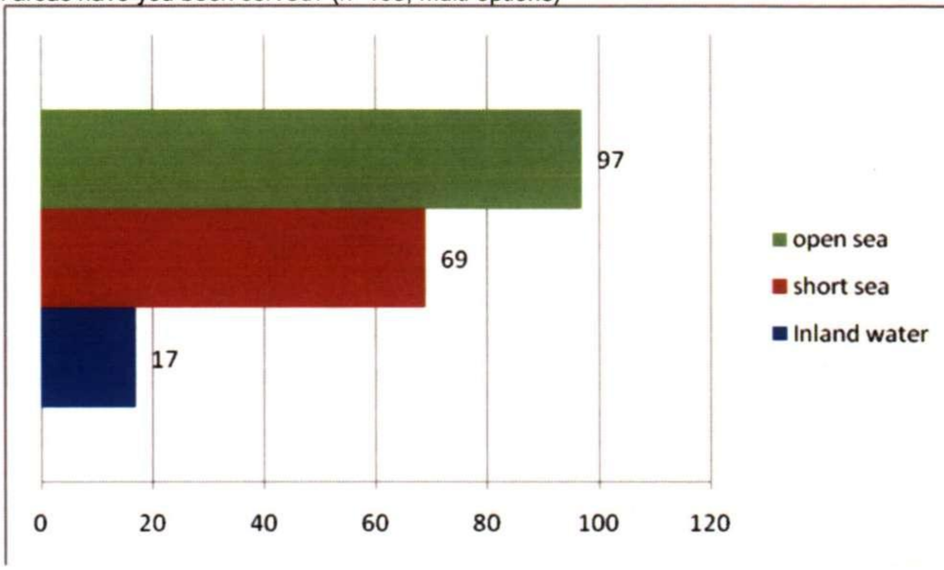
3. What type of ship have you been worked on? (n=103; multi options)



4. What type of ship are you working on? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	container	84	81.6	81.6	81.6
	other	1	1.0	1.0	82.5
	working on land	18	17.5	17.5	100.0
	Total	103	100.0	100.0	

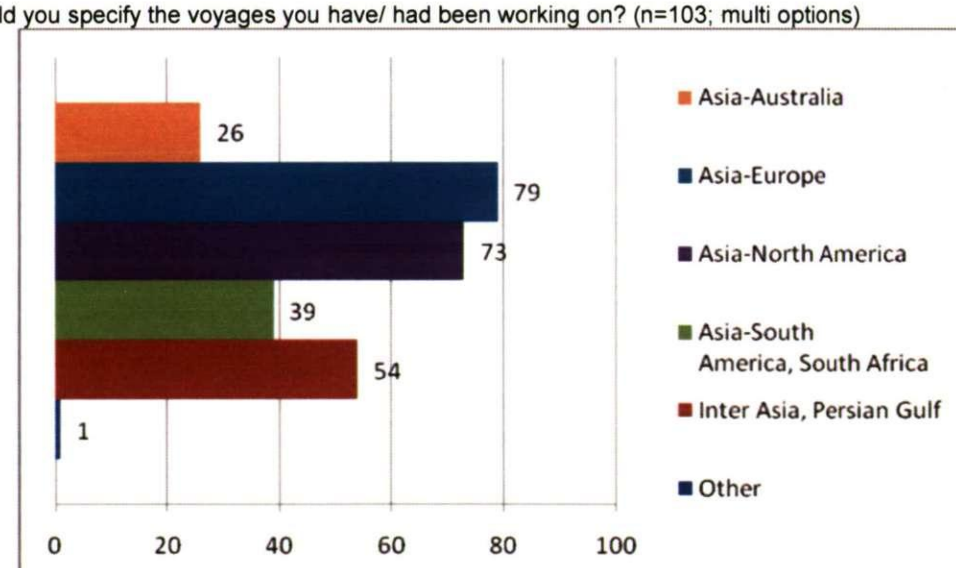
5. Which areas have you been served? (n=103; multi options)



6. What is the area of your service? (n=102)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	current work on land	18	17.5	17.6	17.6
	open sea	59	57.3	57.8	75.5
	short sea	25	24.3	24.5	100.0
	Total	102	99.0	100.0	
Missing	other	1	1.0		
Total		103	100.0		

7. Could you specify the voyages you have/ had been working on? (n=103; multi options)



B. General view of AIS

8. Have you heard about AIS? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	101	98.1	98.1	98.1
	no	2	1.9	1.9	100.0
	Total	103	100.0	100.0	

9. Do you have any experience of using AIS? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	81	78.6	78.6	78.6
	no	22	21.4	21.4	100.0
	Total	103	100.0	100.0	

10. Do you think AIS is one of the key devices dealing with navigational operation? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	94	91.3	91.3	91.3
	no	4	3.9	3.9	95.1
	don't know	5	4.9	4.9	100.0
	Total	103	100.0	100.0	

11. To What degree will you use AIS as a navigational aid? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	positioning and collision avoidance	39	37.9	37.9	37.9
	positioning only	20	19.4	19.4	57.3
	communication	34	33.0	33.0	90.3
	security	10	9.7	9.7	100.0
	Total	103	100.0	100.0	

12. Apart from the navigational usage, do you think AIS can be used for other purposes? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	89	86.4	86.4	86.4
	no	3	2.9	2.9	89.3
	don't know	11	10.7	10.7	100.0
	Total	103	100.0	100.0	

13. What do you think about the changed timescale? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	too early	2	1.9	1.9	1.9
	early	17	16.5	16.5	18.4
	neither/nor	51	49.5	49.5	68.0
	late	30	29.1	29.1	97.1
	too late	3	2.9	2.9	100.0
	Total	103	100.0	100.0	

14. Do you think the change of implementation date will cause any considerations? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	18	17.5	17.5	17.5
	no	60	58.3	58.3	75.7
	don't know	25	24.3	24.3	100.0
	Total	103	100.0	100.0	

15. Do you believe that the issue is considering more about the security reasons for the littoral countries rather than safety at sea? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	68	66.0	66.0	66.0
	no	22	21.4	21.4	87.4
	don't know	13	12.6	12.6	100.0
	Total	103	100.0	100.0	

16. Do you still think it would be appropriate to adhere to the original plan rather than the revised time schedule of AIS carriage requirement? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	22	21.4	21.4	21.4
	no	47	45.6	45.6	67.0
	don't know	34	33.0	33.0	100.0
	Total	103	100.0	100.0	

C. Training Issues

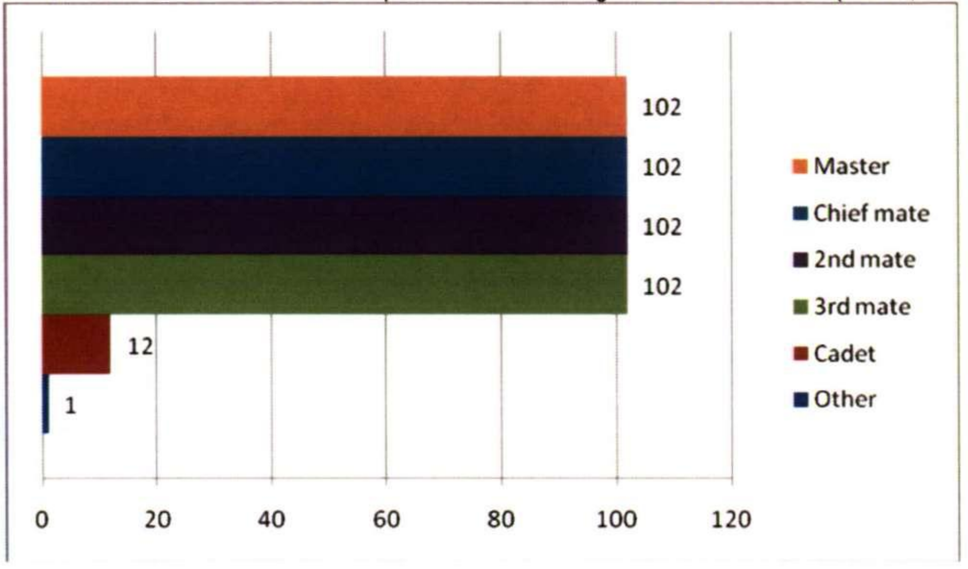
17. Should the master be trained properly in order to use AIS? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	98	95.1	95.1	95.1
	no	3	2.9	2.9	98.1
	don't know	2	1.9	1.9	100.0
	Total	103	100.0	100.0	

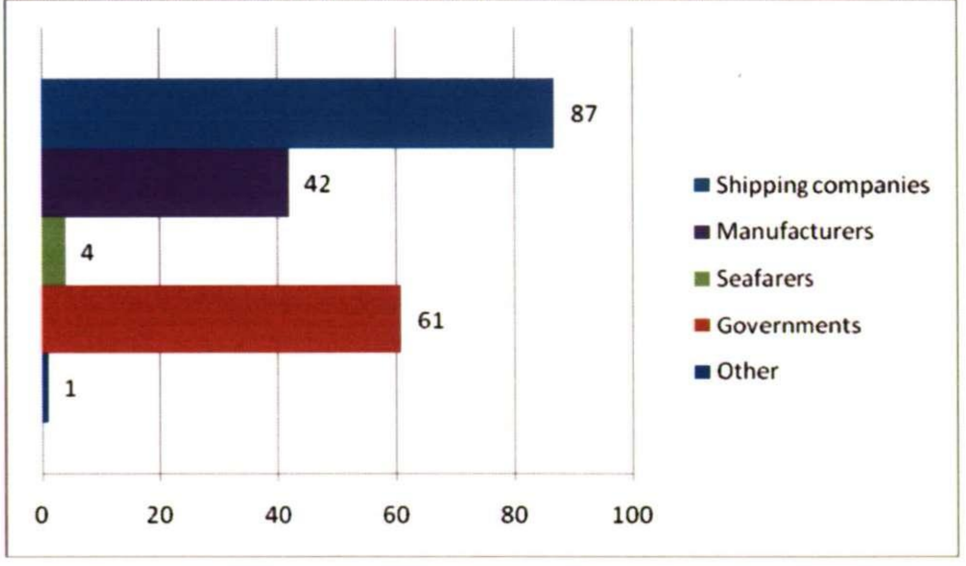
18. Should anyone else on board be trained in order to use AIS? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	102	99.0	99.0	99.0
	no	1	1.0	1.0	100.0
	Total	103	100.0	100.0	

19. What rank of OOW should be allowed to operate the AIS during collision avoidance? (n=103; multi options)



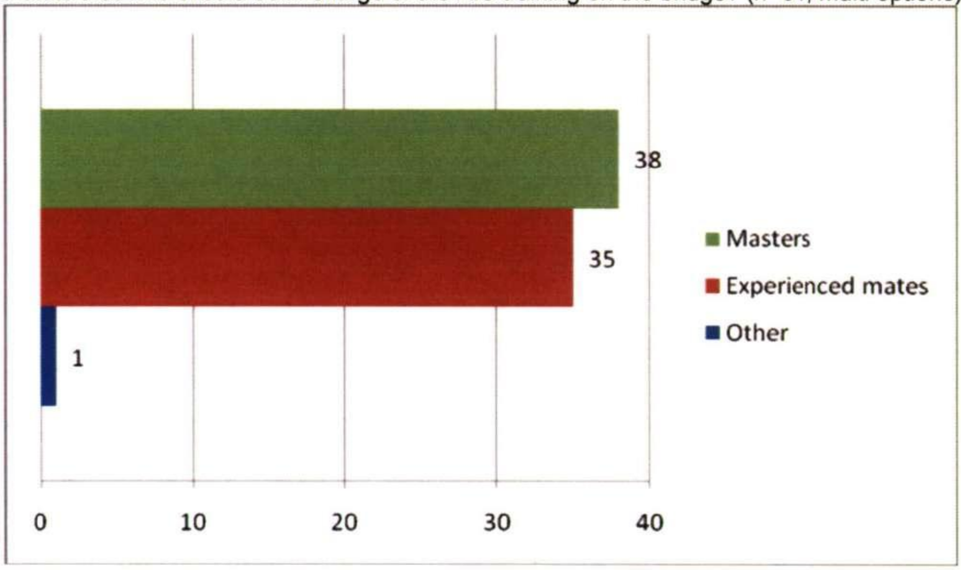
20. Who should be responsible for paying for training? (n=103; multi options)



21. Where do you think is the best place to hold the AIS training? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	special organisation onshore	20	19.4	19.4	19.4
	shipping company	22	21.4	21.4	40.8
	on board training	61	59.2	59.2	100.0
	Total	103	100.0	100.0	

22. Please State that who should be in charge of the AIS training on the bridge? (n=61; multi options)



23. Is it necessary to train all users on watch regarding the use of AIS? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	97	94.2	94.2	94.2
	no	4	3.9	3.9	98.1
	don't know	2	1.9	1.9	100.0
	Total	103	100.0	100.0	

24. Should the AIS be brought into the STCW standard? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	70	68.0	68.0	68.0
	no	23	22.3	22.3	90.3
	don't know	10	9.7	9.7	100.0
	Total	103	100.0	100.0	

D. AIS and Collision Avoidance

25. Do you think that AIS is currently suitable as an aid to collision avoidance? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	55	53.4	53.4	53.4
	no	28	27.2	27.2	80.6
	don't know	20	19.4	19.4	100.0
	Total	103	100.0	100.0	

26. With the possibility that other ships (e.g. non-SOLAS ships) might not install AIS on board; will you still consider fully relying on AIS for collision avoidance? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	8	7.8	7.8	7.8
	no	90	87.4	87.4	95.1
	don't know	5	4.9	4.9	100.0
	Total	103	100.0	100.0	

27. Please explain why AIS is appropriate for collision avoidance? (6 responses)
    1. Basic data of target ships available;
    2. Course and speed are much more accurate;
    3. Course, speed, destination and call sign are up for grab;
    4. Read targets' information quickly and reduce time on communication;
    5. Ship's name, bearing and distance available;
    6. VHF calling and Radar monitor.

28. Please explain how you use AIS as a main function in the Aids-to-Navigation? (Please go to question 31) (2 responses)
    1. Communication, target's destination and waypoint;
    2. Use Radar with AIS to confirm target.

29. Will you use AIS in order to reduce verbal communication while operating collision avoidance with another ship? (n=99)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	48	46.6	48.5	48.5
	no	48	46.6	48.5	97.0
	don't know	3	2.9	3.0	100.0
	Total	99	96.1	100.0	
Missing	System	4	3.9		
Total		103	100.0		

30. Please explain why AIS is appropriate for collision avoidance? (same question to Q27) (27 responses)
    1. AIS can only get target's course and speed but ARPA can do better by CPA, TCPA
    2. Assist VHF communication because AIS has GPS position and speed
    3. Assisting VHF calling and get target's intention position quickly
    4. By AIS name and position to call them to assist CA
    5. Can assist knowing target's data for collision avoidance and necessary communication
    6. Can understand ship's name and alter obvious collision avoidance
    7. Compare with radar monitor
    8. Confirm targets' position, distance, course and speed
    9. Easy to call dedicate ships, reduce the chance of close quarter
    10. Easy to identify bearing distance and ship name and then to confirm target by VHF
    11. Identify ships, with GPS position

12. Improving target identification for communication to prevent collision
13. It can early obtain traffic condition
14. It can show speed with names, can assist VHF calling
15. Name, course, speed can be given to VTS for traffic management
16. Name, speed, course, size for identification and communication
17. Object bearing distance for better judgement
18. Object identification assistance
19. Object name obtained to assist VHF to get intention, have early and correct CA
20. Other ship info like name position distance bearing speed relative motion for CA
21. Position, speed and CPA for CA as well as ship name for communication protocol
22. Ship name, position to build communication and notice their intention
23. To get information as bearing and type of another vessel and call sign to communicate with VHF
24. Type, destination and course, and name for VHF calling.
25. Using displayed CPA to adjust CA.
26. VHF friendly.
27. When using VHF calling, ship name can be obtained before hand and assure two parties understand it.

31. Do you use VHF while carrying out collision avoidance at sea? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	90	87.4	87.4	87.4
	no	12	11.7	11.7	99.0
	don't know	1	1.0	1.0	100.0
	Total	103	100.0	100.0	

32. In what order (1-6) do you consider the importance to collision avoidance of the following onboard equipment? (Radar, ARPA, VHF, AIS, Visual navigation, etc)

NAV AIDS\OOWS	Master	CO	2O	3O	Cadet	Other	Total	Rank
AIS	3	2	2	2	3	1	2	4th
ARPA	5	5	4	5	4	3	5	2nd
RADAR	5	4	4	5	5	5	5	2nd
VHF	2	3	2	3	2	2	2	4th
VISUAL LOOKOUT	6	6	6	6	6	6	6	1st
OTHER	1	1	1	1	1	1	1	6th
Size(n=)	17	21	25	30	7	3	103	
Range score, 1,2,3,4,5,6; The higher the score the more important by the respondents opinions								

Descriptive Statistics (Mode): ranking officers vs. navigational aids

33. How do you see the impact of AIS on the bridge? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	better integration	59	57.3	57.3	57.3
	stand alone	43	41.7	41.7	99.0
	don't know	1	1.0	1.0	100.0
	Total	103	100.0	100.0	

34. Do you think AIS will increase the workload on the bridge? (n=91)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	28	27.2	30.8	30.8
	no	61	59.2	67.0	97.8
	don't know	2	1.9	2.2	100.0
	Total	91	88.3	100.0	
Missing	System	12	11.7		
Total		103	100.0		

35. Will you use AIS as part of your navigation operation? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	87	84.5	84.5	84.5
	no	11	10.7	10.7	95.1
	don't know	5	4.9	4.9	100.0
	Total	103	100.0	100.0	

36. Do you think the recent ISPS Code meant AIS is only to meet statutory requirements? (n=91)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	49	47.6	53.8	53.8
	no	21	20.4	23.1	76.9
	don't know	21	20.4	23.1	100.0
	Total	91	88.3	100.0	
Missing	System	12	11.7		
Total		103	100.0		

37. What do you expect the usage of AIS to be? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	standalone	13	12.6	12.6	12.6
	aids to navigation	34	33.0	33.0	45.6
	integratiion	56	54.4	54.4	100.0
	Total	103	100.0	100.0	

E. Long term expectation on AIS: if all SOLAS-ships have already installed AIS.

38. Do you agree with the following statements? (n=103)

38_1 Non-SOLAS vessels should give way to SOLAS ship except in emergency situations.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	50	48.5	48.5	48.5
	no	47	45.6	45.6	94.2
	don't know	6	5.8	5.8	100.0
	Total	103	100.0	100.0	

38_2 Non-SOLAS vessels should be exempt from the compulsory carriage requirement of AIS.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	20	19.4	19.4	19.4
	no	75	72.8	72.8	92.2
	don't know	8	7.8	7.8	100.0
	Total	103	100.0	100.0	

38_3 Non-SOLAS vessels should be compelled to install AIS.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	74	71.8	71.8	71.8
	no	21	20.4	20.4	92.2
	don't know	8	7.8	7.8	100.0
	Total	103	100.0	100.0	

38_4 There should be no-go zones for non-SOLAS vessels in specific waters.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	52	50.5	50.5	50.5
	no	47	45.6	45.6	96.1
	don't know	4	3.9	3.9	100.0
	Total	103	100.0	100.0	

39. Do you agree with the following statements? (n=103)

39_1 After AIS is fully implemented every OOW should be capable of using AIS for collision avoidance.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	93	90.3	90.3	90.3
	no	6	5.8	5.8	96.1
	don't know	4	3.9	3.9	100.0
	Total	103	100.0	100.0	

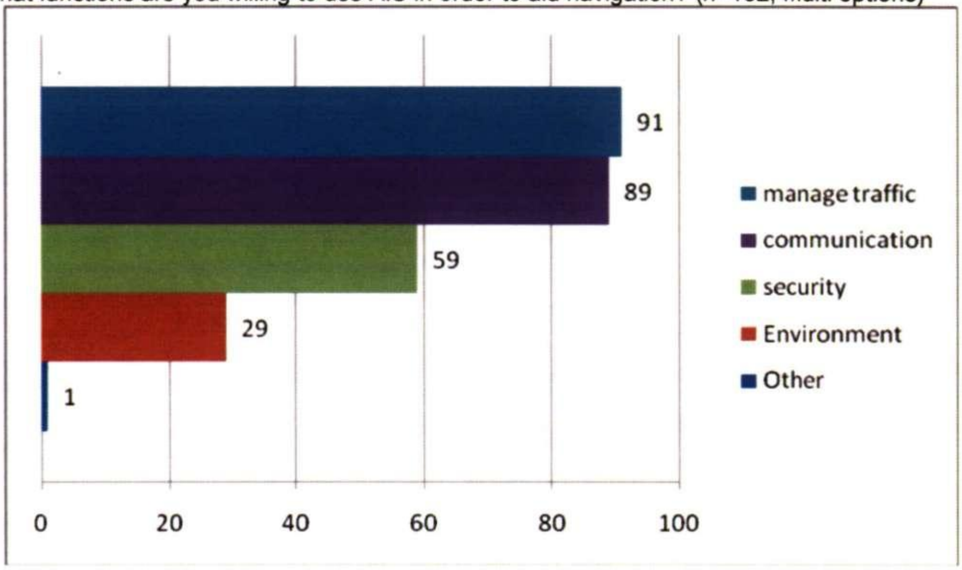
39_2 After AIS is fully implemented AIS should be replacing the use of verbal communication for collision avoidance.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	6	5.8	5.8	5.8
	no	84	81.6	81.6	87.4
	don't know	13	12.6	12.6	100.0
	Total	103	100.0	100.0	

39_3 After AIS is fully implemented every ship should be operated under the AIS system in order to interact between themselves, and between them and VTS controller.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	76	73.8	73.8	73.8
	no	15	14.6	14.6	88.3
	don't know	12	11.7	11.7	100.0
	Total	103	100.0	100.0	

40. For what functions are you willing to use AIS in order to aid navigation? (n=102; multi options)



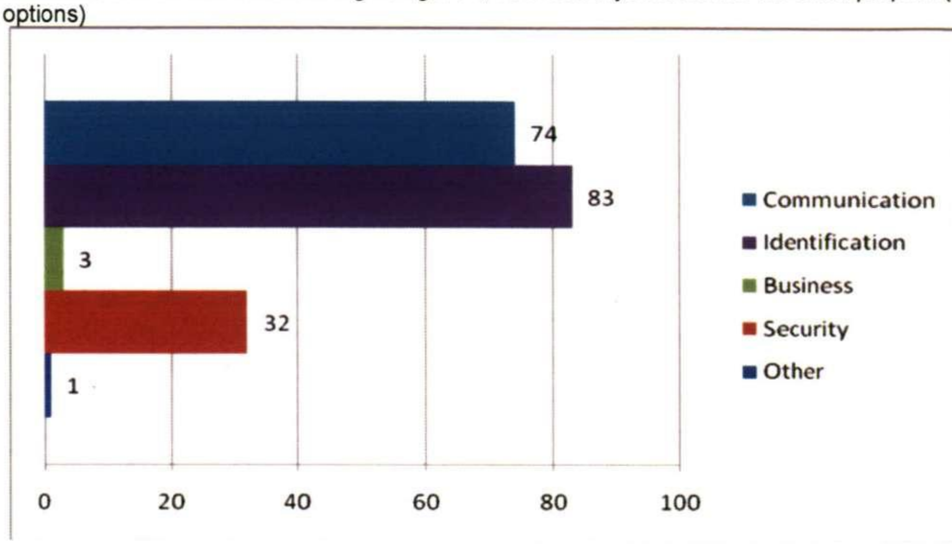
41. Do you think the use of AIS will trigger the modification to COLREGS? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	50	48.5	48.5	48.5
	no	41	39.8	39.8	88.3
	don't know	12	11.7	11.7	100.0
	Total	103	100.0	100.0	

42. Do you think AIS can be used to enhance the navigation? (n=91)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	82	79.6	90.1	90.1
	no	4	3.9	4.4	94.5
	don't know	5	4.9	5.5	100.0
	Total	91	88.3	100.0	
Missing	System	12	11.7		
Total		103	100.0		

43. If you think AIS can do more than aiding navigation, how would you describe the other purpose(s)? (n=101; multi options)



F. Other topics on AIS

44. If all the vessels are carrying AIS, do you think there might not be enough capacity on VHF channels for operating the AIS network? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	42	40.8	40.8	40.8
	no	46	44.7	44.7	85.4
	don't know	15	14.6	14.6	100.0
	Total	103	100.0	100.0	

45. Do you think merchant vessels should have a priority over leisure users in using the AIS VHF channel? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	53	51.5	51.5	51.5
	No	43	41.7	41.7	93.2
	don't know	7	6.8	6.8	100.0
	Total	103	100.0	100.0	

46. With the introduction of AIS, do you think there will be a tendency to reduce time on physical lookout on the bridge? (n=103)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	13	12.6	12.6	12.6
	no	87	84.5	84.5	97.1
	don't know	3	2.9	2.9	100.0
	Total	103	100.0	100.0	

Appendix I

Survey II Questionnaire

The aim of this questionnaire is to investigate the impact of introducing Automatic Identification System (AIS) to Far Eastern seafarers

此問卷調查的目的是爲了查訪新制船舶自動識別系統 AIS 對遠東船員之影響

There are 42 questions and it takes approximately 10 minutes to complete.

Please tick the answer that best fits how you feel.

此問卷調查共有四十二題大約耗時十分鐘填寫

請填選您覺得最適當之選項

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AIS the user's perspective (English-Chinese version)
船舶自動識別系統用戶觀點問卷調查 (中英對照版)

We would like to assure you that all replies will be treated in confidence and answers will be anonymous if used for research publication and thesis. We would like to illustrate seafarers' general views on AIS and how seafarers can benefit from the newly introduced bridge device.

Automatic Identification System (AIS) has been a mandatory carriage requirement on bridge of merchant ships, passenger vessels and tankers since 2002. Most AIS manufacturers and law regulators are from Western countries, and may have a different view and understanding of the new kit, whereas the majority of the seafarers are from Asia. Moreover, if AIS is going to assist collision avoidance, an international agreement on collision avoidance is imperative.

Generally, AIS aims to improve the safety of navigation at sea and also give better traffic efficiency without adding to the workload of officers on watch.

The research project aims to gather the opinions and experiences of users (mainly the Officer On Watch) regarding the operation of AIS in order to remedy the lack of seafarer's point of view on AIS.

<u>Thank you for taking the time to participate in this survey.</u>

此問卷調查採不具名樣本抽查,並僅用於學術期刊及博士班論文發表。期待能近身觀察遠東船員普遍對船舶自動識別系統 AIS 的使用心得及意見。

自 2002 年以來船舶自動識別系統 AIS 已陸續成爲客,貨,油輪駕駛台之必須裝備, 由於大部份製造廠商及法律規範者多來自西方國家,然而海事從業人員卻多以來自亞洲國家爲主,對於此新裝備之操作及定位難免有認知及解讀的出入,若將應用於海上避碰時更突顯國際統一規範的迫切性。

AIS 應以提高船員海上航行安全爲首, 增進船舶航行效率爲輔 且以不增加當值工作負荷爲前提

此學術研究計劃之目的是探訪及收集海事工作者對 AIS 的看法及使用經驗藉以傳達海事工作者對 AIS 普遍觀點以期對海上人命,航安能有正面之貢獻。

<u>感謝您抽空參與本次問卷調查</u>

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<u>Section A Personal working experience 個人經歷</u>

1. What is your professional rank? (Please tick one) 請點選您目前的職位? (請單選)
   Master 船長 ❑ / 1st Matc 大副❑ / 2nd Mate 二副 ❑ / 3rd Mate 三副 ❑ / Cadet 艙面實習生 ❑ /
   Other (please specify) 其他 (請註明) ❑ ....

2. Are You 性別: Male 男性 ❑ / Female 女性 ❑

3. How many years have you been serving at sea? (Please tick one) 請問您於海上服務多久? (請單選)
   Less than one year 少於一年 ❑ / 1 year to 5 years 一至五年 ❑ /
   6 years to 10 years 六至十年 ❑ / 11 years to 15 years 十一年至十五年 ❑ /
   More than 15 years 十五年以上 ❑ / No experience 無經驗 ❑

4. What is you nationality? 國籍? (e.g. Chinese, Indonesian, Philippine, Taiwanese, Vietnamese, etc)
   ....

5. With which company are you currently working? (Please tick one) 請選擇您現在服務之公司? (請單選)
   EVERGREEN 長榮❑ / U-MING 裕民❑ / WANHAI LINE 萬海❑ / YANGMING LINE 陽明❑ /
   Other (please specify) 其他 (請註明) ❑ ....

6. What types of ships have you worked on in the past? (Please select all that apply) 請選擇您以前曾服務過之船舶種類? (可複選)
   Bulk carrier 散裝船 ❑ / Tanker 油輪 ❑ / Container ship 貨櫃船 ❑ /
   Cruise ship or Ferry 客渡輪 ❑ / Naval ship 海軍艦艇 ❑ / No experience 無經驗 ❑ /
   Other (please specify) 其他 (請註明) ❑ ....

7. What type of ship do you now work on? (Please tick one) 請選擇您現在服務的船舶種類? (請單選)
   Bulk carrier 散裝船 ❑ / Tanker 油輪 ❑ / Container ship 貨櫃船 ❑ / Cruise ship or Ferry 客, 渡輪 ❑ / Naval ship 海軍艦艇 ❑ / Recently working on land 目前岸上工作 ❑ (including sea/land shift) /
   Other (please specify) 其他 (請註明) ❑ ....

8. Would you also specify the voyages you are working on? (Please tick one) 請選擇您目前服務之航線? (請單選)
   Asia <> North America 亞洲<>北美 ❑ /
   Asia <> South America 亞洲<>南美 ❑ /
   Asia <> Europe 亞洲<>歐洲 ❑ /
   Asia <> Australia 亞洲<>澳洲 ❑ /
   Asia <> Africa 亞洲<>非洲 ❑ /
   Inter-Asia, Persian Gulf 亞洲區域, 紅海, 波斯灣 ❑ /
   Recently working on land 目前岸上工作 ❑ (including sea/land shift)/
   Other (please specify) 其他 (請註明) ❑..

Section B General View 一般概念

9. Do you have any experience of using AIS? (Please tick one) 您曾操作過船舶自動識別系統 AIS 嗎? (請單選)
    - YES 是 ☐
    - NO 否 ☐
      If 'No', have you heard about AIS? (Please tick one) 若選擇'無', 您聽說過船舶自動識別系統 AIS 嗎? (請單選) YES 是 ☐/ NO 否 ☐/ DON'T KNOW 不清楚 ☐
    - DON'T KNOW 不清楚 ☐
      If 'Don't know', have you heard about AIS? (Please tick one) 若選擇'不清楚', 您聽說過船舶自動識別系統 AIS 嗎? (請單選) YES 是 ☐/ NO 否 ☐/ DON'T KNOW 不清楚 ☐

10. Have you ever used AIS to aid decision making in **collision avoidance**? (Please tick one) 您曾用過船舶自動識別系統 AIS **避碰**嗎? (請單選)
    YES 是 ☐ / NO 否 ☐ / DON'T KNOW 不清楚 ☐

11. To what degree do you see AIS as useful for these applications on board? 您認爲船舶自動識別系統 AIS 對下列應用的重要性爲何?

	Very useful 非常重要	Useful 重要	Neither/nor 一般	Not useful 不重要	Least useful 很不重要
An aid for collision avoidance 避碰決策之一	☐	☐	☐	☐	☐
Assist positioning 輔助定位	☐	☐	☐	☐	☐
Assist communication 輔助通訊	☐	☐	☐	☐	☐
Security identification 識別防恐/盜	☐	☐	☐	☐	☐

Section C Lookout on the bridge & Collision Avoidance 航行當值及避碰

12. Do you find it difficult to get in contact with another ship using VHF? Please use the space provided for further comment if you require. (Please tick one) 您是否在使用無線電呼叫他船時感到困難? 請踴躍於備註欄進一步闡述您的意見。(請單選)
    YES 是 ☐
    If '**YES**', indicate more in detail. (Please select all that apply) 如果'是',請進一步選擇原因 (可複選)
    - Is it because of language barrier? 是語言溝通障礙嗎? ☐
    - Is it because of vessel identification problem? 是辨識目標困難嗎? ☐
    - Is it because of busy traffic around? 是水域船舶太多嗎? ☐
    - Other (please specify) 其他 (請註明) ☐........................

    NO 否 ☐
    DON'T KNOW 不清楚 ☐

    Further Comment 備註..

13. Do you agree the nearby ships tend NOT to take action if you only use shapes, lights and sound signals to indicate your intention? (Please tick one) 在您單純使用號標, 燈光, 號笛等信號表達您的意圖時, 您同意周遭船舶傾向不作爲嗎? (請單選)
    YES 是 ☐ / NO 否☐ / DON'T KNOW 不清楚 ☐

14. Do you use VHF to assist you when taking collision avoidance action? (Please tick one) 您使用無線電呼叫對方來協助您進行避碰嗎? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

15. Do you use VHF when a **Close-quarters situation** has developed? (Please tick one) 在逼近情勢下您是否使用無線電呼叫對方進行避碰呢? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

16. How do you currently like to set up the volume of your VHF ch16? (Please tick one) 您通常無線電 16 頻道的音量設定多少呢? (請單選)
Mute 靜音 (0/10) ❑ / Very low 很小聲 (1/10) ❑ / Low 小聲 (3/10) ❑ / Medium 中等音量 (5/10) ❑ /
Loud 大聲 (7/10) ❑ / Very Loud 很大聲 (10/10) ❑ / No opinion 沒意見 ❑ /
Other (please specify) 其他 (請註明) ❑..

17. Are you worried about the Radar's detection while sailing at a bend channel or an obstructed landscape ahead? (Please tick one) 在您航行於彎曲水道或前有阻礙之地形地物時, 是否覺得雷達偵測有不足的地方? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

18. Are you worried about the Radar's detection for Identification of small boats? (Please tick one) 您是否覺得雷達對小船偵測有不足的地方? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

19. What function do you normally use for ARPA decision on collision avoidance? (Please tick one) 您通常都使用 ARPA 何種穩定顯示模式來進行避碰呢? (請單選)
   - Sea Stabilized 海面穩定顯示模式 ❑
   - Ground Stabilized 地面穩定顯示模式 ❑
   - Other (please specify) 其他 (請註明) ❑..

20. What scores you will give to these vessels for obeying **the rules of the road** generally. 您對下列船舶對避碰規則遵守的滿意程度。

	Very satisfied 很滿意	Fairly satisfied 滿意	Neither/nor 一般	Fairly dissatisfied 不滿意	Very dissatisfied 很不滿意
Cargo ship(under 50,000 tons) 一般商船 (五萬噸以下)	❑	❑	❑	❑	❑
Large cargo ship(over 50,000 tons) 大型商船 (五萬噸以上)	❑	❑	❑	❑	❑
Fishing boat 漁船	❑	❑	❑	❑	❑
Naval ship 海軍艦艇	❑	❑	❑	❑	❑
Sailing boat & yacht 帆船及遊艇	❑	❑	❑	❑	❑
High Speed Craft (HSC) 高速船	❑	❑	❑	❑	❑
Ferry 渡輪	❑	❑	❑	❑	❑

Section D Layout of NAV AIDS on the bridge 船橋導航設備配置

21. Overall, how satisfied are you overall with the location of aids to navigation on the bridge? Please use the space provided for further comment if you require.
您滿意您目前駕駛台導航系統裝設的位置嗎? 請踴躍於備註欄進一步闡述您的寶貴意見。

	Very satisfied 很滿意	Fairly satisfied 滿意	Neither/nor 一般	Fairly dissatisfied 不滿意	Very dissatisfied 很不滿意
Are you satisfied with the location of AIS Minimum Keypad Display on bridge? 您滿意您駕駛台 AIS MKD 裝設的位置嗎?	☐	☐	☐	☐	☐

Comment 備註...

	Very satisfied 很滿意	Fairly satisfied 滿意	Neither/nor 一般	Fairly dissatisfied 不滿意	Very dissatisfied 很不滿意
Are you satisfied with the location of Radar/ARPA on bridge? 您滿意您駕駛台雷達裝設的位置嗎?	☐	☐	☐	☐	☐

Comment 備註...

	Very satisfied 很滿意	Fairly satisfied 滿意	Neither/nor 一般	Fairly dissatisfied 不滿意	Very dissatisfied 很不滿意
Are you satisfied with the location of VHF on bridge? 您滿意您駕駛台無線電裝設的位置嗎?	☐	☐	☐	☐	☐

Comment 備註...

	Very satisfied 很滿意	Fairly satisfied 滿意	Neither/nor 一般	Fairly dissatisfied 不滿意	Very dissatisfied 很不滿意
Are you satisfied with the location of (Electronic) Chart on bridge? 您滿意您駕駛台(電子)海圖的位置嗎?	☐	☐	☐	☐	☐

Comment 備註...

	Very satisfied 很滿意	Fairly satisfied 滿意	Neither/nor 一般	Fairly dissatisfied 不滿意	Very dissatisfied 很不滿意
Are you satisfied with overall bridge layout? 您滿意您駕駛台的整體配置嗎?	☐	☐	☐	☐	☐

Comment 備註...

<u>Section E Training, Implementation and Installing Issues 訓練, 實施及安裝</u>

22. Do you have experienced any adjustments because of the change of implementation date being moved forward? (Please tick one) 您認爲改過的裝配時間表對您當值時產生任何困擾嗎? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

23. Do you agree that the revised timescale is more about security for the littoral countries than navigation at sea? (Please tick one) 您是否同意海事國家更改 AIS 裝配時間表時, 考慮其沿海安全 (或反恐) 勝過於航行安全? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

24. Although present regulations require SOLAS ships to install AIS MKD on board, are you aware that there is no requirement for mariners to be trained in its use? (Please tick one) 您是否知道目前法規只強制規定商船必須安裝船 AIS MKD, 但並沒有對如何使用它有進一步的規範? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

25. Do you think Officers on Watch should receive proper training to use AIS for collision avoidance? (Please tick one) 您認爲船副是否需接受正規船舶自動識別系統訓練以應用於避碰呢? (請單選)
YES 是 ❑ /
If '**YES**', where do you think is the best place to hold AIS operation training? (Please tick one) 如果'是', 請問您認爲何處最適合進行訓練? (請單選)
- Special organization onshore 指定之陸上訓練機構 ❑
- Self-training course at the shipping company, ashore 船公司岸上訓練 ❑
- Tutorial by technicians on bridge when on birth 靠港時安裝工程師協助訓練 ❑
- Self-training on bridge 駕駛台船員自行訓練 ❑
- Other (please specify) 其他 (請註明) ❑ ....

NO 否 ❑ / Please specify why? 請註明原因? ....
DON'T KNOW 不清楚 ❑ / Please specify why? 請註明原因? ....

26. Do you have difficulty communicating with technicians who install and service electronic equipment on board? (Please tick one) 您與安裝及維修電子儀器的工程師是否有溝通上的困難? (請單選)
YES 是 ❑ Why? (Please specify) 爲什麼? (請註明原因)../
NO 否 ❑ / DON'T KNOW 不清楚 ❑

27. If there is mandatory training in the use of AIS, who should pay for it? (Please select all that apply) 假如有訓練課程, 您認爲誰該負責 AIS 的訓練費用呢? (可複選)
Shipping companies 船公司 ❑ / Manufacturers AIS 廠商 ❑ / Seafarers 海員自付 ❑ /
Government 政府相關單位 ❑ / Other (please specify) 其他 (請註明) ❑................................

28. AIS can provide ground speed information, rate of turn, identification of target, etc. Would you like to see AIS data integrated into the fellow electronic devices on board? (Please tick one) 船舶自動識別系統 AIS 可提供對地運動航向速率, 轉向 (率), 目標識別, 等等, 您是否傾向將此資訊與其他電子儀器整合顯示呢? (請單選)
- YES 是 ❑
  Please tick all that apply 請註明何種電儀 (可複選)
  ARPA 雷達 ❑ / ECDIS 電子海圖 ❑ / VDR 航程記錄器 ❑ /
  Other (please specify) 其他 (請註明) ❑..
- NO 否 ❑
  Please specify why? 請註明原因? ....
- DON'T KNOW 不清楚 ❑
  Please specify why? 請註明原因? ....

<u>Section F AIS and Collision Avoidance 船舶自動識別系統與避碰</u>

29. Do you think that AIS data is currently suitable as an aid to collision avoidance? (Please tick one)
 您同意目前船舶自動識別系統 AIS 可用來協助避碰嗎?(請單選)
 YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

30. Would you indicate the importance of following navigation aids for collision avoidance decisions?
 請評論下列導航方法對避碰決策的重要性。

	Very important 非常重要	Important 重要	Neither/nor 一般	Not important 不重要	Least important 很不重要
ARPA Radar 碰撞雷達	❑	❑	❑	❑	❑
VHF communication 無線電通訊	❑	❑	❑	❑	❑
Visual lookout 目視瞭望	❑	❑	❑	❑	❑
AIS 船舶自動識別系統	❑	❑	❑	❑	❑
GPS 全球衛星定位系統	❑	❑	❑	❑	❑

31. Please indicate what you think about the accuracy of navigation aids for position fixing.
 請評論您對下列導航方法的定位準確率。

	Very accurate 非常準確	Accurate 準確	Neither/nor 一般	Not accurate 不準確	Least accurate 很不準確
ARPA Radar 雷達	❑	❑	❑	❑	❑
Visual lookout 目視瞭望	❑	❑	❑	❑	❑
AIS 船舶自動識別系統	❑	❑	❑	❑	❑
GPS 全球衛星定位系統	❑	❑	❑	❑	❑

32. What do you feel about the following attributes of Radar?
 您覺得使用雷達導航與下列各特性的關係?

	Very good 非常好	Good 好	Fair 一般	Not Very Good 不太好	Poor 非常差
Accuracy 準確率	❑	❑	❑	❑	❑
Integrity 完整率	❑	❑	❑	❑	❑
Coverage 涵蓋範圍	❑	❑	❑	❑	❑
Reliability 信賴度	❑	❑	❑	❑	❑
Harmonization 協調性	❑	❑	❑	❑	❑

33. What do you feel about the following attributes of AIS?
您覺得使用船舶自動識別系統 AIS 導航與下列各特性的關係?

	Very good 非常好	Good 好	Fair 一般	Not Very Good 不太好	Poor 非常差
Accuracy 準確率	☐	☐	☐	☐	☐
Integrity 完整率	☐	☐	☐	☐	☐
Coverage 涵蓋範圍	☐	☐	☐	☐	☐
Reliability 信賴度	☐	☐	☐	☐	☐
Harmonization 協調性	☐	☐	☐	☐	☐

34. What do you feel about the following attributes of GPS?
您覺得使用衛星定位系統 GPS 導航與下列各特性的關係?

	Very good 非常好	Good 好	Fair 一般	Not Very Good 不太好	Poor 非常差
Accuracy 準確率	☐	☐	☐	☐	☐
Integrity 完整率	☐	☐	☐	☐	☐
Coverage 涵蓋範圍	☐	☐	☐	☐	☐
Reliability 信賴度	☐	☐	☐	☐	☐
Harmonization 協調性	☐	☐	☐	☐	☐

35. What do you feel about the following attributes of Visual Lookout?
您覺得使用目視導航與下列各特性的關係?

	Very good 非常好	Good 好	Fair 一般	Not Very Good 不太好	Poor 非常差
Accuracy 準確率	☐	☐	☐	☐	☐
Integrity 完整率	☐	☐	☐	☐	☐
Coverage 涵蓋範圍	☐	☐	☐	☐	☐
Reliability 信賴度	☐	☐	☐	☐	☐
Harmonization 協調性	☐	☐	☐	☐	☐

36. Would you fully rely on AIS data for collision avoidance? (Please tick one)
您是否會完全仰賴船舶自動識別系統 AIS 進行避碰措施? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

37. AIS can easily get the call sign/ name of the target nearby, do you think you will take advantage of this capability to call for collision avoidance via VHF communication? (Please tick one)
您是否會因 AIS 可自動辨識目標呼號/船名, 進而搭配使用無線電呼叫他船進行避碰? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

38. Does reading the AIS MKD display delay your collision avoidance decision? (Please tick one)
您認爲讀取船舶自動識別系統簡化鍵控顯示器（AIS MKD）會延遲您作避碰的決定嗎? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

39. Does reading the AIS MKD display influence your collision avoidance decision? (Please tick one)
您認爲讀取船舶自動識別系統簡化鍵控顯示器（AIS MKD）會影響您避碰的決定嗎? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

40. Do you agree with the following statements? (Please tick one) 您同意下列陳述嗎? (請單選)

- Non-SOLAS vessels should also be compelled to install AIS. 非 SOLAS 船隻也應強制配備船舶自動識別系統 AIS。
  YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑
- There should be no-go zones for non-SOLAS vessels in specific waters. 在特定海域 (如繁忙狹窄水道) 應設置非 SOLAS 船隻禁航區。
  YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑
- After AIS is fully implemented, AIS **text message** will be used in preference to the use of verbal communication for collision avoidance. 在船舶自動識別系統 AIS 被正式採用後, AIS 簡訊功能會取代在避碰時的 VHF 無線電通訊。
  YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

41. Do you think the use of AIS will trigger the modification of the COLREGS? (Please tick one)
您認爲船舶自動識別系統 AIS 應該被納入避碰章程嗎? (請單選)
YES 是 ❑ /
If '**YES**', which rules shall involve the use of AIS for collision avoidance? (Please select all that apply)
如果'是', 船舶自動識別系統 AIS 應被納入哪一條避碰章程呢? (可複選)

- Rule 6 Safe Speed 安全速度 ❑
- Rule 7 Risk of Collision 碰撞危機 ❑
- Rule 8 Action to Avoid Collision 避碰措施 ❑
- Rule 9 Narrow Channel 狹窄水道 ❑
- Rule 10 Traffic Separation Schemes 分道航行制 ❑
- Rule 19 Conduct of Vessels in Restricted Visibility 能見度受限制之措施 ❑
- Other (please specify) 其他 (請註明) ❑..

NO 否 ❑ /
DON'T KNOW 不清楚 ❑

42. Are you worried about sharing ship's detail with other people at sea via AIS broadcasting network? (Please tick one) 您對區域 AIS 用戶皆可獲得您船舶資料是否感到不妥? (請單選)
YES 是 ❑ / NO 否 ❑ / DON'T KNOW 不清楚 ❑

Overall Comment 整體批評與指教:

Thank you for taking part of this survey.

由衷感謝您參與問卷調查

Appendix J

Results of Survey II

Section A Personal working experience

1. What is your professional rank? (n=189)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Pilot	13	6.8	6.9	6.9
	Master	53	27.9	28.0	34.9
	CO	44	23.2	23.3	58.2
	2O	39	20.5	20.6	78.8
	3O	33	17.4	17.5	96.3
	Cadet	3	1.6	1.6	97.9
	Other	4	2.1	2.1	100.0
	Total	189	99.5	100.0	
Missing	Not given	1	.5		
Total		190	100.0		

2. Are you male or female? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	186	97.9	97.9	97.9
	female	4	2.1	2.1	100.0
	Total	190	100.0	100.0	

3. How many years have you been serving at sea? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than 1 year	7	3.7	3.7	3.7
	1 to 5 years	50	26.3	26.3	30.0
	6 to 10 years	39	20.5	20.5	50.5
	11 to 15 years	30	15.8	15.8	66.3
	more than 15 years	64	33.7	33.7	100.0
	Total	190	100.0	100.0	

4. What is you nationality? (n=154)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Taiwanese	103	54.2	66.9	66.9
	Chinese	38	20.0	24.7	91.6
	HK Chinese	10	5.3	6.5	98.1
	Burma	3	1.6	1.9	100.0
	Total	154	81.1	100.0	
Missing	Not Given	36	18.9		
Total		190	100.0		

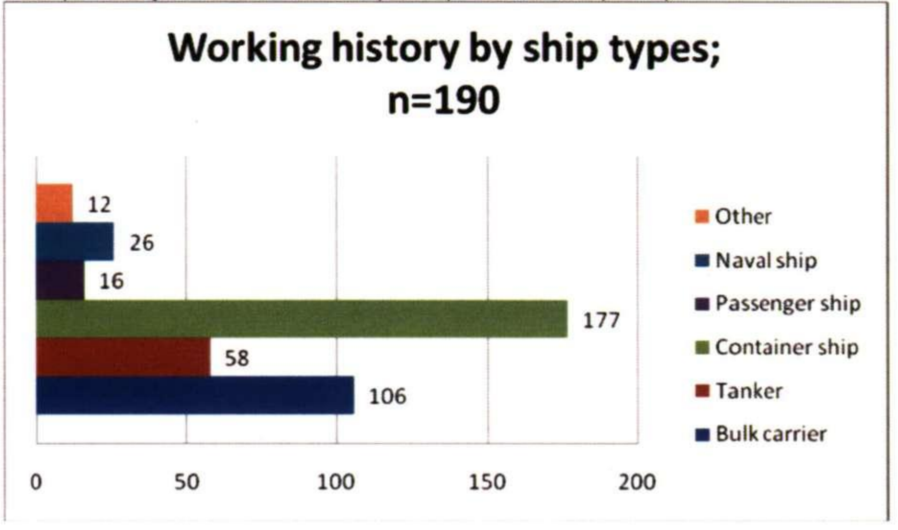
5. With which company are you currently working? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	EVERGREEN	29	15.3	15.3	15.3
	U-Ming	5	2.6	2.6	17.9
	WANHAI	18	9.5	9.5	27.4
	YANGMING	110	57.9	57.9	85.3
	OTHER	13	6.8	6.8	92.1
	HK Pilot Association Ltd	15	7.9	7.9	100.0
	Total	190	100.0	100.0	

Comment:

- Other; OOCL shipping company (no. 6);
- Other; JACKSOON Shipping Safety Management Consultant Co., Ltd. (no. 8).

6. What types of ships have you worked on in the past? (n=190; multi options)



7. What type of ship do you now work on? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bulk carrier	19	10.0	10.0	10.0
	Tanker	2	1.1	1.1	11.1
	Container ship	117	61.6	61.6	72.6
	Working on land	32	16.8	16.8	89.5
	Other	20	10.5	10.5	100.0
	Total	190	100.0	100.0	

8. Would you also specify the voyages you are working on?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Asia/N. America	44	23.2	25.4	25.4
	Asia/S. America	2	1.1	1.2	26.6
	Asia/Europe	31	16.3	17.9	44.5
	Asia/Africa	2	1.1	1.2	45.7
	Inter Asia, Persian Gulf	27	14.2	15.6	61.3
	Working on land	32	16.8	18.5	79.8
	Other	35	18.4	20.2	100.0
	Total	173	91.1	100.0	
Missing	System	17	8.9		
Total		190	100.0		

Section B General View

9. Do you have any experience of using AIS? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	176	92.6	92.6	92.6
	NO	14	7.4	7.4	100.0
	Total	190	100.0	100.0	

9_1 If answer 'no', have you heard about AIS? (n=14)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	12	6.3	85.7	85.7
	NO	2	1.1	14.3	100.0
	Total	14	7.4	100.0	
Missing	Not Given	176	92.6		
Total		190	100.0		

10. Have you ever used AIS to aid decision making in collision avoidance? (n=187)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	108	56.8	57.8	57.8
	NO	76	40.0	40.6	98.4
	DON'T KNOW	3	1.6	1.6	100.0
	Total	187	98.4	100.0	
Missing	System	3	1.6		
Total		190	100.0		

11. To what degree do you see AIS as useful for these applications on board? (n=174)

11_1 AIS for Collision Avoidance aid

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very useful	26	14.9	14.9	14.9
	Useful	66	37.9	37.9	52.9
	Neither/nor	56	32.2	32.2	85.1
	Not useful	17	9.8	9.8	94.8
	Least useful	9	5.2	5.2	100.0
	Total	174	100.0	100.0	

11_2 AIS for positioning

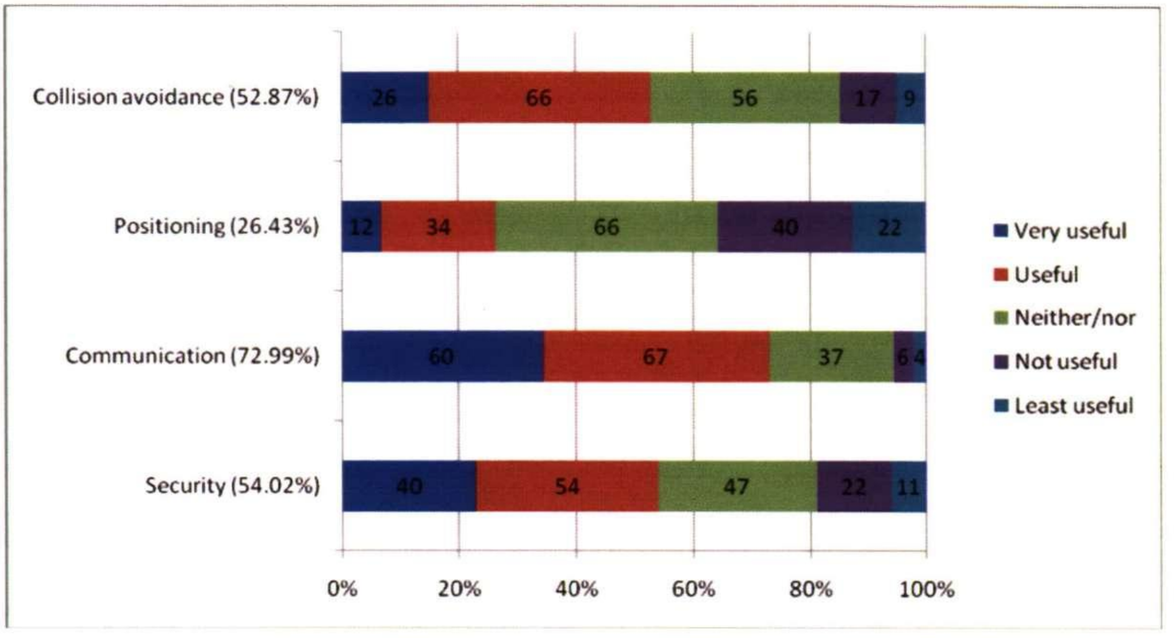
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very useful	12	6.9	6.9	6.9
	Useful	34	19.5	19.5	26.4
	Neither/nor	66	37.9	37.9	64.4
	Not useful	40	23.0	23.0	87.4
	Least useful	22	12.6	12.6	100.0
	Total	174	100.0	100.0	

11_3 AIS for communication

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very useful	60	34.5	34.5	34.5
	Useful	67	38.5	38.5	73.0
	Neither/nor	37	21.3	21.3	94.3
	Not useful	6	3.4	3.4	97.7
	Least useful	4	2.3	2.3	100.0
	Total	174	100.0	100.0	

11_4 AIS for security

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very useful	40	23.0	23.0	23.0
	Useful	54	31.0	31.0	54.0
	Neither/nor	47	27.0	27.0	81.0
	Not useful	22	12.6	12.6	93.7
	Least useful	11	6.3	6.3	100.0
	Total	174	100.0	100.0	



Section C Lookout on the bridge & Collision Avoidance

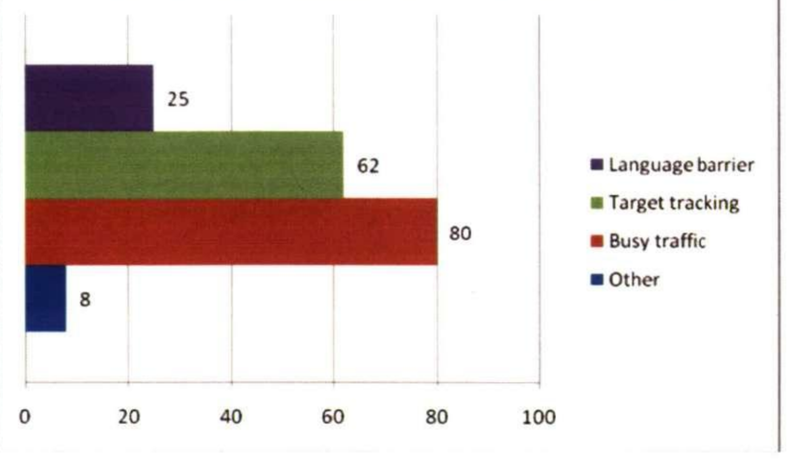
12. Do you find it difficult to get in contact with another ship using VHF? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	114	60.0	60.0	60.0
	NO	74	38.9	38.9	98.9
	DON'T KNOW	2	1.1	1.1	100.0
	Total	190	100.0	100.0	

Comment:

- Yes; some vessels do not respond to the VHF calling (no. 33);
- Yes; some vessels do not respond to the VHF calling especially in busy waters (no. 37);
- Don't know; it takes several times calling to get a response (no. 47);
- Yes; the OOWs not aware (no. 80);
- Yes; cannot acquire ship's name (no. 180).

12_1 If answer 'YES', what are the reasons? (n=110)



Comment:

- Other; too much noise (no.3);
- Target tracking; difficulties appear when the weather is worsening or when a navigation aid is needed (no. 8);
- Other; the font size is too small (no. 14);
- Other; the opponent did not listen to the radio and keep the lookout (no. 61);
- Language barrier; Non native English mariners tend not to respond to the VHF calling (no. 63);
- Other; sometimes the other ships do not always reply to the VHF calling (no. 111).

13. Do you agree the nearby ships tend NOT to take action if you only use shapes, lights and sound signals to indicate your intention? (n=186)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	54	28.4	29.0	29.0
	NO	117	61.6	62.9	91.9
	DON'T KNOW	15	7.9	8.1	100.0
	Total	186	97.9	100.0	
Missing	System	4	2.1		
Total		190	100.0		

14. Do you use VHF to assist you when taking collision avoidance action? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	180	94.7	94.7	94.7
	NO	9	4.7	4.7	99.5
	DON'T KNOW	1	.5	.5	100.0
	Total	190	100.0	100.0	

Comment:

- Yes; only use VHF when the traffic density is low (no. 47).

15. Do you use VHF when a Close-quarters situation has developed? (n=189)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	155	81.6	82.0	82.0
	NO	33	17.4	17.5	99.5
	DON'T KNOW	1	.5	.5	100.0
	Total	189	99.5	100.0	
Missing	System	1	.5		
Total		190	100.0		

16. How do you currently like to set up the volume of your VHF channel 16? (n=185)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Mute	2	1.1	1.1	1.1
	Very low	1	.5	.5	1.6
	Low	25	13.2	13.5	15.1
	Medium	129	67.9	69.7	84.9
	Loud	26	13.7	14.1	98.9
	Very Loud	2	1.1	1.1	100.0
	Total	185	97.4	100.0	
Missing	No opinion	2	1.1		
	Other	3	1.6		
	Total	5	2.6		
Total		190	100.0		

Comment:

- Medium; two VHF channels will be switched on in busy waters (no.3).

17. Are you worried about the Radar's detection while sailing at a bend channel or an obstructed landscape ahead? (n=189)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	149	78.4	78.8	78.8
	NO	39	20.5	20.6	99.5
	DON'T KNOW	1	.5	.5	100.0
	Total	189	99.5	100.0	
Missing	System	1	.5		
Total		190	100.0		

18. Are you worried about the Radar's detection for identification of small boats? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	170	89.5	89.5	89.5
	NO	18	9.5	9.5	98.9
	DON'T KNOW	2	1.1	1.1	100.0
	Total	190	100.0	100.0	

19. What function do you normally use for ARPA decision on collision avoidance? (n=186)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sea Stab.	83	43.7	44.6	44.6
	Ground Stab.	96	50.5	51.6	96.2
	Other	7	3.7	3.8	100.0
	Total	186	97.9	100.0	
Missing	System	4	2.1		
Total		190	100.0		

Comment:

- Other; turn on all RADARs on the bridge (no.3);
- Other; exchange between the two modes (no. 13);
- Other; not using ARPA for collision avoidance just for reference (no. 25);
- Other; randomly (no. 39);

- Other; it depends on master's choice (no. 87);
- Missing answer; in practice, the RADAR setup shall be true motion or relative motion (no. 186).

20. What scores you will give to these vessels for obeying the rules of the road generally.

20_1 Cargo Ship/COLREGs? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	30	15.8	15.8	15.8
	Fairly Satisfied	103	54.2	54.2	70.0
	Neither/nor	53	27.9	27.9	97.9
	Fairly Dissatisfied	4	2.1	2.1	100.0
	Total	190	100.0	100.0	

20_2 Large Cargo ship/ COLREGs? (n=189)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	50	26.3	26.5	26.5
	Fairly Satisfied	108	56.8	57.1	83.6
	Neither/nor	30	15.8	15.9	99.5
	Fairly Dissatisfied	1	.5	.5	100.0
	Total	189	99.5	100.0	
Missing	System	1	.5		
Total		190	100.0		

20_3 Fishing boat/COLREGs? (n=188)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fairly Satisfied	4	2.1	2.1	2.1
	Neither/nor	25	13.2	13.3	15.4
	Fairly Dissatisfied	78	41.1	41.5	56.9
	Very Dissatisfied	81	42.6	43.1	100.0
	Total	188	98.9	100.0	
Missing	System	2	1.1		
Total		190	100.0		

20_4 Naval ship/COLREGs? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	10	5.3	5.3	5.3
	Fairly Satisfied	50	26.3	26.3	31.6
	Neither/nor	85	44.7	44.7	76.3
	Fairly Dissatisfied	36	18.9	18.9	95.3
	Very Dissatisfied	9	4.7	4.7	100.0
	Total	190	100.0	100.0	

20_5 Sailing boat & Yacht/COLREGs? (n=190)

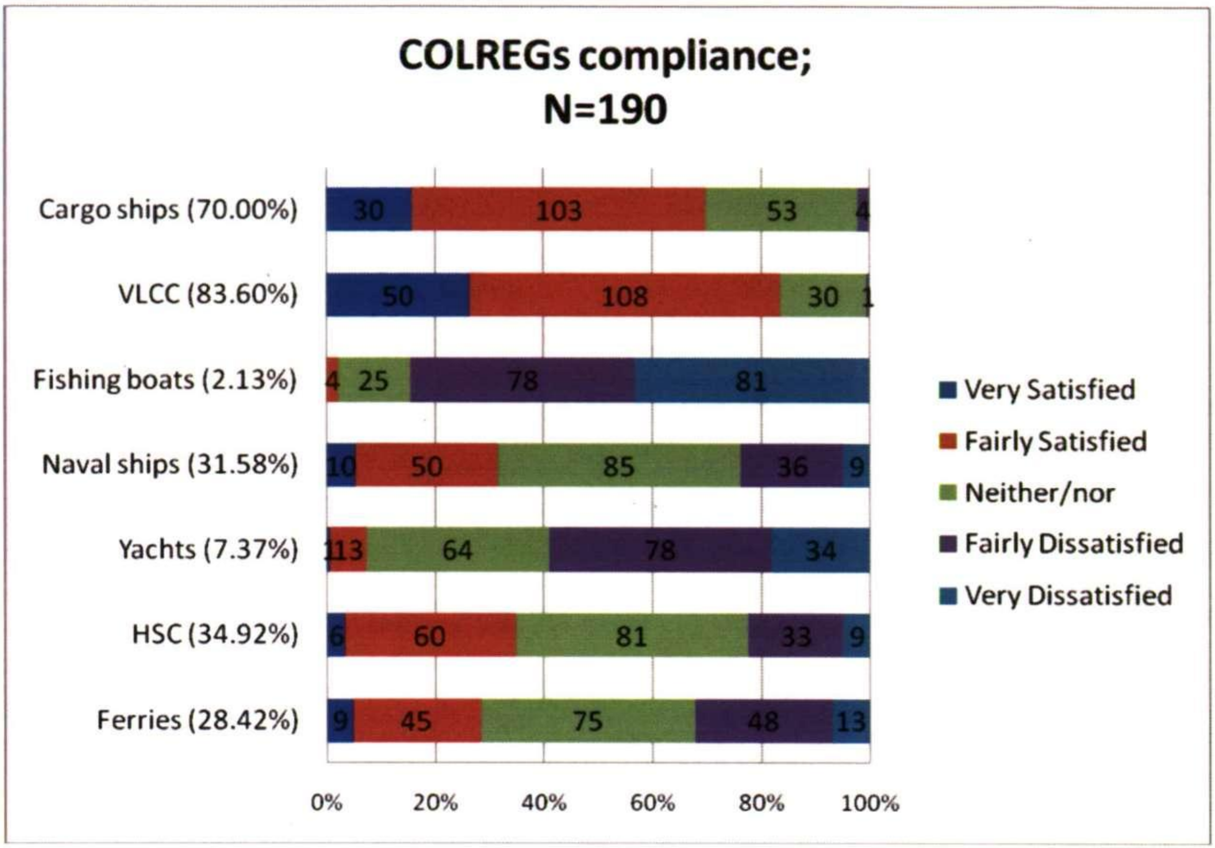
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	1	.5	.5	.5
	Fairly Satisfied	13	6.8	6.8	7.4
	Neither/nor	64	33.7	33.7	41.1
	Fairly Dissatisfied	78	41.1	41.1	82.1
	Very Dissatisfied	34	17.9	17.9	100.0
	Total	190	100.0	100.0	

20_6 High Speed Craft/COLREGs? (n=189)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	6	3.2	3.2	3.2
	Fairly Satisfied	60	31.6	31.7	34.9
	Neither/nor	81	42.6	42.9	77.8
	Fairly Dissatisfied	33	17.4	17.5	95.2
	Very Dissatisfied	9	4.7	4.8	100.0
	Total	189	99.5	100.0	
Missing	System	1	.5		
Total		190	100.0		

20_7 Ferry/COLREGs? (n=190)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	9	4.7	4.7	4.7
	Fairly Satisfied	45	23.7	23.7	28.4
	Neither/nor	75	39.5	39.5	67.9
	Fairly Dissatisfied	48	25.3	25.3	93.2
	Very Dissatisfied	13	6.8	6.8	100.0
	Total	190	100.0	100.0	



Section D Layout of NAV AIDS on the bridge

21. Overall, how satisfied are you overall with the location of aids to navigation on the bridge?

21_1 Are you satisfied with the location of AIS Minimum Keypad Display on bridge? (n=174)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	17	9.8	9.8	9.8
	Fairly Satisfied	73	42.0	42.0	51.7
	Neither/nor	54	31.0	31.0	82.8
	Fairly Dissatisfied	28	16.1	16.1	98.9
	Very Dissatisfied	2	1.1	1.1	100.0
	Total	174	100.0	100.0	

Comment:

- Fairly Dissatisfied; AIS is next to the window and easy to be overheated by sun (no.5);
- Very Satisfied; AIS is generally fitted in some place easier to operate when on lookout (no. 8);
- Fairly Dissatisfied ; location is not ideal and it takes several times to compare data from both RADAR and AIS (no. 52);
- Fairly Dissatisfied; should be placed at close proximately with RADAR (no. 77).

21_2 Are you satisfied with the location of Radar/ARPA on bridge? (n=188)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	24	12.6	12.8	12.8
	Fairly Satisfied	129	67.9	68.6	81.4
	Neither/nor	32	16.8	17.0	98.4
	Fairly Dissatisfied	2	1.1	1.1	99.5
	Very Dissatisfied	1	.5	.5	100.0
	Total	188	98.9	100.0	
Missing	System	2	1.1		
Total		190	100.0		

21_3 Are you satisfied with the location of VHF on bridge? (n=188)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	20	10.5	10.6	10.6
	Fairly Satisfied	104	54.7	55.3	66.0
	Neither/nor	44	23.2	23.4	89.4
	Fairly Dissatisfied	18	9.5	9.6	98.9
	Very Dissatisfied	2	1.1	1.1	100.0
	Total	188	98.9	100.0	
Missing	System	2	1.1		
Total		190	100.0		

Comment:

- Neither/nor; need more VHF on the bridge (no. 5);
- Fairly Dissatisfied; it would be better if VHF is next to RADAR (no. 52);
- Fairly Satisfied; some ships are fitted with VHF, one on each bridge wing. It is not convenient to pilotage usage (no. 86).

21_4 Are you satisfied with the location of (Electronic) Chart on bridge? (n=180)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	25	13.2	13.9	13.9
	Fairly Satisfied	108	56.8	60.0	73.9
	Neither/nor	41	21.6	22.8	96.7
	Fairly Dissatisfied	6	3.2	3.3	100.0
	Total	180	94.7	100.0	
Missing	System	10	5.3		
Total		190	100.0		

Comment:

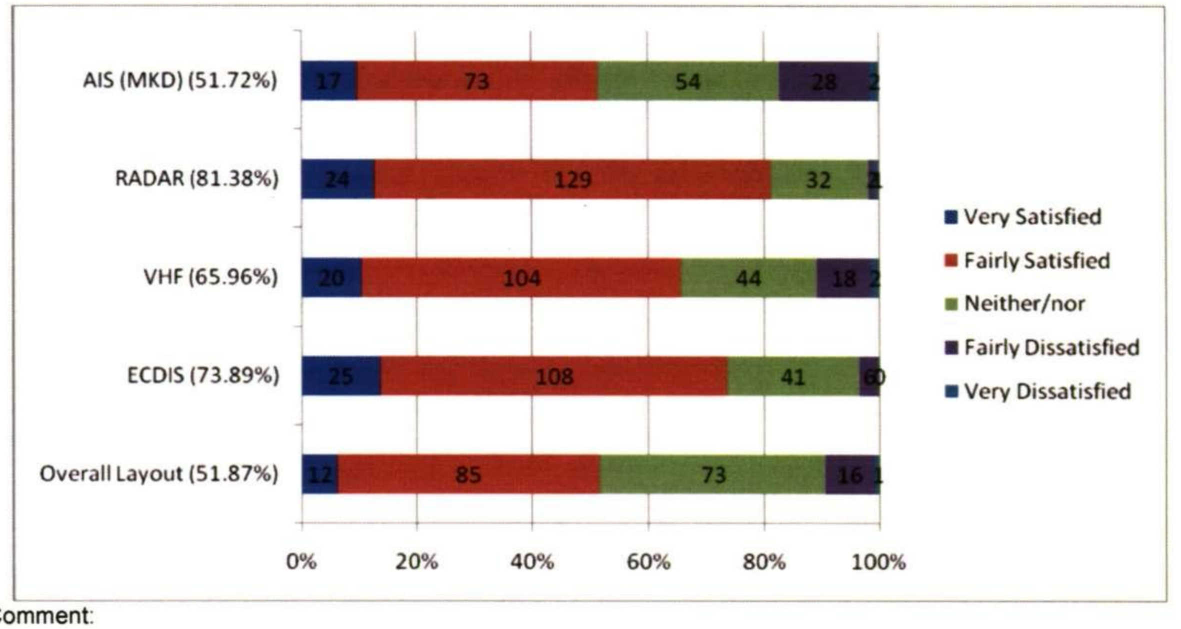
- Missing answer; no ECDIS on the bridge (no. 74).

21_5 Are you satisfied with overall bridge layout? (n=187)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	12	6.3	6.4	6.4
	Fairly Satisfied	85	44.7	45.5	51.9
	Neither/nor	73	38.4	39.0	90.9
	Fairly Dissatisfied	16	8.4	8.6	99.5
	Very Dissatisfied	1	.5	.5	100.0
	Total	187	98.4	100.0	
Missing	System	3	1.6		
Total		190	100.0		

Comment:

- Neither/nor; overall installation is sometimes too old and does not fulfil the demand (no. 5).



Comment:

- Different types of ship will have different opinions (no. 186).

Section E Training, Implementation and Installing Issues

22. Do you have experience of any problems because of the change of implementation date being moved forward? (n=171)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	21	12.1	12.3	12.3
	NO	119	68.4	69.6	81.9
	DON'T KNOW	31	17.8	18.1	100.0
	Total	171	98.3	100.0	
Missing	System	3	1.7		
Total		174	100.0		

23. Do you agree that the revised timescale is more about security for the littoral countries than navigation at sea? (n=173)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	69	39.7	39.9	39.9
	NO	59	33.9	34.1	74.0
	DON'T KNOW	45	25.9	26.0	100.0
	Total	173	99.4	100.0	
Missing	System	1	.6		
Total		174	100.0		

24. Although present regulations require SOLAS ships to install AIS MKD on board, are you aware that there is no requirement for mariners to be trained in its use? (n=172)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	116	66.7	67.4	67.4
	NO	22	12.6	12.8	80.2
	DON'T KNOW	34	19.5	19.8	100.0
	Total	172	98.9	100.0	
Missing	System	2	1.1		
Total		174	100.0		

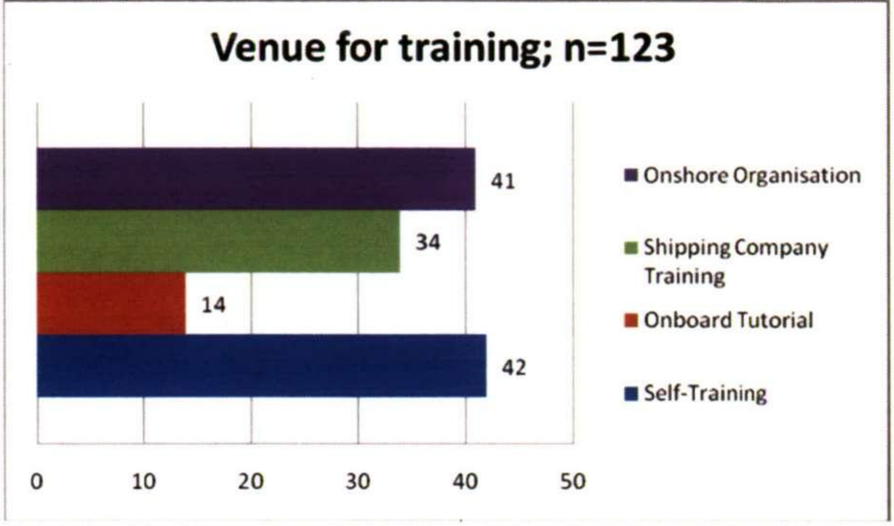
25. Do you think Officers on Watch should receive proper training to use AIS for collision avoidance? (n=171)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	122	70.1	71.3	71.3
	NO	49	28.2	28.7	100.0
	Total	171	98.3	100.0	
Missing	System	3	1.7		
Total		174	100.0		

Comment:

- No; AIS is not an active operation panel, you need to read COLREGs carefully when doing collision avoidance (no.3)
- No; it does not need training to use AIS in collision avoidance (no. 13);
- No; it is enough just to apply ARPA and visual bearing (no. 14);
- No; AIS does not have warning function for collision avoidance (no. 15);
- No; AIS is easy to operate and it can be seen as one of the aids to navigation (no. 24);
- Don't know; haven't used AIS yet (no. 25);
- No; ARPA is enough (no. 59);
- No; AIS is better in identification than collision avoidance (no. 65);
- No; easy operation and not necessary (no. 78);
- No; AIS cannot be used in collision avoidance alone (no. 98);
- No; AIS cannot be used in collision avoidance alone (no. 99);
    - No; there is too much training for OOWs (no. 108);
- No; the purpose of AIS is not for collision avoidance. Also, the OOWs have already taken training of ARPA RADAR collision avoidance (no. 113);
- No; AIS cannot be used in collision avoidance (no. 171);
- No; AIS cannot be used in collision avoidance (no. 172);
- No; AIS positioning data source are from GPS, which is not reliable (no. 173);
- No; AIS cannot be used in collision avoidance (no. 174);
- No; only for identification is enough (no 180);
- No; it is dangerous using AIS in collision avoidance (no. 186).

25_1 If yes, where do you think is the best place to hold AIS operation training? (n=123; multi options)



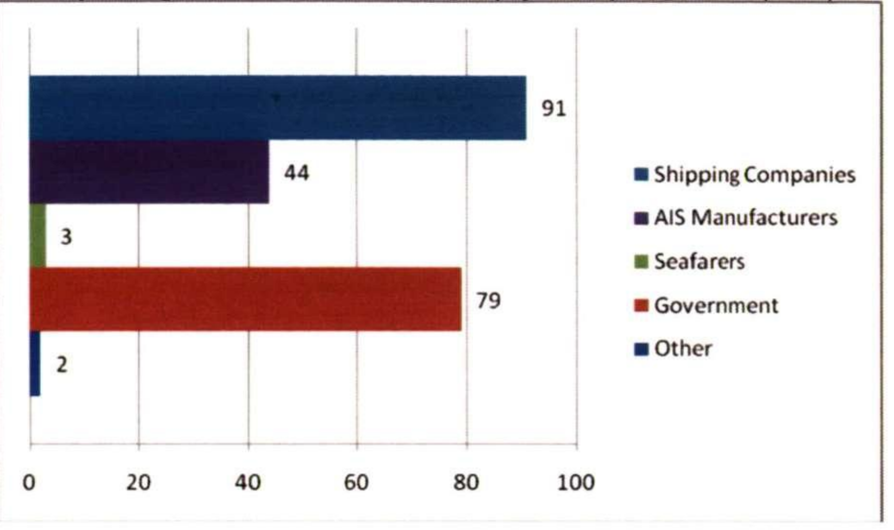
26. Do you have difficulty communicating with technicians who install and service electronic equipment on board? (n=100)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	10	5.7	13.5	13.5
	NO	54	31.0	73.0	86.5
	DON'T KNOW	10	5.7	13.5	100.0
	Total	74	42.5	100.0	
Missing	System	100	57.5		
Total		174	100.0		

Comment:

- Technicians do not know much about the equipment they install (no. 5);
- Yes; Technicians does not know the real usage of it (no. 15);
- Yes; there is a big gap between technicians and users (no. 25);
- Yes; the manufacturer agent does not know much about the system and even don't provide the password to the device (no. 41);
- Yes; the maintenance technician normally does not allow watching due to there are some internal setup restricted to the manufacturers (no. 70);
- Yes; they are either technical or whatever but not operator (no. 77);
- Yes; they don't know the user's needs (no. 83);
- No; AIS is complex to confuse the display, therefore, the main display is enough (no. 184).

27. If there is mandatory training in the use of AIS, who should pay for it? (n=172; multi options)



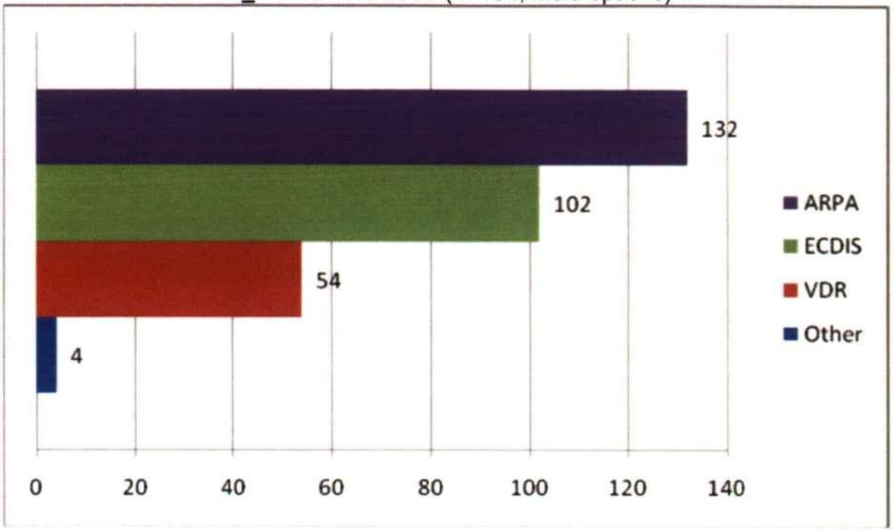
28. AIS can provide ground speed information, rate of turn, identification of target, etc. Would you like to see AIS data integrated into the fellow electronic devices on board? (n=173)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	159	91.4	91.9	91.9
	NO	13	7.5	7.5	99.4
	DON'T KNOW	1	.6	.6	100.0
	Total	173	99.4	100.0	
Missing	System	1	.6		
Total		174	100.0		

Comment:

- No; AIS is a passive operation, need to read individual data and then make decision (no.3);
- No; too much information fed into the ARPA's screen may not be useful (no. 24);
- Don't know; haven't used AIS yet (no. 25);
- No; too much information on same piece of equipment lead to confusion (no. 77);
- No; the AIS information carries too much detail (no. 82);
- No; too much information from those equipment already (no. 83);
- No; GPS signal fed into AIS contains errors (no. 98);
- No; GPS signal fed into AIS contains errors, the data presented on AIS may have errors too (no.99);
- No; accuracy is questionable where errors exist in heading and speed data (no.108).

28_1 which device? (n=154; multi options)



Comment:

- Other; TOTAL NAV (no. 39).

Section F AIS and Collision Avoidance

29. Do you think that AIS data is currently suitable as an aid to collision avoidance? (n=169)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	125	71.8	74.0	74.0
	NO	42	24.1	24.9	98.8
	DON'T KNOW	2	1.1	1.2	100.0
	Total	169	97.1	100.0	
Missing	System	5	2.9		
Total		174	100.0		

30. Would you indicate the importance of following navigation aids for collision avoidance decisions? (n=174)

30_1 Importance for anti-collision/ARPA?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	132	75.9	75.9	75.9
	Important	40	23.0	23.0	98.9
	Neither/nor	2	1.1	1.1	100.0
	Total	174	100.0	100.0	

30_2 Importance for anti-collision/VHF?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	79	45.4	45.4	45.4
	Important	64	36.8	36.8	82.2
	Neither/nor	28	16.1	16.1	98.3
	Not Important	2	1.1	1.1	99.4
	Least Important	1	.6	.6	100.0
	Total	174	100.0	100.0	

30_3 Importance for anti-collision/Watchkeeping?

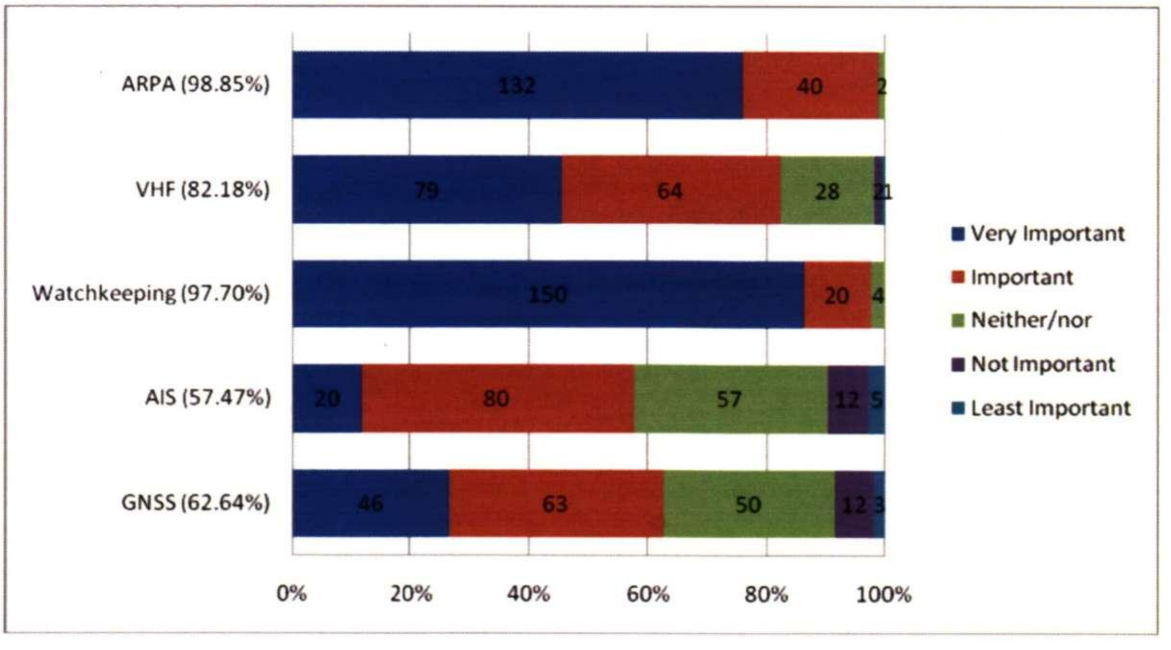
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	150	86.2	86.2	86.2
	Important	20	11.5	11.5	97.7
	Neither/nor	4	2.3	2.3	100.0
	Total	174	100.0	100.0	

30_4 Importance for anti-collision/AIS?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	20	11.5	11.5	11.5
	Important	80	46.0	46.0	57.5
	Neither/nor	57	32.8	32.8	90.2
	Not Important	12	6.9	6.9	97.1
	Least Important	5	2.9	2.9	100.0
	Total	174	100.0	100.0	

30_5 Importance for anti-collision/GNSS?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	46	26.4	26.4	26.4
	Important	63	36.2	36.2	62.6
	Neither/nor	50	28.7	28.7	91.4
	Not Important	12	6.9	6.9	98.3
	Least Important	3	1.7	1.7	100.0
	Total	174	100.0	100.0	



31. Please indicate what you think about the accuracy of navigation aids for position fixing. (n=174)

31_1 Accuracy for Positioning/ARPA?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Accurate	77	44.3	44.3	44.3
	Accurate	88	50.6	50.6	94.8
	Neither/nor	9	5.2	5.2	100.0
	Total	174	100.0	100.0	

31_2 Accuracy for Positioning/Watchkeeping?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Accurate	55	31.6	31.6	31.6
	Accurate	70	40.2	40.2	71.8
	Neither/nor	41	23.6	23.6	95.4
	Not Accurate	7	4.0	4.0	99.4
	Least Accurate	1	.6	.6	100.0
	Total	174	100.0	100.0	

Comment:

- Neither/nor; although visual is not very accurate but it is the most reliable way without interference of mechanical malfunction (no. 42).

31_3 Accuracy for Positioning/AIS?

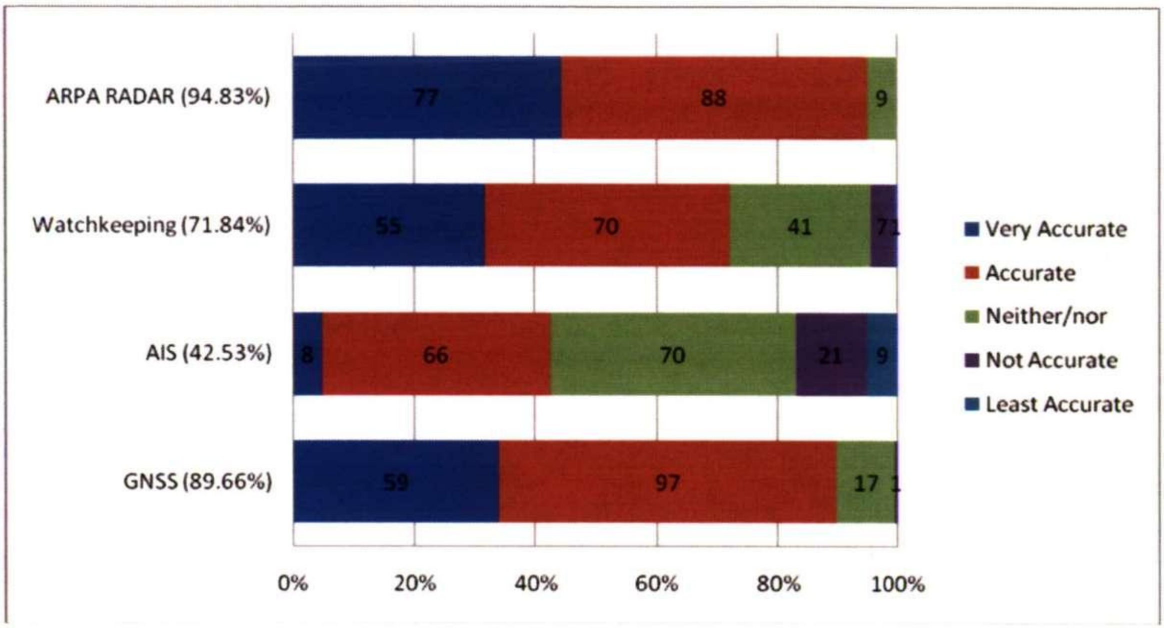
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Accurate	8	4.6	4.6	4.6
	Accurate	66	37.9	37.9	42.5
	Neither/nor	70	40.2	40.2	82.8
	Not Accurate	21	12.1	12.1	94.8
	Least Accurate	9	5.2	5.2	100.0
	Total	174	100.0	100.0	

Comment:

- Missing answer; AIS connects to data source of GPS (no. 13).

31_4 Accuracy for Positioning/GNSS?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Accurate	59	33.9	33.9	33.9
	Accurate	97	55.7	55.7	89.7
	Neither/nor	17	9.8	9.8	99.4
	Not Accurate	1	.6	.6	100.0
	Total	174	100.0	100.0	



32. What do you feel about the following attributes of Radar? (n=174)

32_1 Radar/Accuracy?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	51	29.3	29.3	29.3
	Good	111	63.8	63.8	93.1
	Fair	12	6.9	6.9	100.0
	Total	174	100.0	100.0	

32_2 Radar/Integrity?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	31	17.8	17.8	17.8
	Good	109	62.6	62.6	80.5
	Fair	34	19.5	19.5	100.0
	Total	174	100.0	100.0	

32_3 Radar/Coverage?

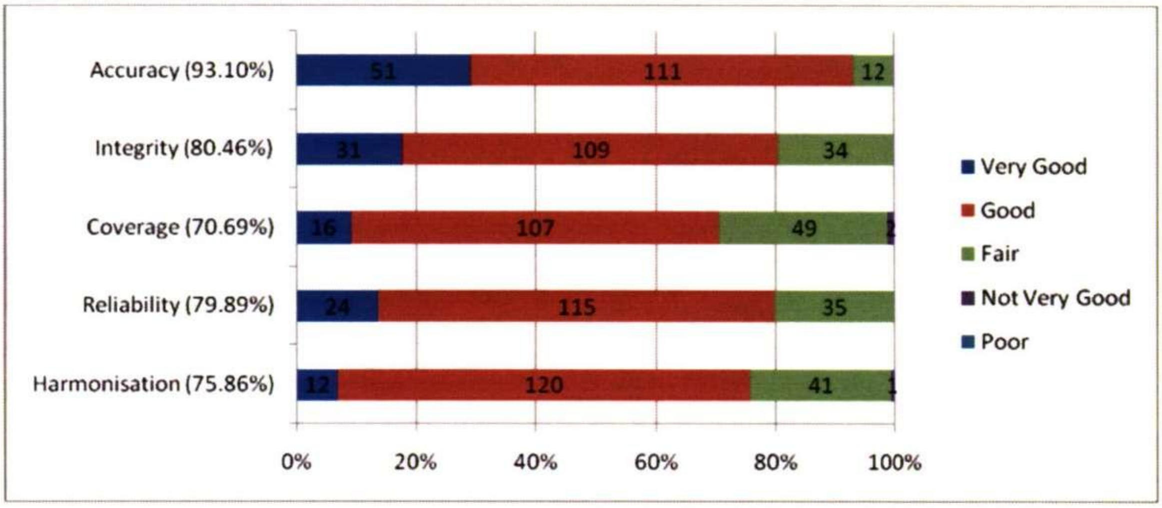
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	16	9.2	9.2	9.2
	Good	107	61.5	61.5	70.7
	Fair	49	28.2	28.2	98.9
	Not Very Good	2	1.1	1.1	100.0
	Total	174	100.0	100.0	

32_4 Radar/Reliability?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	24	13.8	13.8	13.8
	Good	115	66.1	66.1	79.9
	Fair	35	20.1	20.1	100.0
	Total	174	100.0	100.0	

32_5 Radar/Harmonisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	12	6.9	6.9	6.9
	Good	120	69.0	69.0	75.9
	Fair	41	23.6	23.6	99.4
	Not Very Good	1	.6	.6	100.0
	Total	174	100.0	100.0	



33. What do you feel about the following attributes of AIS? (n=174)

33_1 AIS/Accuracy?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	9	5.2	5.2	5.2
	Good	75	43.1	43.1	48.3
	Fair	63	36.2	36.2	84.5
	Not Very Good	22	12.6	12.6	97.1
	Poor	5	2.9	2.9	100.0
	Total	174	100.0	100.0	

33_2 AIS/Integrity?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	6	3.4	3.4	3.4
	Good	68	39.1	39.1	42.5
	Fair	74	42.5	42.5	85.1
	Not Very Good	22	12.6	12.6	97.7
	Poor	4	2.3	2.3	100.0
	Total	174	100.0	100.0	

33_3 AIS/Coverage?

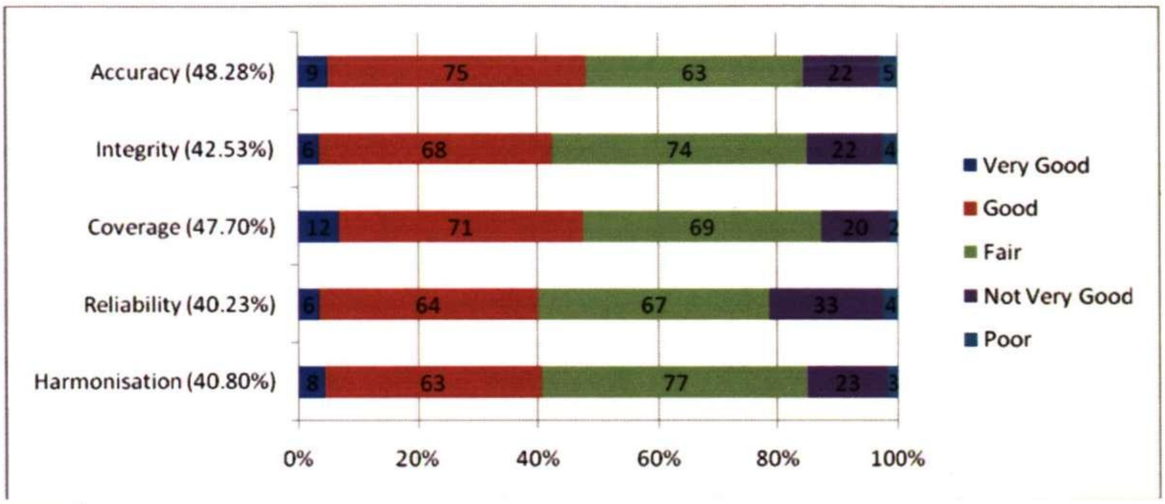
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	12	6.9	6.9	6.9
	Good	71	40.8	40.8	47.7
	Fair	69	39.7	39.7	87.4
	Not Very Good	20	11.5	11.5	98.9
	Poor	2	1.1	1.1	100.0
	Total	174	100.0	100.0	

33_4 AIS/Reliability?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	6	3.4	3.4	3.4
	Good	64	36.8	36.8	40.2
	Fair	67	38.5	38.5	78.7
	Not Very Good	33	19.0	19.0	97.7
	Poor	4	2.3	2.3	100.0
	Total	174	100.0	100.0	

33_5 AIS/Harmonisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	8	4.6	4.6	4.6
	Good	63	36.2	36.2	40.8
	Fair	77	44.3	44.3	85.1
	Not Very Good	23	13.2	13.2	98.3
	Poor	3	1.7	1.7	100.0
	Total	174	100.0	100.0	



Comment:

- AIS is not required on small boats and fishing boats (no. 42).

34. What do you feel about the following attributes of GNSS? (n=174)

34_1 GNSS/Accuracy?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	48	27.6	27.6	27.6
	Good	105	60.3	60.3	87.9
	Fair	18	10.3	10.3	98.3
	Not Very Good	3	1.7	1.7	100.0
	Total	174	100.0	100.0	

34_2 GNSS/Integrity?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	35	20.1	20.1	20.1
	Good	114	65.5	65.5	85.6
	Fair	22	12.6	12.6	98.3
	Not Very Good	3	1.7	1.7	100.0
	Total	174	100.0	100.0	

34_3 GNSS/Coverage?

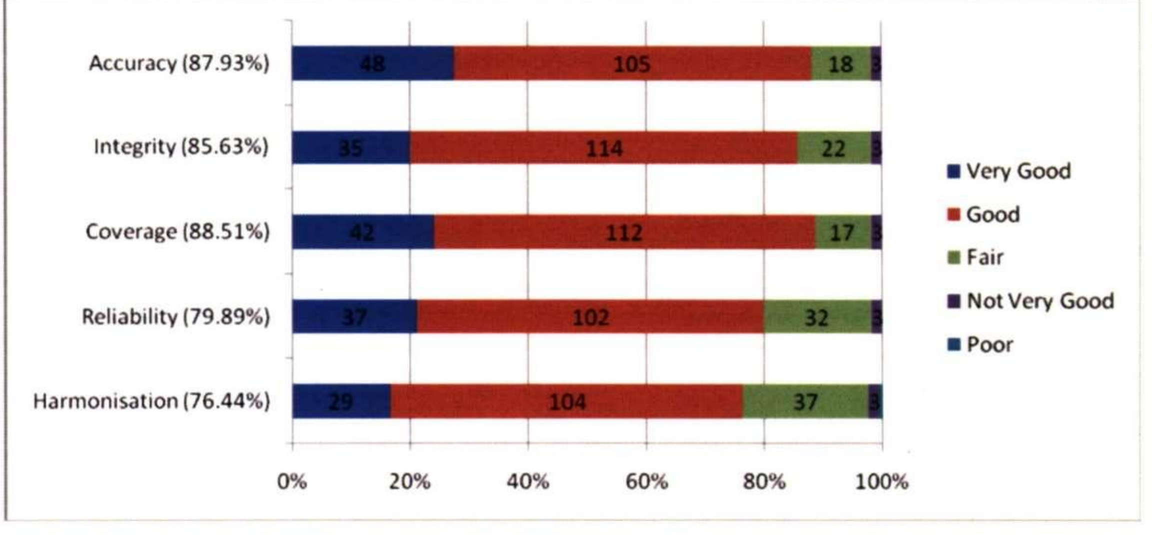
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	42	24.1	24.1	24.1
	Good	112	64.4	64.4	88.5
	Fair	17	9.8	9.8	98.3
	Not Very Good	3	1.7	1.7	100.0
	Total	174	100.0	100.0	

34_4 GNSS/Reliability?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	37	21.3	21.3	21.3
	Good	102	58.6	58.6	79.9
	Fair	32	18.4	18.4	98.3
	Not Very Good	3	1.7	1.7	100.0
	Total	174	100.0	100.0	

34_5 GNSS/Harmonisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	29	16.7	16.7	16.7
	Good	104	59.8	59.8	76.4
	Fair	37	21.3	21.3	97.7
	Not Very Good	3	1.7	1.7	99.4
	Poor	1	.6	.6	100.0
	Total	174	100.0	100.0	



35. What do you feel about the following attributes of Visual Lookout? (n=174)

35_1 Visual/Accuracy?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	41	23.6	23.6	23.6
	Good	78	44.8	44.8	68.4
	Fair	51	29.3	29.3	97.7
	Not Very Good	4	2.3	2.3	100.0
	Total	174	100.0	100.0	

35_2 Visual/Integrity?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	23	13.2	13.2	13.2
	Good	87	50.0	50.0	63.2
	Fair	56	32.2	32.2	95.4
	Not Very Good	7	4.0	4.0	99.4
	Poor	1	.6	.6	100.0
	Total	174	100.0	100.0	

35_3 Visual/Coverage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	9	5.2	5.2	5.2
	Good	59	33.9	33.9	39.1
	Fair	80	46.0	46.0	85.1
	Not Very Good	24	13.8	13.8	98.9
	Poor	2	1.1	1.1	100.0
	Total	174	100.0	100.0	

Comment:

- Good; coverage is affected by visibility (no. 42).

35_4 Visual/Reliability?

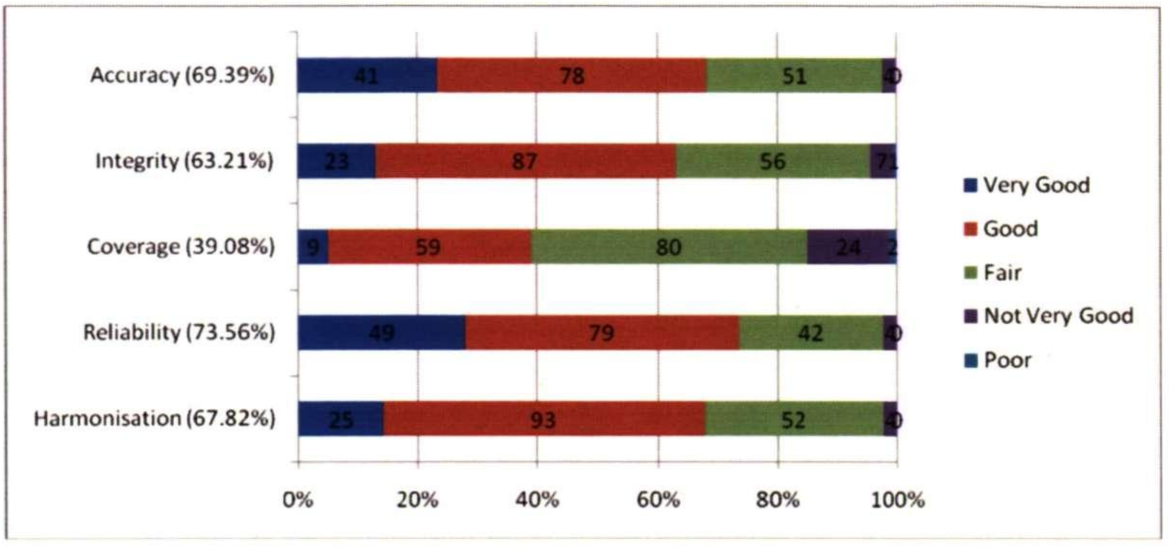
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	49	28.2	28.2	28.2
	Good	79	45.4	45.4	73.6
	Fair	42	24.1	24.1	97.7
	Not Very Good	4	2.3	2.3	100.0
	Total	174	100.0	100.0	

Comment:

- Good; visual is reliable during the night time watch (no. 24).

35_5 Visual/Harmonisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Good	25	14.4	14.4	14.4
	Good	93	53.4	53.4	67.8
	Fair	52	29.9	29.9	97.7
	Not Very Good	4	2.3	2.3	100.0
	Total	174	100.0	100.0	



36. Would you fully rely on AIS data for collision avoidance? (n=168)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	5	2.9	3.0	3.0
	NO	162	93.1	96.4	99.4
	DON'T KNOW	1	.6	.6	100.0
	Total	168	96.6	100.0	
Missing	System	6	3.4		
Total		174	100.0		

37. AIS can easily get the call sign/ name of the target nearby, do you think you will take advantage of this capability to call for collision avoidance via VHF communication? (n=174)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	164	94.3	94.3	94.3
	NO	10	5.7	5.7	100.0
	Total	174	100.0	100.0	

38. Does reading the AIS MKD display delay your collision avoidance decision? (n=173)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	51	29.3	29.5	29.5
	NO	113	64.9	65.3	94.8
	DON'T KNOW	9	5.2	5.2	100.0
	Total	173	99.4	100.0	
Missing	System	1	.6		
Total		174	100.0		

Comment:

- Don't know; don't use AIS often (no. 24).

39. Does reading the AIS MKD display influence your collision avoidance decision? (n=173)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	43	24.7	24.9	24.9
	NO	120	69.0	69.4	94.2
	DON'T KNOW	10	5.7	5.8	100.0
	Total	173	99.4	100.0	
Missing	System	1	.6		
Total		174	100.0		

40. Do you agree with the following statements?

40_1 Non-SOLAS vessels should also be compelled to install AIS. (n=173)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	133	76.4	76.4	76.4
	NO	30	17.2	17.2	93.7
	DON'T KNOW	11	6.3	6.3	100.0
	Total	174	100.0	100.0	

40_2 There should be no-go zones for non-SOLAS vessels in specific waters. (n=173)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	112	64.4	64.7	64.7
	NO	36	20.7	20.8	85.5
	DON'T KNOW	25	14.4	14.5	100.0
	Total	173	99.4	100.0	
Missing	System	1	.6		
Total		174	100.0		

Comment:

- Yes; however, it is not possible (no.108).

40_3 After AIS is fully implemented, AIS text message will be used in preference to the use of verbal communication for collision avoidance. (n=174)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	12	6.9	6.9	6.9
	NO	151	86.8	86.8	93.7
	DON'T KNOW	11	6.3	6.3	100.0
	Total	174	100.0	100.0	

Comment:

- Don't know; the speed is too slow (no. 24);
- No; it does not ease the workload of communication (no. 108).

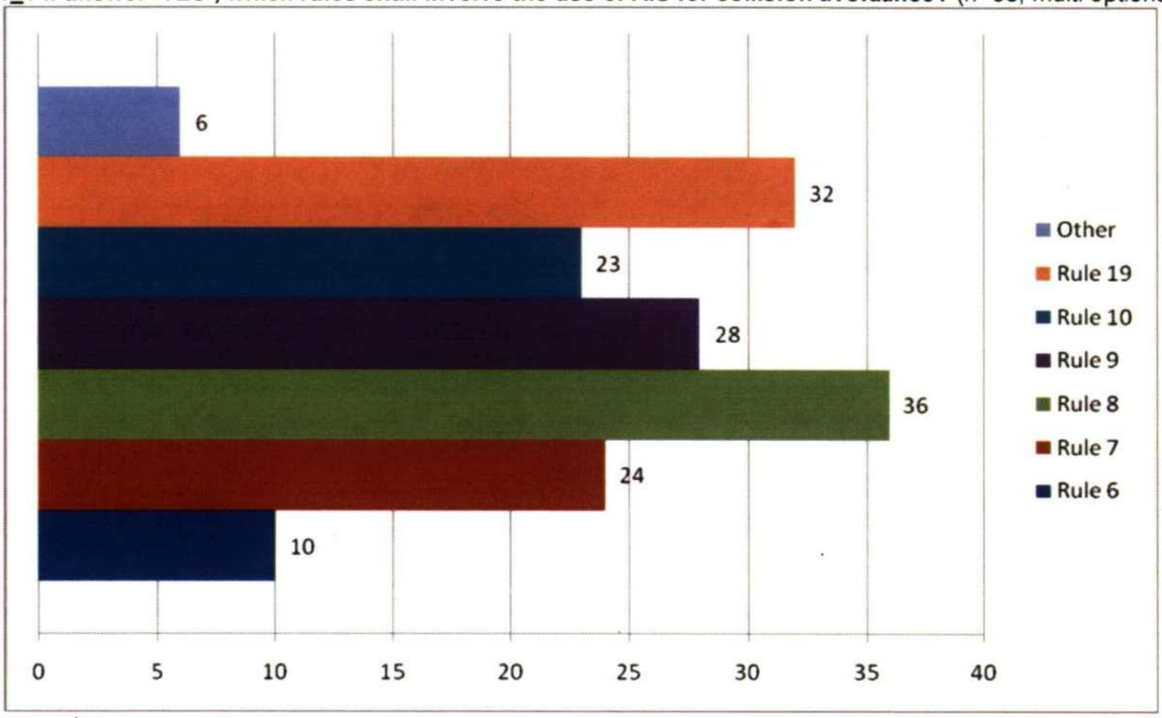
41. Do you think the use of AIS will trigger the modification of the COLREGs? (n=174)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	64	36.8	36.8	36.8
	NO	95	54.6	54.6	91.4
	DON'T KNOW	15	8.6	8.6	100.0
	Total	174	100.0	100.0	

Comment:

- Yes; new added regulation (no. 186).

41_1 If answer 'YES', which rules shall involve the use of AIS for collision avoidance? (n=68; multi options)



Comment:

- Other; Rule 5 (no. 64).

42. Are you worried about sharing ship's detail with other people at sea via AIS broadcasting network? (n=58)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	15	8.6	25.9	25.9
	NO	38	21.8	65.5	91.4
	DON'T KNOW	5	2.9	8.6	100.0
	Total	58	33.3	100.0	
Missing	Not Given	115	66.1		
	System	1	.6		
	Total	116	66.7		
Total		174	100.0		

Overall comments

- AIS enhances the communication system when doing collision avoidance and it is very useful for the safety of navigation (no.18);
- Analysis of target proved to be useful to the navigators by using AIS (no. 20);
- Different situation affects every concerned device; GPS to the chart accuracy, fog or rain may appear different on RADAR. Therefore NAV aids shall be supplemented and not quantified individually. AIS currently will delay the decision making on collision avoidance due to the problem of interface but it is not AIS own problem. A mouse function could be easier to find a target on AIS (no. 42);
- Regulation needed to be simple clear and easy to run. There are too many regulations and they sometimes against to each other. It should be a demand for tightly and integrated regulations (no. 57);
- Good improvement depends on better construction (no. 65);
- To some ships AIS is just another piece of equipment stood there. Some ships are informed by port authorities that AIS are not operated or the position shown are incorrect (no. 77);
- Certain type of AIS require long time to search for a particular vessel (no. 87);
- AIS is a good system to provide ship's information for safe navigation. However, the AIS information should be used in early state of collision avoidance only. Some model of the AIS has small display that consume more time to identify the target (no. 90);
- AIS can be used as an assistance but not major device in collision avoidance. Watchkeeping, ARPA RADAR monitoring and VHF communication are the priorities in collision avoidance (no. 94);
- AIS is able to assist OOWs in collision avoidance because it supports some reference data. However, the accuracy and data maintenance (the respondent has experienced some incorrect AIS data displayed by intention) are not so good. Currently, it should not be over reliance on AIS in navigation and collision avoidance (no. 108);
- Ship name and call sign are available on AIS. It can save time in VHF communication. Although AIS should not be over relied in collision avoidance, the improvement can be foreseen when the RADAR visibility is restricted by weather or sea condition (no. 110);
- AIS is very important as an assistant in collision avoidance (no. 111);
- The service provided by the AIS manufacturers varies. The system is sometimes unstable. The errors in AIS heading could vary from 30 degree to 180 degree. The trial display by APAR RADAR can detect the error sent via AIS (no. 113);
- The design of AIS is good in theory, but not good in practice (no. 115);
- Navigational devices are only used to assist in decision making. The experience, knowledge and judgement of the OOWs are the most critical element in collision avoidance (no. 119);
- The AIS collision avoidance and offshore navigation were on stage of testing and evaluations in Canada and USA. Situation awareness could be misjudged by AIS alone as errors occur in target's position, distance, heading, speed because of the elements of signal, accuracy, delay and wave interference. On the other hand, it is practical to have AIS in establishing VHF communication especially in busy waters.

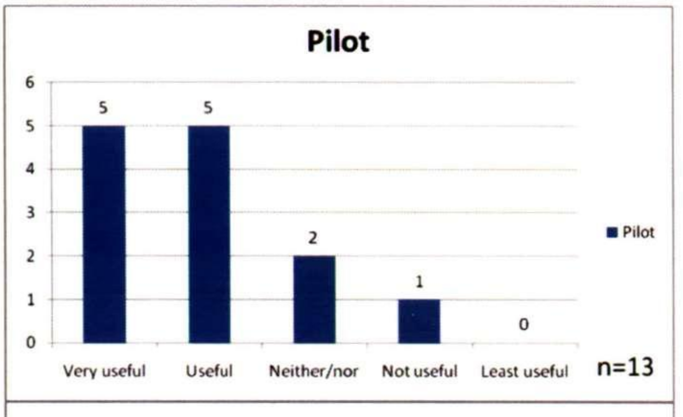
Nevertheless, fishing boats and small vessels do not need to carry AIS, and the non SOLAS vessels often interfere the navigation of merchant ships (no. 132);

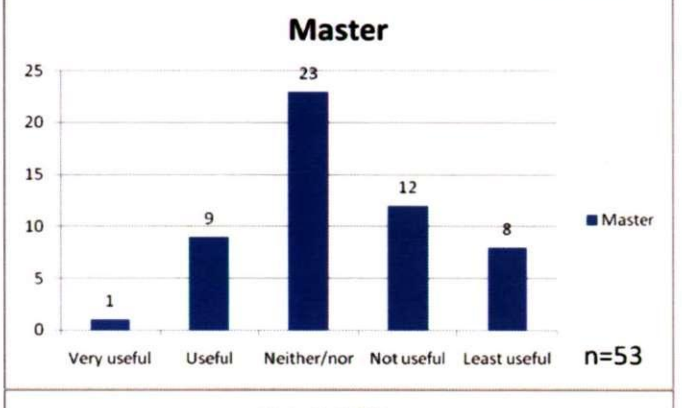
- AIS can only be used in ship identification. It does not have functions of navigation and collision avoidance. The reliability of AIS heading and position is not as good as the data from RADAR and GPS. An early awareness of coming traffic in restricted visibility can be useful by applying AIS. AIS is useful in ship-to-ship and ship-to-shore communication (no. 145);
- For obeying the COLREGs, it depends on the quality of the seafarers and the degress of obeying rules, not depends on the tonnage of the ships. AIS can only be used to identify the ships only (no. 171);
- As a new onboard device, AIS has its disadvantages, such as malfunction when turning at large angle or missing tracking targets, etc. (no. 172);
- AIS can only be referred to collision avoidance as a reference and cannot be relied totally. Every device has its limitations and errors (no. 174);
- The traditional navigation is more important than the modern electronic aids to navigation, such as ARPA RADAR, GPS and AIS. They cannot be fully depended and therefore OOWs should be aware of the traditional one then apply them into the other aids to navigation (no. 175);
- AIS can only assist target identification, which has its certain usage in collision avoidance. However, AIS cannot be depended fully especially text messaging function due to no alarm in AIS (no. 176);
- AIS can only be used in ship identification, cannot be used in collision avoidance (no. 187).

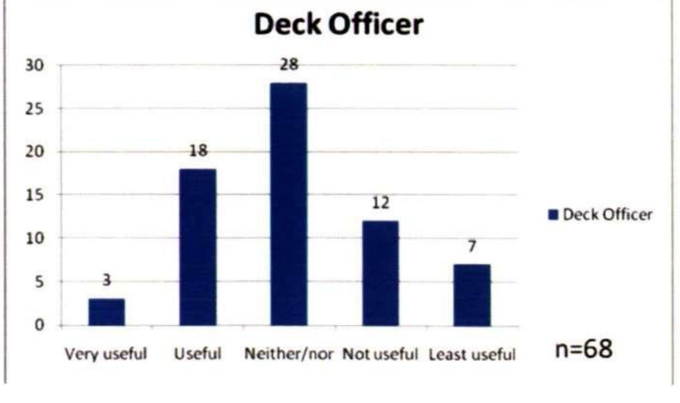
Appendix K

Survey II Detailed significance results

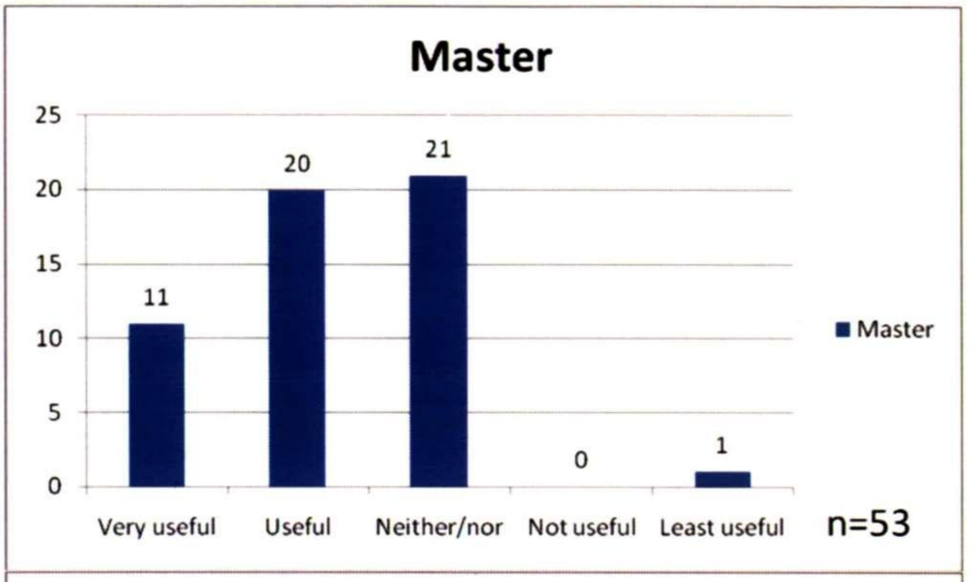
- Q11_2 Frequency distribution of four ranking groups on positioning application (Significance appeared in Pilots/Masters; Pilots/Chief officers; Pilot/Deck officers)

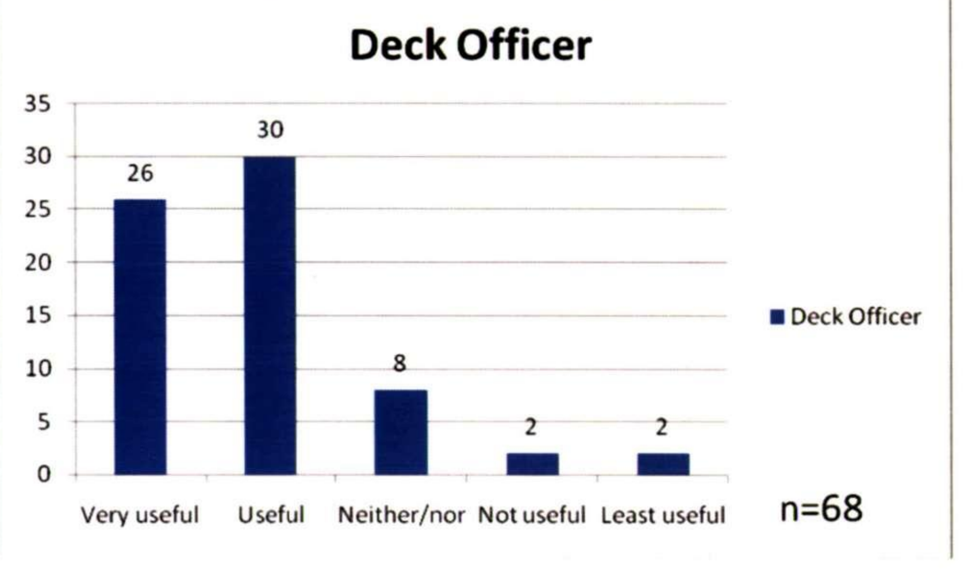




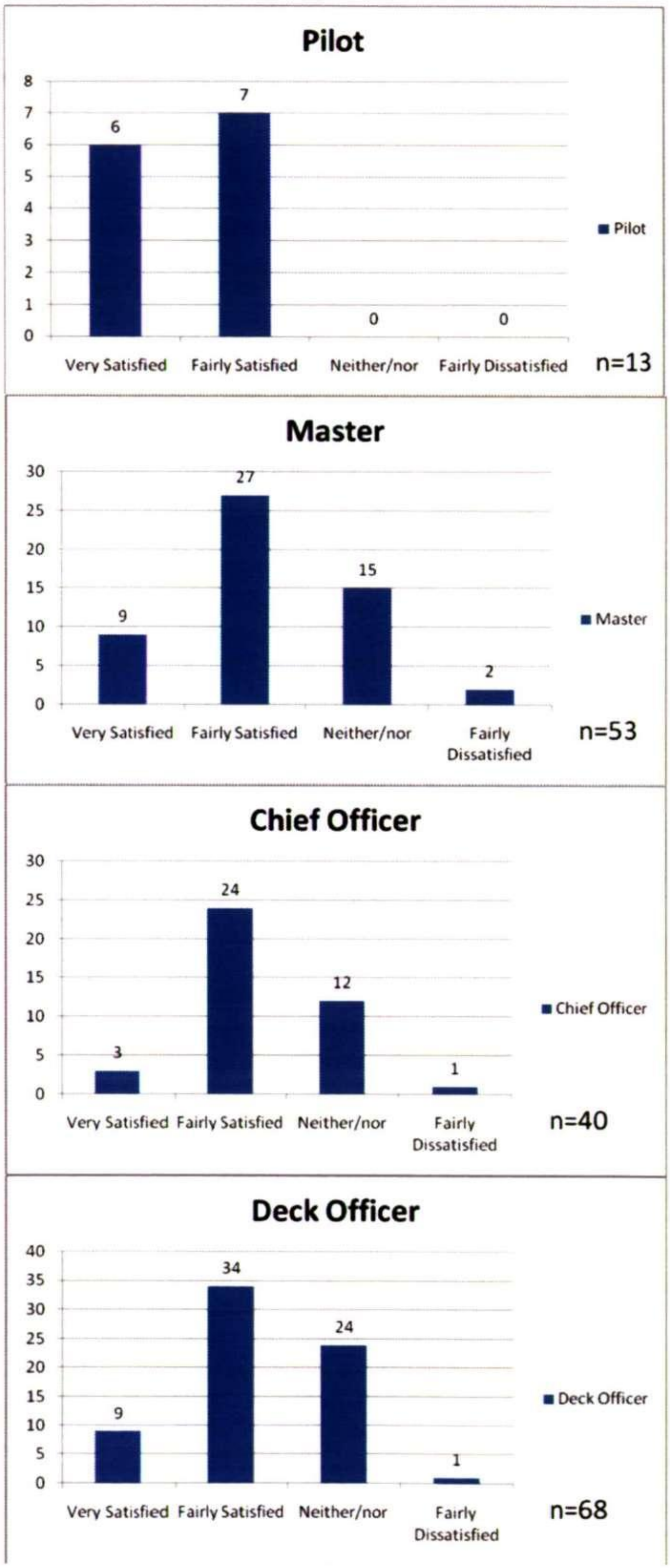


- Q11_3 Frequency distribution of two ranking groups on communication application (Significance appeared in Masters/Deck officers)

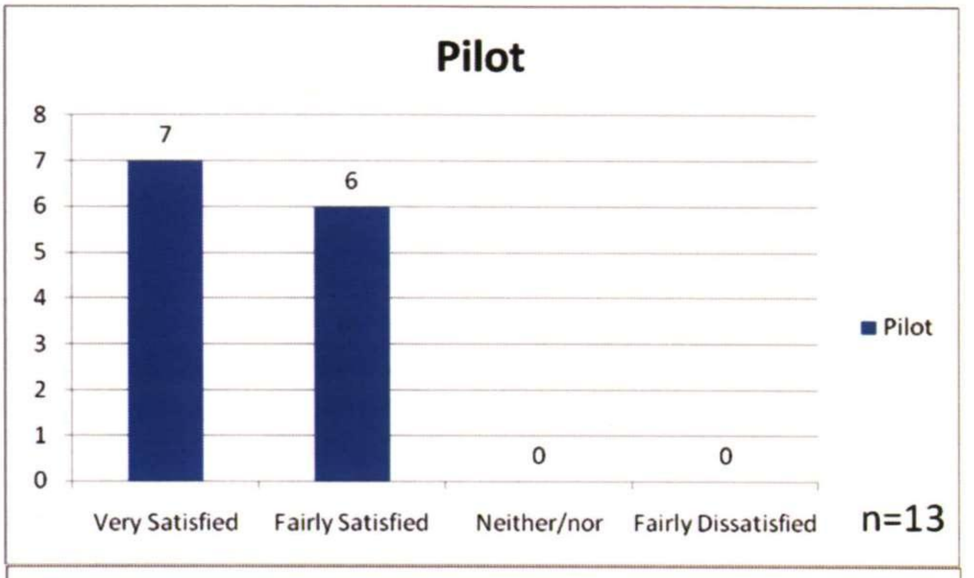


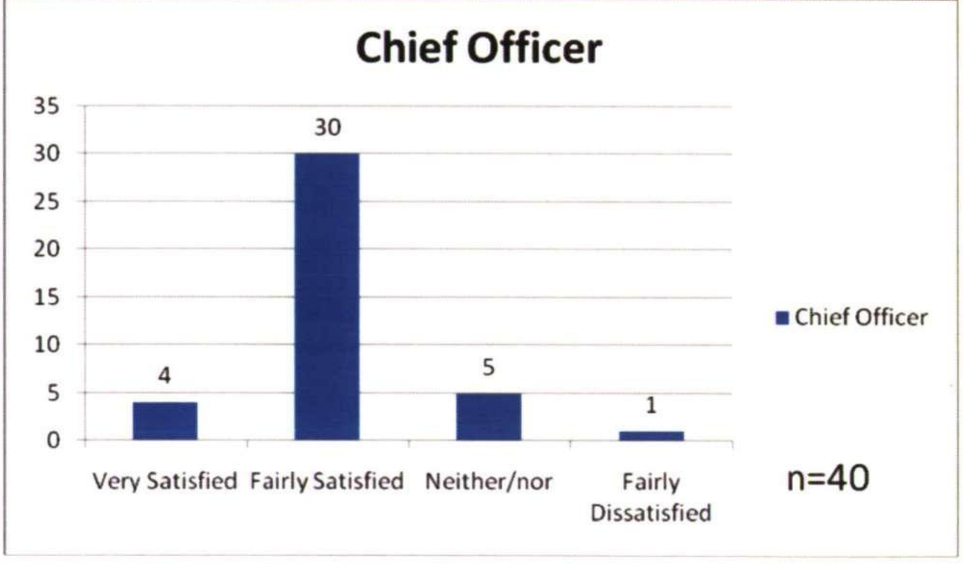


- Q20_1 Frequency distribution of four ranking groups on Cargo ships/COLREGs (Significance appeared in Pilots/Masters; Pilots/Chief officers; Pilots/Deck officers)

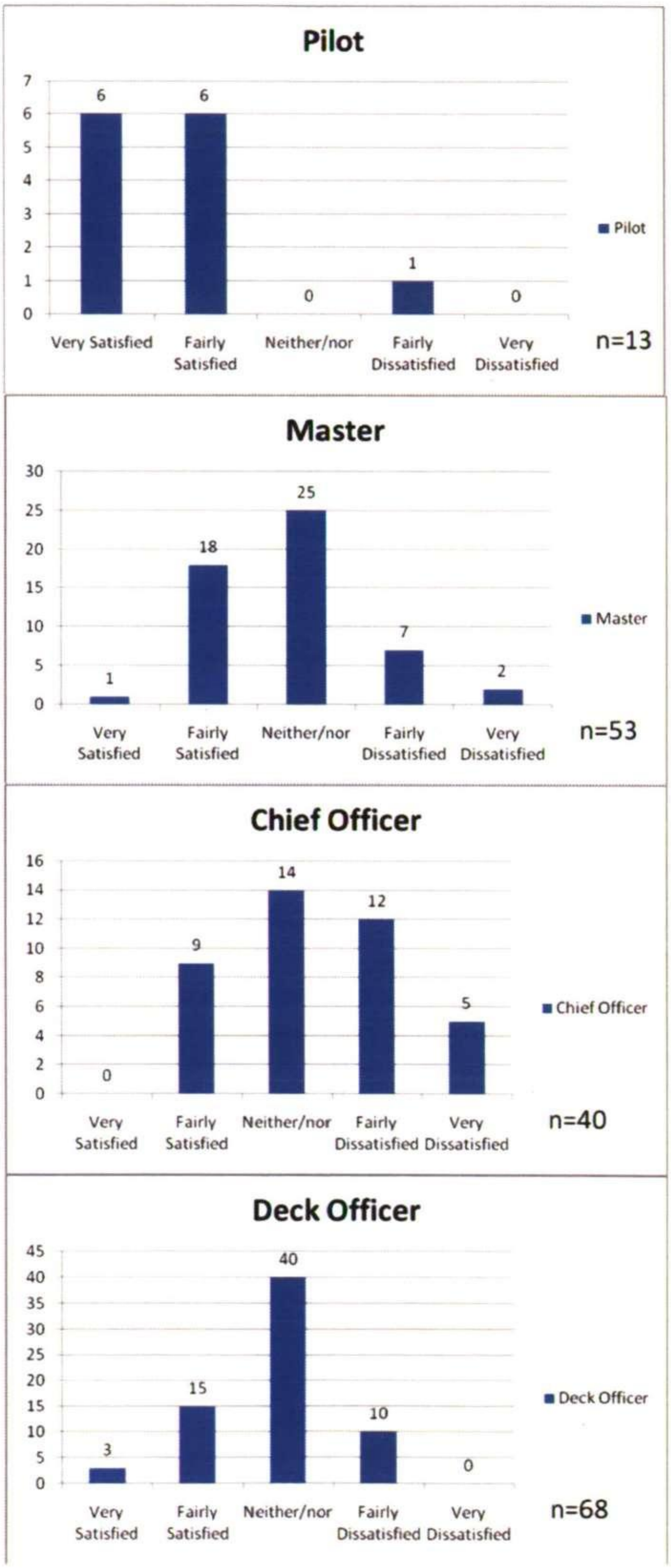


- Q20_2 Frequency distribution of two ranking groups on VLCC /COLREGs (Significance appeared in Pilots/Chief officers)

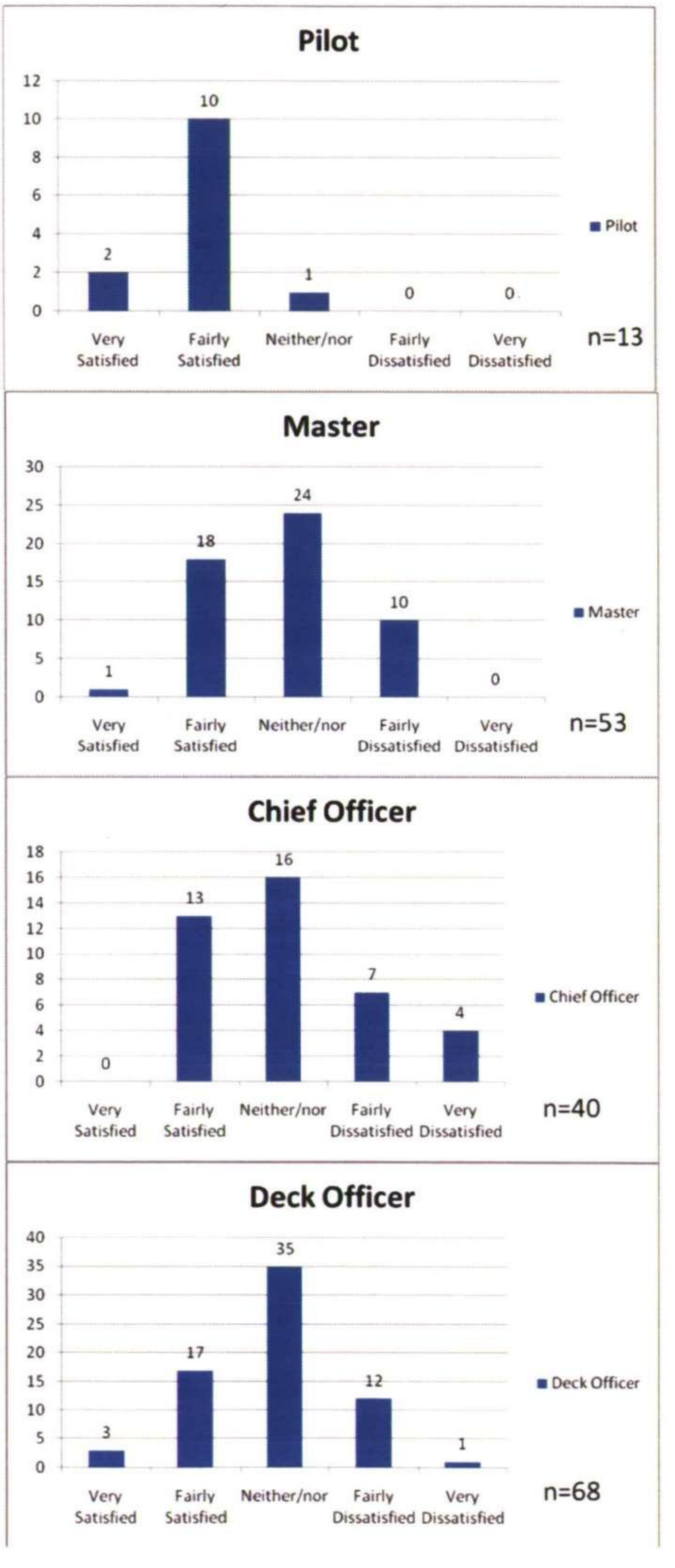




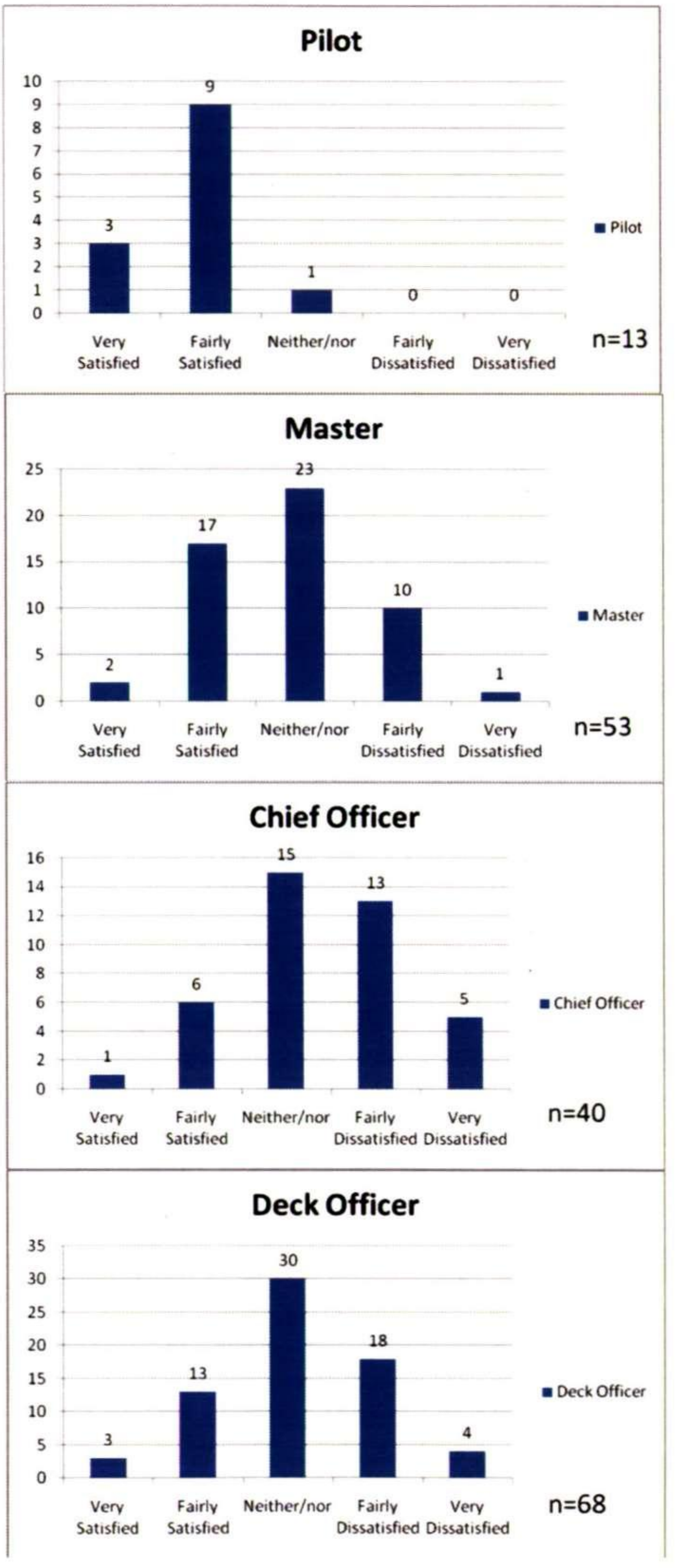
- Q20_4 Frequency distribution of four ranking groups on Naval ships /COLREGs (Significance appeared in Pilots/Masters; Pilots/Chief officers; Pilots/Deck officers)



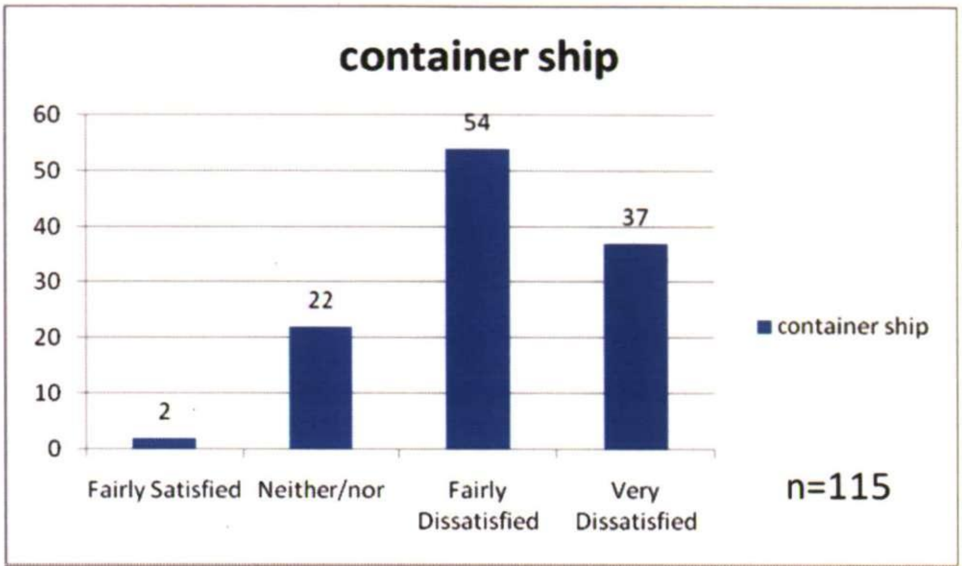
- Q20_6 Frequency distribution of four ranking groups on HSC /COLREGs (Significance appeared in Pilots/Masters; Pilots/Chief officers; Pilots/Deck officers)

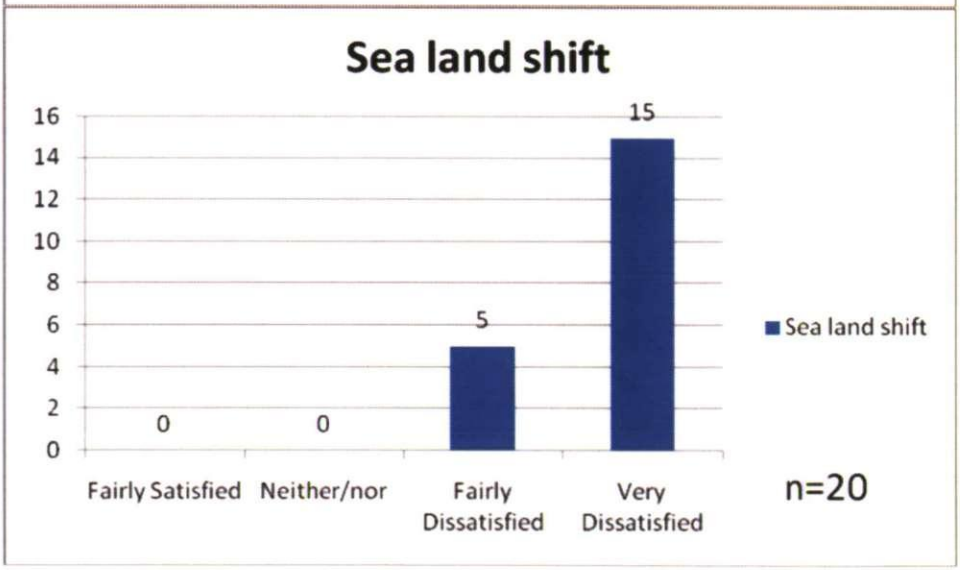


- Q20_7 Frequency distribution of four ranking groups on Ferry /COLREGs (Significance appeared in Pilots/Masters; Pilots/Chief officers; Pilots/Deck officers; Masters/Chief officers)

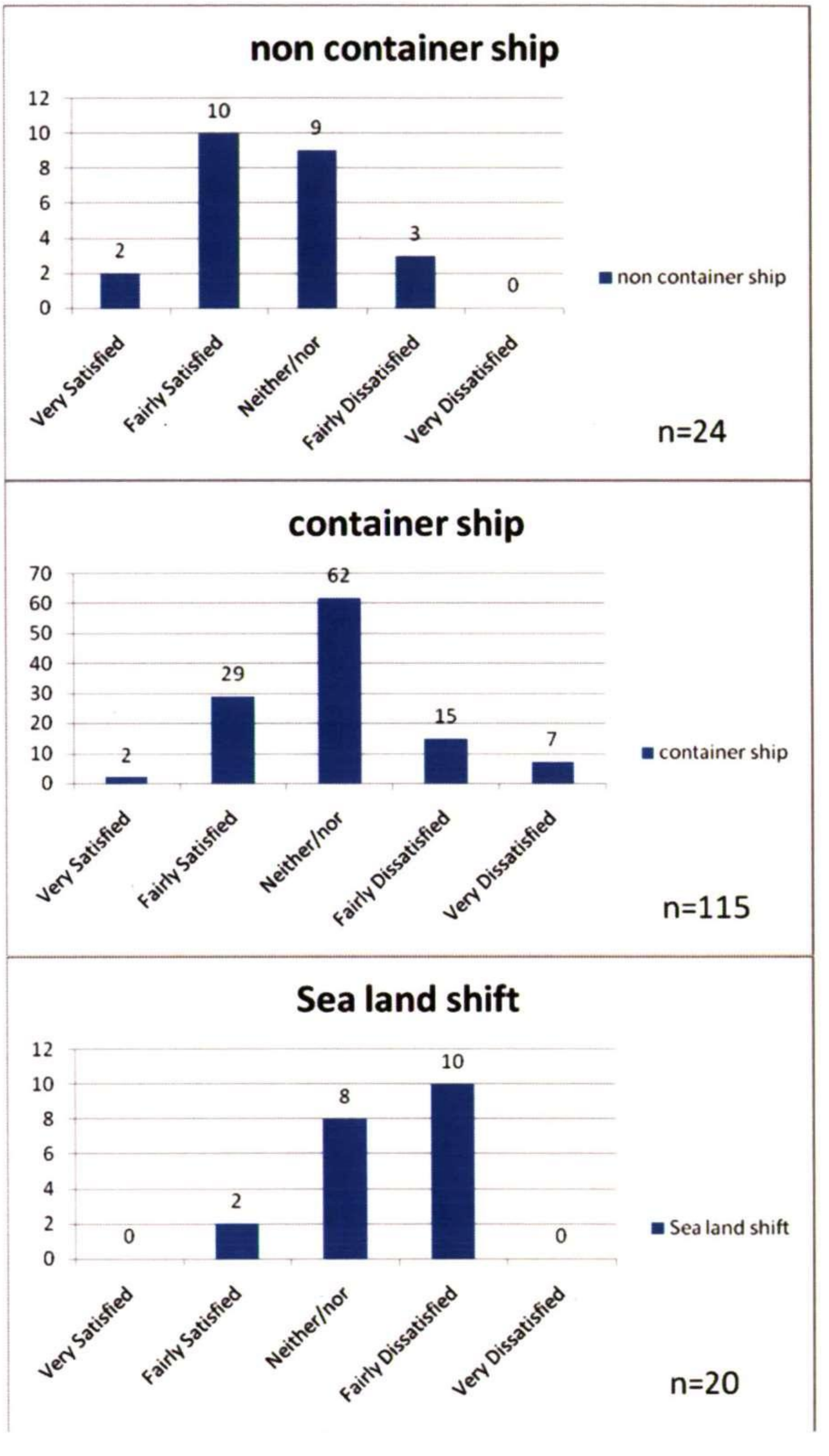


- Q20_3 Frequency distribution of three ship-type groups on Fishing boats /COLREGs (Significance appeared in Container ships/Sea-land shifts)

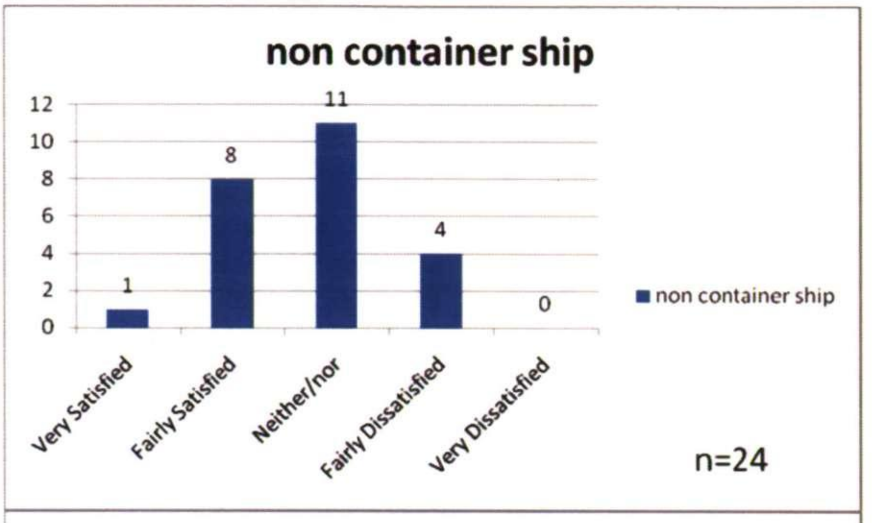


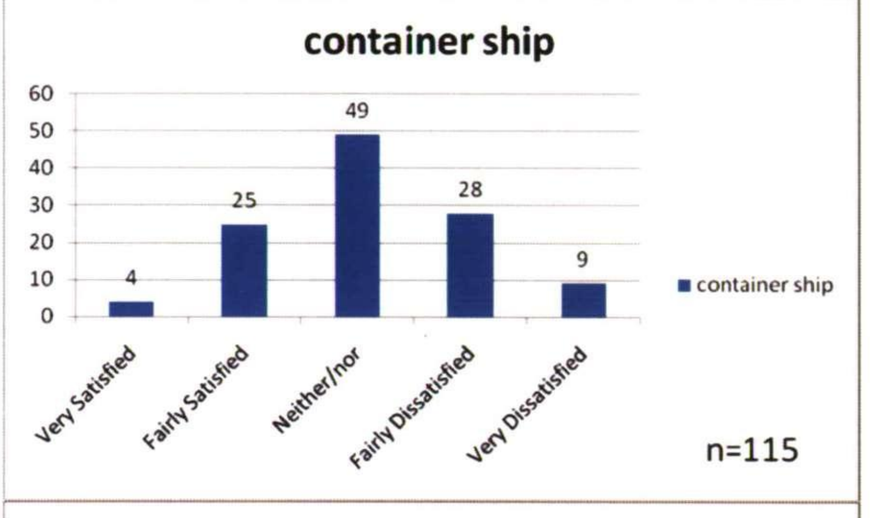


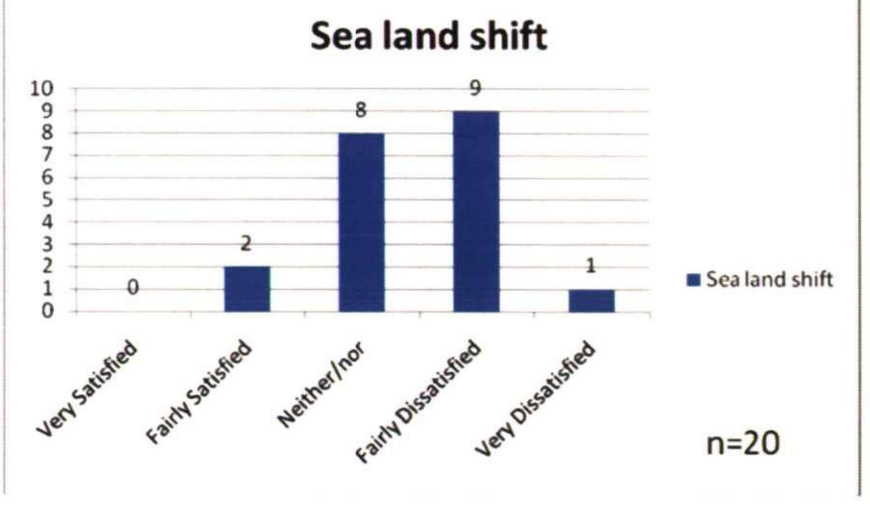
- Q20_4 Frequency distribution of three ship-type groups on Naval ship/COLREGs (Significance appeared in Non-container ships/Container ships; Container ships/Sea-land shifts)



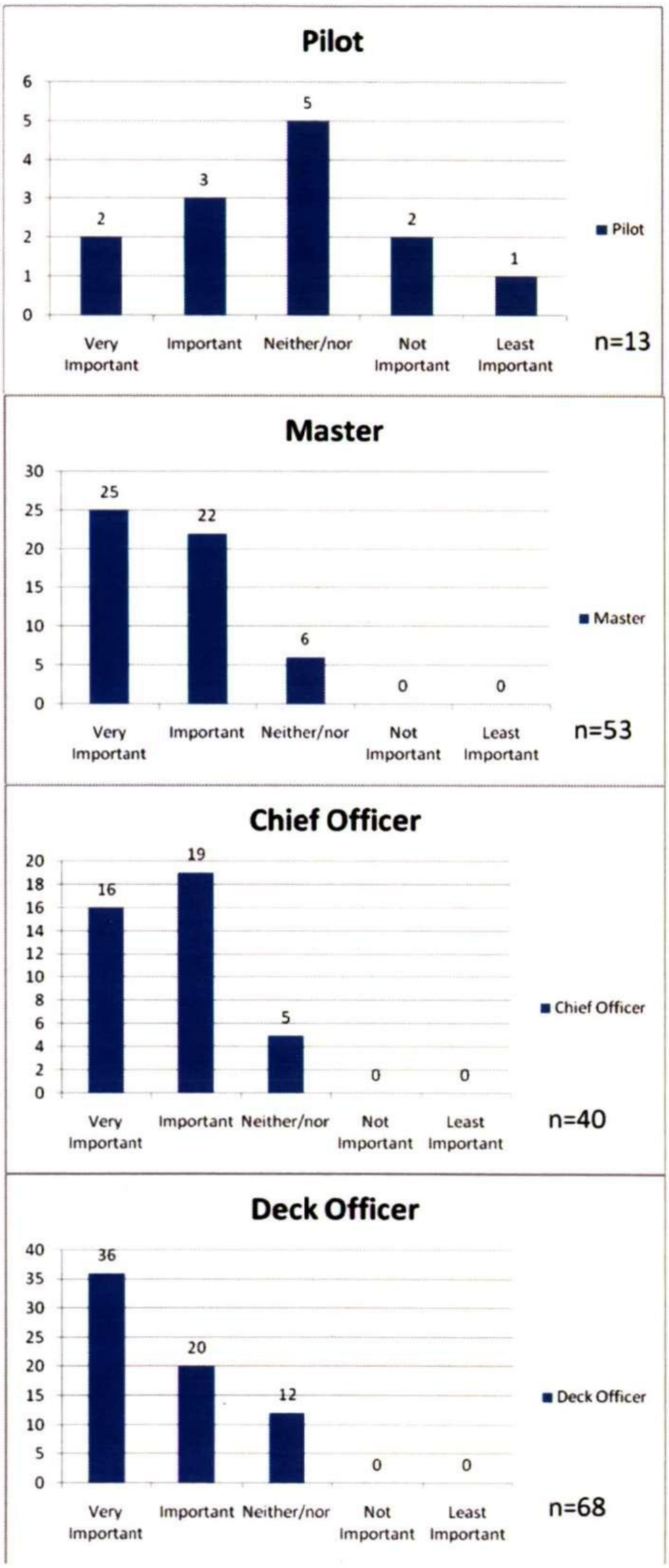
- Q20_7 Frequency distribution of three ship-type groups on Ferry /COLREGs (Significance appeared in Non-container ships/Sea-land shifts)



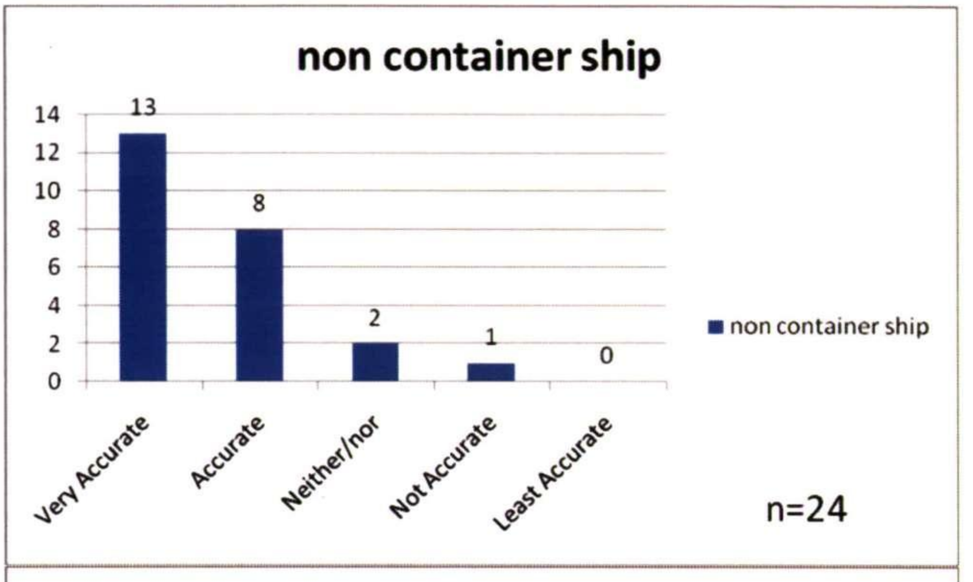


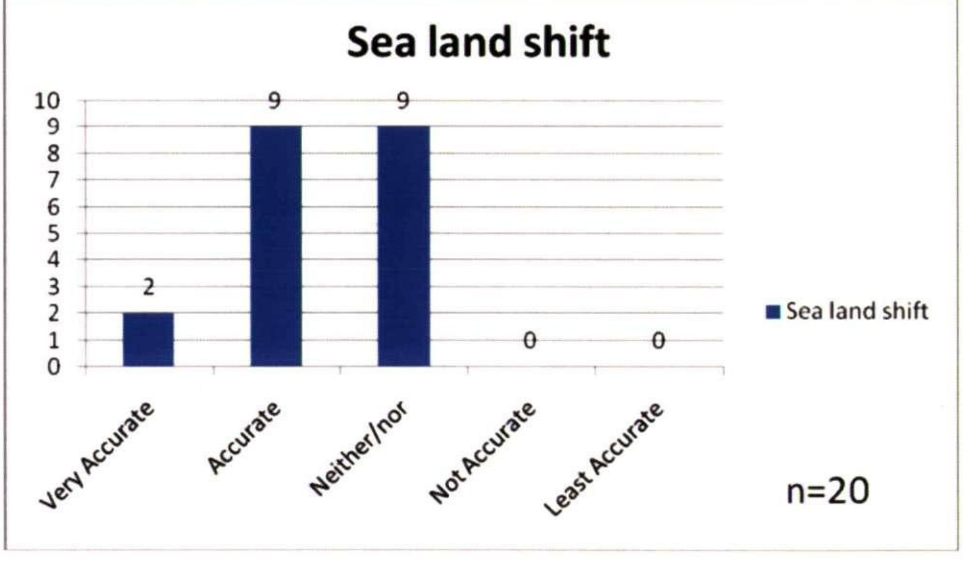


- Q30_2 Frequency distribution of four ranking groups on VHF/Importance for navigation (Significance appeared in Pilots/Masters; Pilots/Chief officers; Pilots/Deck officers)

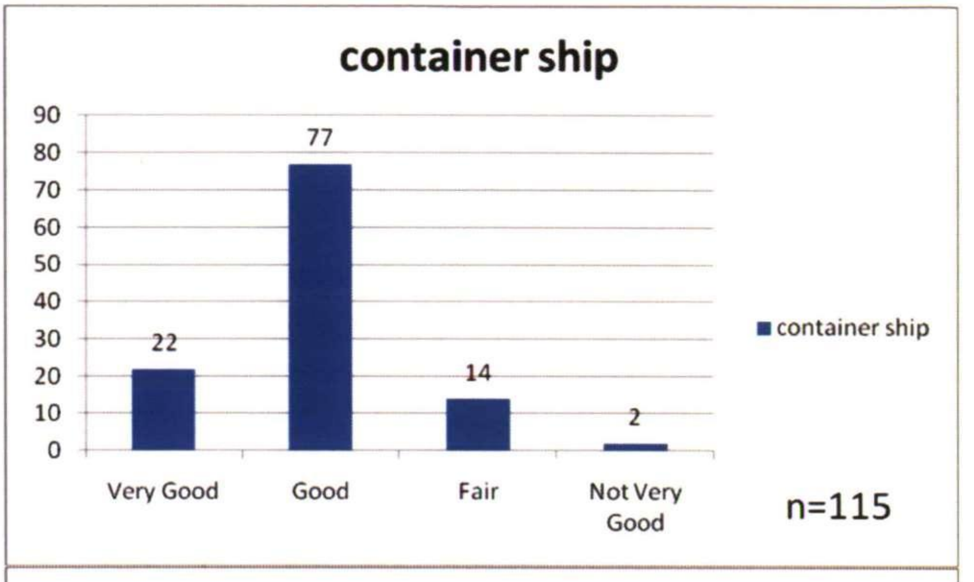


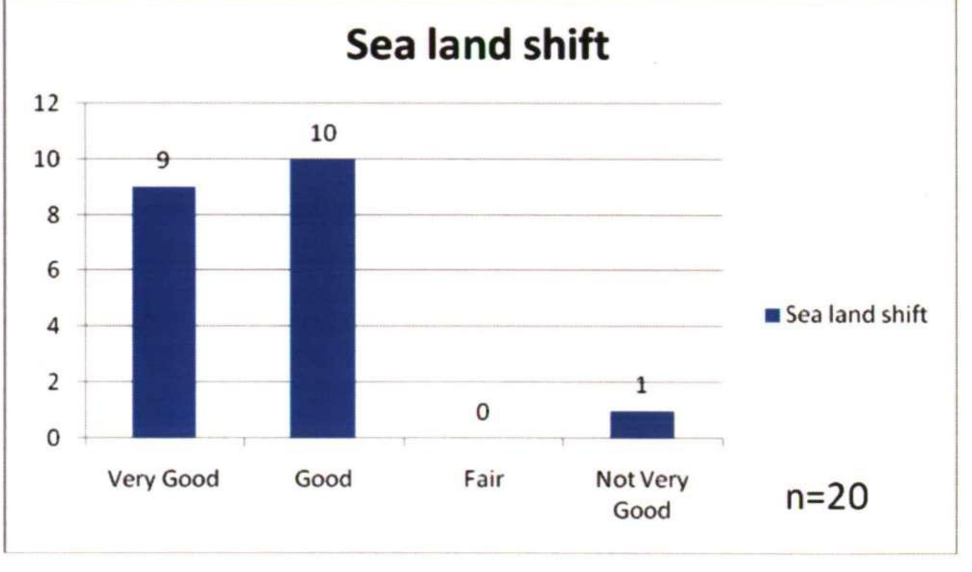
- Q31_2 Frequency distribution of three ship-type groups on Visual lookout/Positioning accuracy (Significance appeared in Non-container ships/Sea-land shifts)



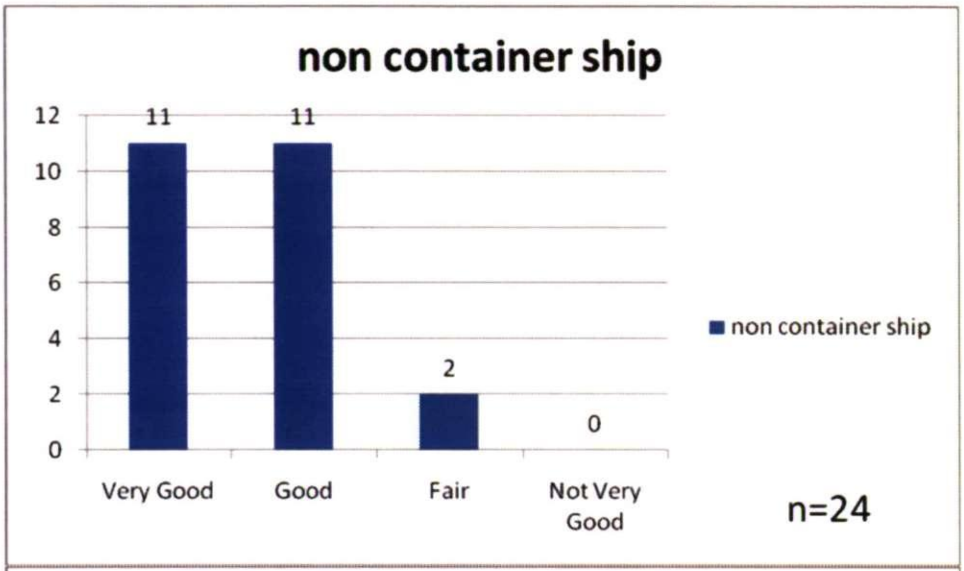


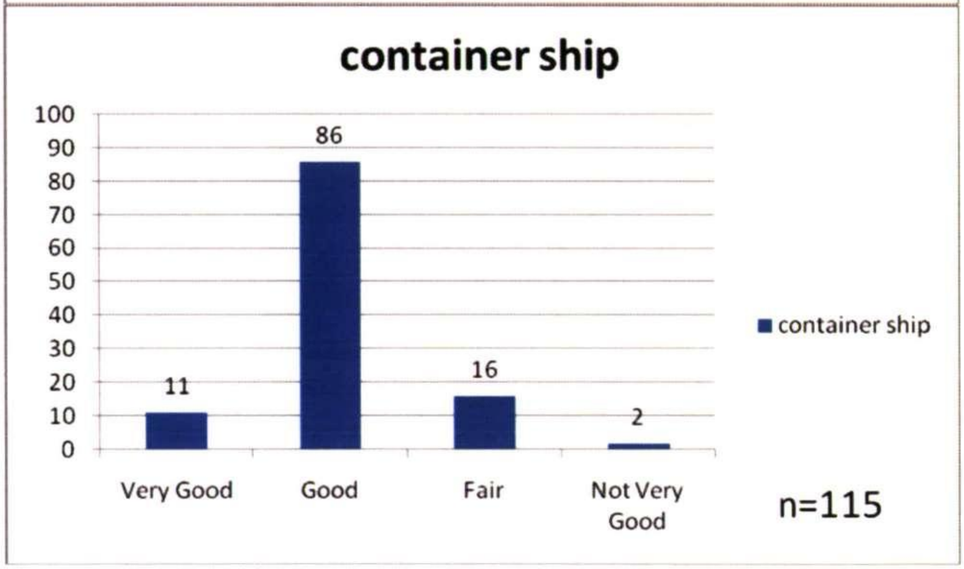
- Q34_1 Frequency distribution of three ship-type groups on GNSS/Attribute accuracy (Significance appeared in Container ships/Sea-land shifts)



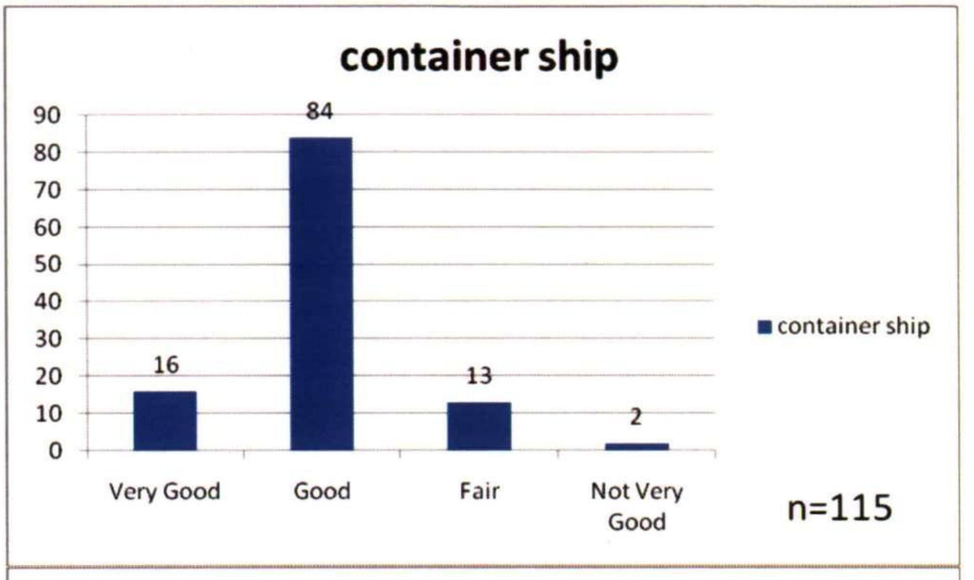


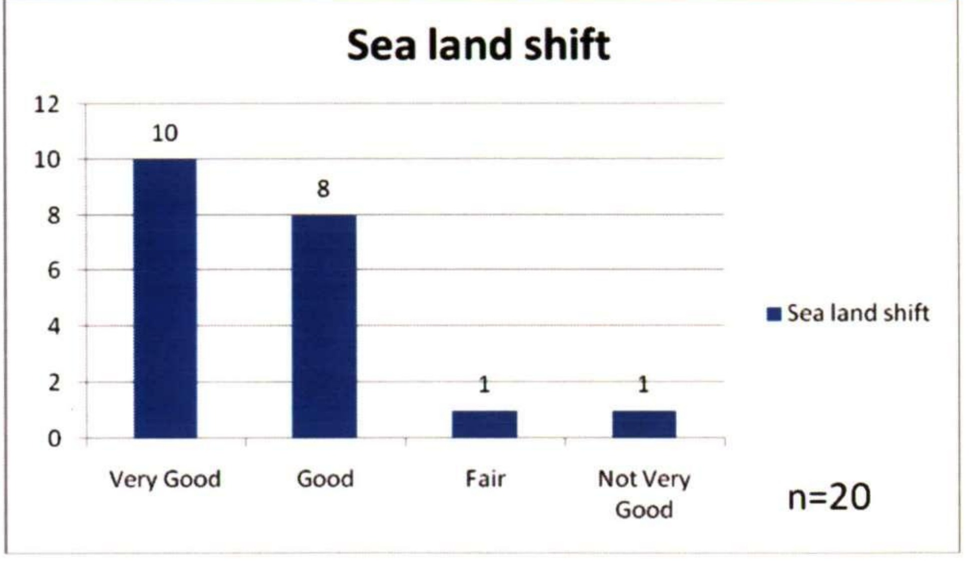
- Q34_2 Frequency distribution of three ship-type groups on GNSS/Attribute integrity (Significance appeared in Non-container ships/Container ships)





- Q34_3 Frequency distribution of three ship-type groups on GNSS/Attribute coverage (Significance appeared in Container ships/Sea-land shifts)





Appendix L

Ship tracks of simulator experiment

Exercise A&B

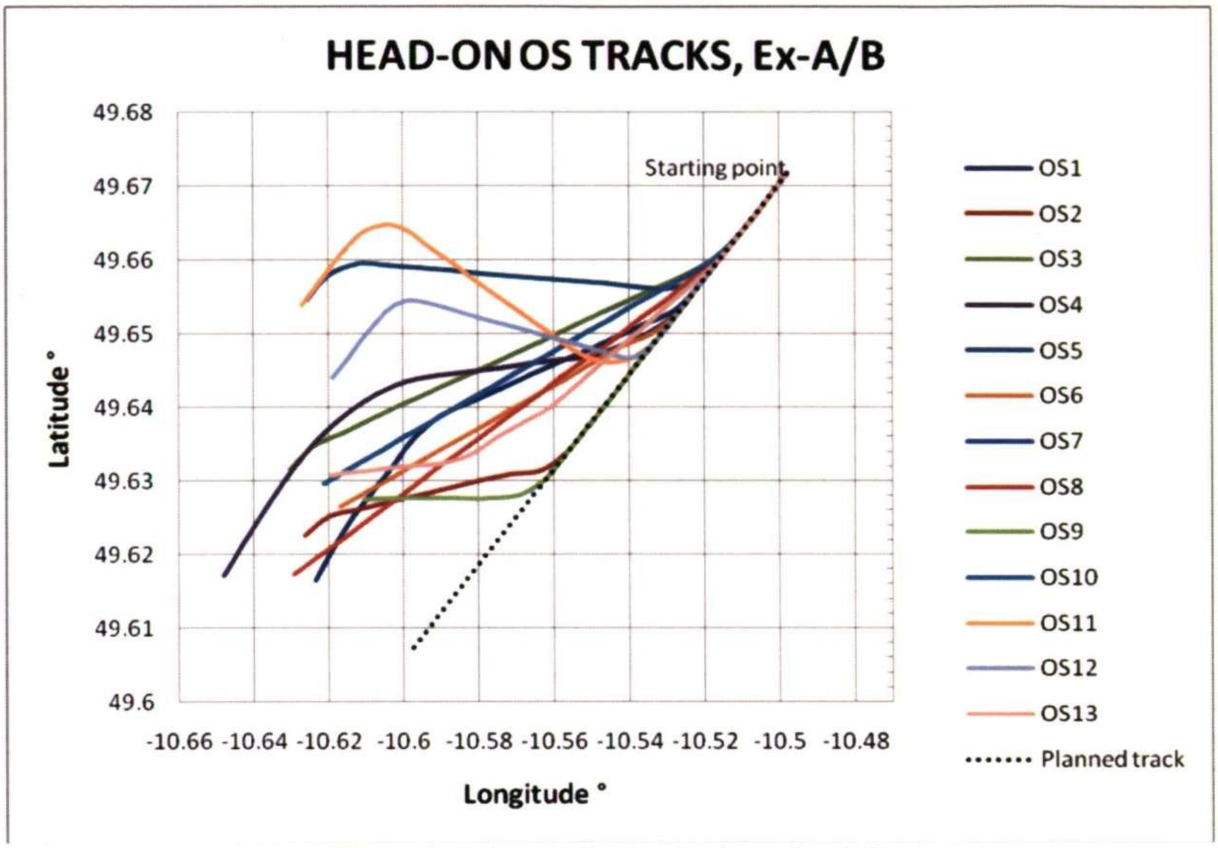


Figure L-1 Own ship tracks from Ex-A/B

Exercise C&D

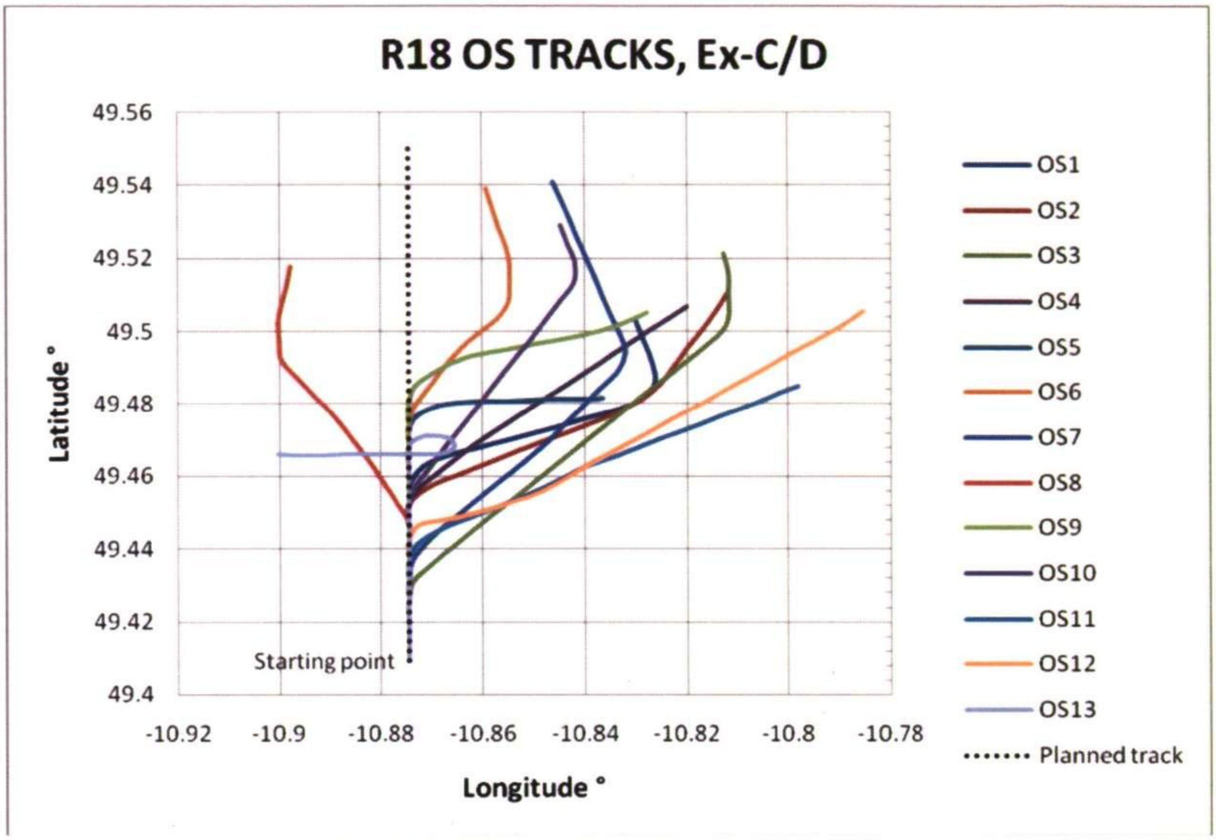


Figure L-2 Own ship tracks from Ex-C/D

Exercise E&F

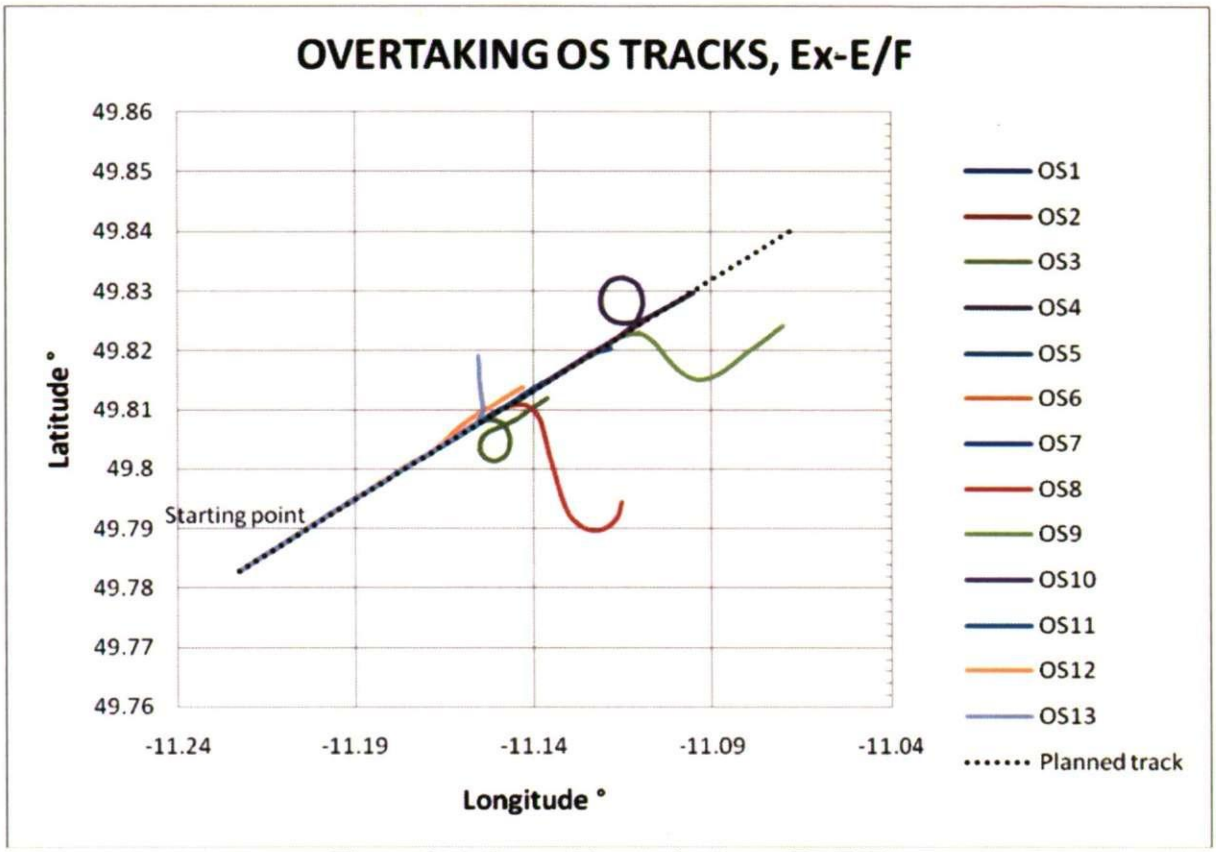


Figure L-3 Own ship tracks from Ex-E/F

Exercise G&H

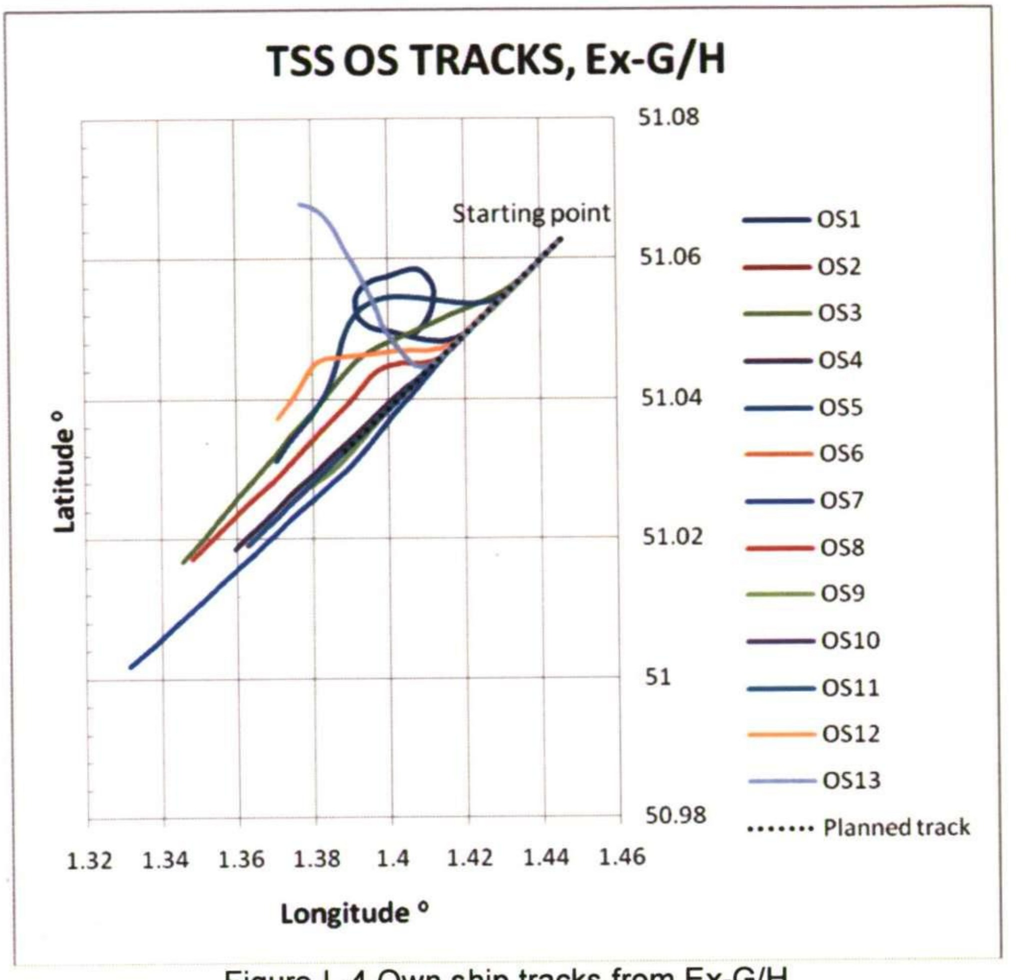


Figure L-4 Own ship tracks from Ex-G/H

Exercise I&J

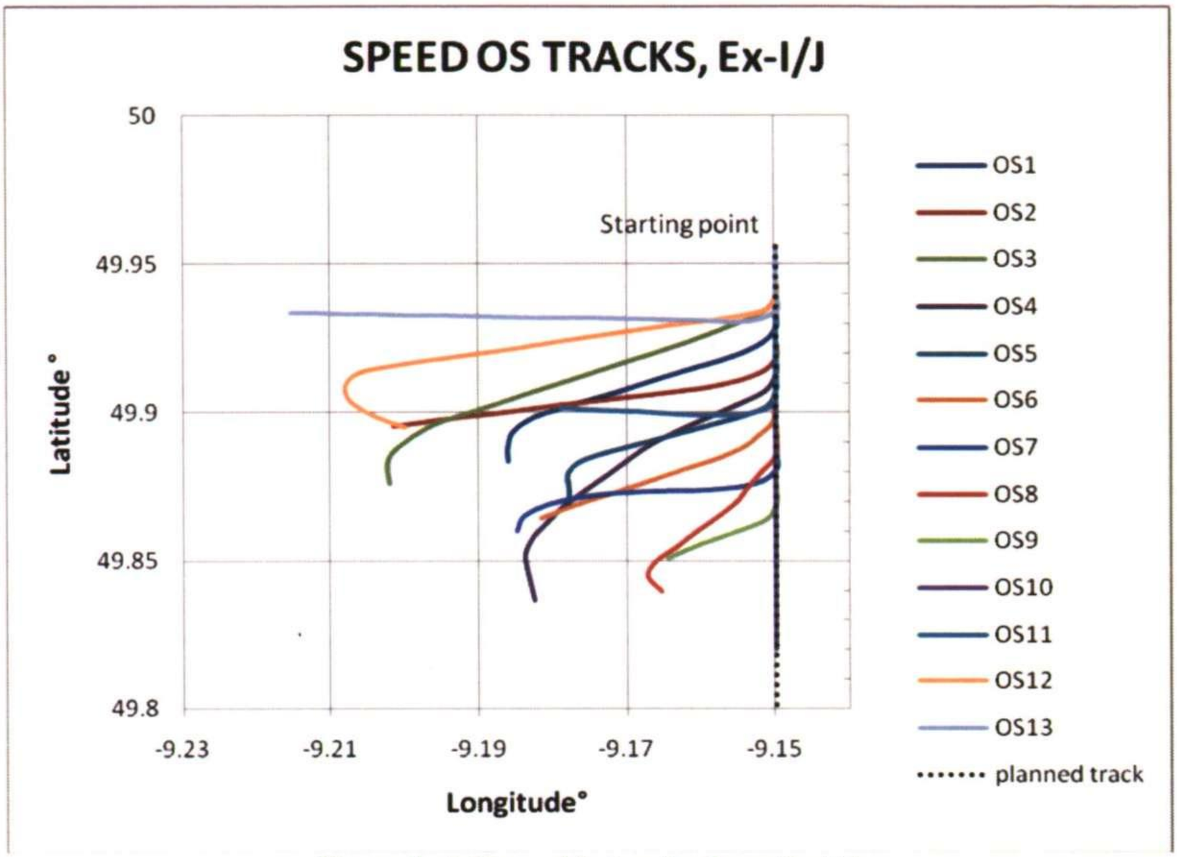


Figure L-5 Own ship tracks from Ex-I/J