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Contents

Glossary:

AIS: Automatic Identification System (also referred to as UAIS – Universal AIS)
ARPA: Automatic Radar Plotting Aid
ASP: Application Service Provider
ATA: Automatic Tracking Aid
BIIT: Built In Integrity Test
CCRP: Consistent Common Reference Position
CCTV: Closed Circuit Television
COG: Course Over Ground
CPA: Closest Point Of Approach
COLREG: Convention on the International Regulations for Preventing Collisions at Sea (of IMO)
COMPRIS: Consortium Operational Management Platform River Information Services
COMSAR: Committee on Radiocommunications and Search and Rescue
CPA: Closest Point of Approach
CPU: Central Processing Unit
CSP: Commercial Service Provider
CSTDMA: Carrier Sense Time Division Multiple Access
DSC: Digital Selective Calling
DGPS: Differential Global Positioning System
EBL: Electronic Bearing Line
EC: European Commission
ECDIS: Electronic Chart Display and Information System
ECS: Electronic Chart System
EGNOS: European Geostationary Navigation Overlay Service
EMSA: European Maritime Safety Agency
ENC: Electronic Nautical Chart
EPA: Electronic Plotting Aid
EPFS: Electronic Position Fixing System
EPIRB: Emergency Position Indicating Radio Beacon
ETA: Electronic Tracking Aid
ETA: Estimated Time of Arrival
EU: European Union
FAL: Facilitation Committee (of IMO)
GEOSAR: Geostationary Search and Rescue System
GLONASS: Global Navigation Satellite System
GMDSS: Global Maritime Distress and Safety System
GNSS: Global Navigation Satellite System

GPS: Global Positioning System
HF: High Frequency
HO: Hydrographic office
IALA: International Association of Marine Aids to Navogation and Lighthouse Authorities
IBS: Integrated Bridge System
ICT: Information and Communications Technology
IEC: International Electrotechnical Committee
IFSMA: International Federation of Shipmasters Association
IHO: International Hydrographic Organization
IMO: International Maritime Organisation
INS: Integrated Navigation System
IPPA: Innovative Portable Pilot Unit
IRNSS: Indian Regional Navigation Satellite System
ISM: International Safety Management
ITU: International Telecommunications Union
LEOSAR: Low Earth Orbit Search and Rescue System
LORAN: Long Range Aid to Navigation
LRIT: Long Range Identification and Tracking
MARNIS: Maritime Navigation and Information Services
MARPOL: International Convention for the Prevention of Pollution from Ships (of IMO)
MEPC: Marine Environment Protection Committee (of IMO)
MF: Medium Frequency
MGN: Marine Guidance Note
MKD: Minimum Keyboard Display
MSC: Maritime Safety Committee
MSI: Maritime Safety Information
NavTex: Navigational Telex
NMEA: National Marine Electronics Association
OOW: Officer of the Watch
PAD: Predicted Area of Danger
PC: Personal Computer
POADS: Portable Operational Approach and Docking Support System
PPI: Plan Position Indicator
PPU: Portable Pilot Unit
PRF: Pulse Repetition Frequency
QMS: Quality Management System
RADAR: Radio Detection And Ranging

RAM: Random Access Memory
RCC: Rescue Coordination Centre
RCDS: Raster Chart Display System
RINA: Royal Institute of Naval Architects
RIS: River Information Services
RO-RO: Roll-on Roll-off
RTK: Real Time Kinematics
SAR: Search and Rescue
SART: Search and Rescue Transponder
SBAS: Satellite Based Augmentation System
SOG: Speed Over Ground
SOLAS: International Convention for the Safety of Life at Sea (of IMO)
SOTDMA: Self-Organising Time Division Multiple Access
S-VDR: Simplified Voyage Data Recorder
TCPA: Time to Closest Point of Approach
UTC: Coordinated Universal Time
VDR: Voyage Data Recorder
VHF: Very High Frequency
VRM: Variable Range Marker
VTS: Vessel Traffic Services
WLAN: Wireless Local Area Network
WGS: World Geodetic System
WWRNS: World-Wide Radionavigation System

1. Overview

One of the main objectives of the European Transport Policy is to maintain a leading position in the use of transport technologies particularly in providing an efficient, safe and optimized maritime transport system. Navigational equipment is one of the major contributors to providing safe and efficient maritime transport. However, the maritime sector has, in the past, been relatively conservative in its adoption of leading edge technologies preferring to opt for well proven equipment. This report examines the emerging navigation related systems and technologies which are specifically aimed at meeting the EU's objectives for maritime transport. The report includes a brief overview of the systems and technologies together with references to relevant documents and websites which provide more detailed information.

2. Objectives of the Study

The objective of this study is to provide information for stakeholders on current state-of-the-art of navigation systems and on the emerging technologies and techniques becoming available in the short term and longer term.

Special attention will be given to future generation navigation systems, termed e-Navigation seeking to increase efficiency and improved performance and to replicate, in the field of marine navigation, the standards of safety achieved in land and air transport navigational sectors.

3. Target Stakeholders

3.1 Stakeholders

Improvements in navigation systems through the use of existing and emerging technologies and systems are of interest to many stakeholders in the maritime industry and impacts on the whole of the maritime community, not just on-board ships, for example:

- mariners/ marine pilots
- ship owners, ship operators and ships
- equipment manufacturers
- Organisations providing Vessel Traffic Services (VTS)
- Coastal States
- Ports
- Hydrographic Offices
- Maritime Training providers

3.2 User Requirements

European ports are among the busiest in the world and associated sea-lanes face growing demands. When accidents occur there is an inevitable risk to human life and the environment and any ensuing clean-up operation could be extremely costly. The English Channel, in particular, is very congested and has high passenger transport numbers.

With the increasing use of fast ferries and the short turnaround times needed to ensure their financial viability, there is a need for further improvements in the control and safety of shipping particularly when approaching harbours and also when manoeuvring/ docking within congested harbours.

Future navigation systems will need to provide the ship's crews with the ability to control their vessels under these demanding conditions with a greater degree of accuracy than possible at present and under all weather conditions and while docking in harbour.

There is therefore a need to:

- minimize navigational errors, incidents and accidents,
- protect people, the marine environment and resources
- improve security
- reduce costs for shipping and coastal states
- deliver increased benefits for the commercial shipping industry

To achieve this there is a need to equip the master of a vessel, and those ashore responsible for the safety of shipping, with the latest proven tools to make maritime navigation more reliable, more user-friendly and safer. This report concentrates on the onboard ship systems and technologies.

4. State of the Art

4.1 Current practices

Conventional navigation methods have involved the manual planning and mapping of routes manually on nautical charts, based on information provided by the ship's sensors, and via ship-to-shore communications, and from visual information. This was very time-consuming as was the manual updating of charts when more up-to-date information became available.

Navigation equipment on-board has also been supplemented by aids to navigation such as lights, buoys and channel markers. These methods are gradually being supplemented due to rapid technology developments particularly in the areas of communication and information technology. However, there is an argument that these aids should be retained for the use of vessels which will not have the sophistication of larger vessels in terms of e-navigation equipment and also to provide a reversionary mode.

Navigational errors or failure to maintain a safe course has been the cause of many marine incidents although some have been caused by other failures (e.g. technical). What is essential is that the master of a ship is given all the assistance available in terms of navigational facilities to enable him to manoeuvre his vessel safely in all waters.

The standard bridge set of equipment, in the past, has consisted of several discrete equipments, often provided by different manufacturers (e.g. radar, communications, engine control equipment) to provide the basic functions to enable ship control and navigation to be conducted. Project management and system integration was often neglected in the design and supply of such equipment. The Bridge facilities were often designed on a piecemeal basis, the main functions and facilities being provided by separate manufacturers with minimal interfacing between equipments and separate man/machine interfaces for each function.

The state-of-the-art in on-board navigation systems, fitted in the latest ships, involves the use of Integrated Bridge Systems (IBS) which take in data from various ship navigation sensors such as GPS, gyrocompass, radar, speed log, depth sounders etc. to enable the overlay of the ship’s position, movement and route on a digital representation of a nautical chart on an electronic display. The aim of such systems is to increase the situation awareness and the automation of most of the time consuming duties associated with traditional bridge navigation activities. Performance standards for integrated bridge systems were adopted by IMO in 1996.

This study will address the limitations and shortfalls of major onboard subsystems which form part of current bridge and navigation systems and which will be the building blocks for e-Navigation systems of the future. The study will address their likely contribution to the e-navigation system of the future. These subsystems include:

- Radar and Automatic Radar Plotting Aids (ARPA)
- Electronic Chart Display and Information Systems (ECDIS)
- Compass technologies
- Global Satellite Navigation Systems (GNSS)
- Long Range Aid to Navigation (LORAN) and eLORAN
- Automatic Identification System (AIS)

- Global Maritime Distress and Safety System (GMDSS)
- Voyage Planning and Weather Routing
- Voyage Data Recorders (VDR)
- Integrated Bridge Systems/Integrated Navigation Systems (IBS/INS)
- Vessel Traffic Services (VTS)
- Long Range Identification and Tracking Systems (LRIT)
- Portable Pilot Systems

4.2 Future aims and research developments

Europe can be considered a maritime superpower and as such its maritime stakeholders are well placed to continue to contribute to this global leadership. This translates to setting the quality standards for safe and efficient maritime operations. The European Commission's WATERBORNE Technology Platform which was launched in January 2005, is aimed to contribute to realization of this objective, involving industry stakeholders, EU member states, the European Commission Services and stakeholders from science and society.

The EC's WATERBORNE Technology Platform has produced its visions of the maritime industry in 2020 and defined the strategic research which will be required to achieve this vision. Navigation and automation including e-Navigation principles feature strongly in the WATERBORNE Road Map for R&D. What is envisaged as being the future situation regarding navigation is outlined in the next paragraph.

Next generation navigation systems on-board of commercial vessels need to be substantially improved in terms of track keeping accuracy. The objective is fully automatic control over the whole passage including docking. The track is prepared by local Vessel Traffic Services (VTS) & River Information Services (RIS) centres with detailed knowledge of the traffic situation. For track keeping in congested waterways a more precise and reliable positioning system than GPS is required. GALILEO is the choice. Navigation and safety systems on board recreational vessels need to be more user-friendly to a wider range of abilities with improved decision support systems.

4.3 References

Relevant Documents

1. Maritime Transport Policy – Improving the competitiveness, safety and security of European Shipping – issued by the European Commission (ISBN-42-79-02947-9)

2. Marine eNavigation – paper by Brian Wadsworth, Director, Logistics and Maritime Transport, Department of Transport, UK, July 2005
3. e-Navigation: The way ahead for the maritime sector, Dr Sally Basker, Trinity House, CGSIC September 2005 Version 1
4. MSC.64 (67) Annex1: Performance Standards for Navigational Equipment (Integrated Bridge Systems) for equipment fitted after 01/01/1999
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6. Strategic Research Agenda - Waterborne Transport & Operations – Key for Europe's Development and Future, issued by the WATERBORNE Technology Platform, an EC funded European Maritime Forum

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1. http://ec.europa.eu/transport/maritime/doc/maritime_transport_policy_en.pdf
2. www.imo.org – The International Maritime Organisation
3. www.iala-aism.org – The International Association of Lighthouse Authorities
4. www.iho.org – The International Hydrographic Organisation
5. www.mcga.gov.uk –The UK Maritime Coastguard Agency
6. http://waterborne.balport.com – European Commission funded WATERBORNE Technology Platform

5. Compass Technologies

5.1 Overview

Compass technologies are an essential part of the navigation equipment fitted on maritime vessels and it is a requirement laid down by the IMO that all ships over 150 gross tonnes carry approved compass equipment (see Section 5.2). Over the years several forms of compasses have been developed using different technologies. Those currently fitted include:

- Magnetic Compass
- Electromagnetic Compass
- Gyro Compass - (mechanical and fibreoptic)
- Satellite

These types of compass are described briefly in the following sections. The basic compasses often interface with processing units and ancillary equipment associated with them to enable the data to be displayed at various locations in the ship and used by different equipment. However, it is not unusual for ships to carry a compass system which includes several forms of compass to cater for all the ship's systems and provide fall back modes.

A ship's compass system, depending on the type of vessel, should be capable of providing data for a wide range of applications such as Radar/ARPA, AIS, ECDIS, Chart Plotters, Satellite Communications, Scanning Sonar and Autopilots.

5.2 Requirements

The IMO requirement for the carriage of a compass states that:

All ships irrespective of size shall have

- a properly adjusted standard magnetic compass or other means, independent of any power supply to determine the ship's heading and display the reading at the main steering position
- a pelorus or compass bearing device, or other means, independent of any power supply to take bearings over an arc of the horizon of 360°
- means of correcting heading and bearings to true at all times

All ships of 150 gross tonnage and upwards and passenger ships irrespective of size shall, in addition to the above be fitted with a spare magnetic compass interchangeable with the magnetic compass, as referred to above, or other means to perform the function referred to above by means of replacement or duplicate equipment;

All ships of 300 gross tonnage and upwards and passenger ships irrespective of size shall, in addition to meeting the above requirements be fitted with a properly adjusted transmitting heading device, or other means to transmit heading information for input to the radar, electronic plotting aids and speed/distance measuring equipment fitted onboard.

All ships of 500 gross tonnage and upwards shall, in addition to meeting the above have:

- a gyro compass, or other means, to determine and display their heading by shipborne non-magnetic means, being clearly readable by the helmsman at the main steering position. These means shall also transmit heading information for input to radar/ARPA and AIS fitted onboard

- a gyro compass heading repeater, or other means, to supply heading information visually at the emergency steering position if provided
- a gyro compass bearing repeater, or other means, to take bearings, over an arc of the horizon of 360º, using the gyro compass or other means referred to above. However ships less than 1,600 gross tonnage shall be fitted with such means as far as possible.

5.3 Magnetic Compass

A magnetic compass is an instrument designed to seek a certain direction in azimuth and to hold that direction permanently, and which depends, for its directional properties, upon the magnetism of the earth. It is the oldest instrument for navigation and steering and has been a vital tool for navigators at sea for centuries.

The magnetic compass should ideally be mounted as near to a vessels metacentre as possible to minimise effects due to the vessels dynamic motion. However, a compass is normally mounted on gimbals in such a way that makes it relatively unaffected by the movement of the ship on the sea. The gimbals are mounted in a binnacle which is the housing for the ship's compass, with an associated watch glass and light to illuminate the compass at night. The binnacle also incorporates a set of magnets which compensate the compass for unwanted distortions of the local magnetic field caused by the metal hull.

5.4 Electromagnetic Compass

The basic electromagnetic compass (also called a flux-gate compass) employs two or more small coils of wire around a core of highly permeable magnetic material, to directly sense the direction of the horizontal component of the earth’s magnetic field. The advantages of this mechanism over a magnetic compass are that the reading is in electronic form and can be digitised and transmitted easily, displayed remotely, and used by other equipment onboard ship.

To minimise inaccuracies created by the vertical component of the earth’s magnetic field, the fluxgate array must be kept as flat as possible by mounting it on a gimbal or a fluid suspension system; fluid or electronic damping can be incorporated.

5.5 Gyro Compass

This is a mechanical unit which utilises an electrically powered rapidly spinning gyro to form the basis of the gyrocompass and exploits the rotation of the earth. Once the gyro is set spinning, it remains pointing in the same direction irrespective of the ship's motion (roll, pitch and yaw). The gyro keeps the compass pointing not to the magnetic north but to true north (on the rotational axis of the earth). It was invented in 1908 and continues to provide the most reliable solution to determine heading on ships over 100 years after its invention

Another form of gyrocompass utilizes a series of fiber optic sensors in conjunction with a computer processing unit to locate north. Unlike the mechanical spinning gyro based compass, the fiber-optic gyrocompass has virtually no rotating or other moving parts and as such it has very high reliability and requires little maintenance during its service life. Its main application has been in the aerospace industry.

5.6 Satellite Compass

The advent of satellites and GNSS has enabled the development and production of a compass based on these technologies. This new compass equipment uses GPS signals to produce ship's heading information. A satellite based compass system generally utilises two GPS antennas/receivers which are positioned in-line with the longitudinal, or fore-aft axis of a ship. By measuring the carrier phases of the GPS signals at the two GPS receivers, the precise differential range between them and the GPS satellites can be calculated. Based on this information, a baseline vector between the two GPS receivers can be calculated resulting in the ship's heading relative to geographic north. A tri-antenna system is sometimes used which provides enhanced accuracy and enables the influence of the ship's motion to be reduced compared to the two antenna system.

Solid state rate sensors and accelerometers can be incorporated into the equipment which can provide data on the ship's roll and pitch. In the event of short term signal loss from the GPS satellites, the rate sensors can be used to provide continuous heading information. This information is not affected by the earth's magnetic field, latitude and ship's speed unlike a conventional compass.

The equipment provides outputs of ship's longitude, latitude, rate of turn, course over the ground and ground speed as well as roll/pitch data. The equipment provides high accuracy (0.5 degrees r.m.s) and angular resolution (0.1 degrees), does not need regular maintenance as for a conventional compass and can meet the IMO requirements for transmitting heading devices (THD).

5.7 References

Relevant Documents

1. IMO, SOLAS Chapter V, Regulation 19 – Carriage Requirements for shipborne navigational systems and equipment
2. IMO, Resolution A.382 (X)-Performance Standards for Magnetic Compasses
3. IMO, Resolution A.424(XI) Performance Standards for Gyro Compasses
4. IMO, SOLAS Chapter V, MSC. 116 (78) Transmitting Heading Device (THD)
5. IMO Resolution MSC.80 (70) Annex 2Transmitting magnetic heading devices
6. IMO, SOLAS Chapter V, RESOLUTION MSC.166(78) (adopted on 20 May 2004) APPLICATION OF PERFORMANCE STANDARDS FOR TRANSMITTING HEADING DEVICES (THDs) TO MARINE TRANSMITTING MAGNETIC HEADING DEVICES (TMHDs)
7. DRAFT INTERNATIONAL STANDARD ISO/DIS 25862, Ships and marine technology — Marine magnetic compasses, azimuth reading devices and binnacles for steering
8. IMO, SOLAS Chapter V, Annex 20, Inspection and Survey of Navigational Equipment (Magnetic and Gyro Compasses)

Websites

1. www.imo.org
2. www.iso.org

6. Radar and Automatic Radar Plotting Aids (ARPA)

6.1 Radar

6.1.1. Radar Requirements

Radar (RAdio Detection And Ranging) with target plotting is accepted by mariners as the primary tool for collision avoidance and a radar is a legal necessity for the safe navigation of vessels of 300gt and above, there being some 50,000 or more such vessels worldwide. The IMO definition of the purpose of a ship's radar is "to assist in the safe navigation and in avoiding collision by providing an indication, in relation to own ship, of the position of other surface craft, obstructions, hazards, navigation objects and shoreline''.

For this purpose, radar should provide the integration and display of radar video, target tracking information, positional data derived from own ship's position (EPFS) and geo-referenced data. The integration and display of AIS information should be provided to complement radar. The capability of displaying selected parts of Electronic Navigation Charts and other vector chart information may be provided to aid navigation and for position monitoring.

The IMO's SOLAS Chapter v, Regulation 19 Carriage requirements for ship-borne navigational equipments defines the carriage requirements for X-Band (9GHz) and S-band (3GHz) Navigation Radars which will be used to determine and display the range and bearing of other surface craft, obstructions, buoys, shorelines and navigational marks to assist in navigation and in collision avoidance

SOLAS Chapter V Annex 9 Performance Standards for Navigational Equipment lists the IMO resolutions relating to X-band and S-Band equipment performance and the relevant standards and regulations which apply to radars fitted since 1974 on-board vessels.

The IMO Resolution MSC.192 (79) adopted in December 2004, ADOPTION OF THE REVISED PERFORMANCE STANDARDS OF RADAR EQUIPMENT define the latest performance requirements for radar equipment. The new IEC standard IEC 22388:2008 reflects the latest radar performance and testing requirements. IEC 62388:2008 has the following improvements and additional functionality compared to the current requirements:

- Improved radar target detection performance in rain and sea clutter.

- Additional changes in the basic requirements for radar performance
- ITU-R Conformity to the frequency band spurious emissions.
- Conformity to IMO performance standards on navigation presentation MSC.191(79)
- Radar image display and measurement by Consistent Common Reference Position (CCRP).

6.1.2 Radar Description

Radar is an active electromagnetic sensor for the detection and location of reflecting objects. The first task of radar is to pick out its target from amongst unwanted background noise. It then has to display its target range and bearing or generate tracks of the target's movements. Radar and visual observation are still the main methods of determining risk of collision with other vessels and floating objects.

Present-day marine navigation radars consist of a mast mounted scanner unit (which carries an antenna and often houses a transmitter/receiver) together with a signal processing unit and a radar display unit housed in the ship's bridge. The output of the signal processing unit provides radar video signals to the display unit and for the Automatic Radar Plotting Aid (ARPA). The latter will output synthetic information on each target detected which will be overlaid on the radar video display.

The transmitter, inside the scanner unit, produces very short pulses of high frequency radio waves (microwaves), which are focused into a narrow beam by the rotating antenna. Pulses reflected back from solid objects such as land or other vessels are collected by the antenna, and passed to the receiver where they are amplified and processed.

Part of that processing involves measuring the time between the pulse being transmitted and the returning echo being received. Radio waves travel at a constant speed of 300 metres per microsecond, so that the time interval is directly related to the distance the pulse has travelled to and from the target.

Echoes are only received when the scanner is pointing straight at a target, so the direction in which the antenna is pointing when an echo is received corresponds to the target's bearing. The distance and bearing and echo signal are then passed to the display, which uses them to build up a map like picture of a boat's surroundings. The on screen intensity of the target depends on how much energy was reflected by target. The size of the target is generally related to the size of the reflecting surface.

It is generally accepted that a competent radar operator will recognise a true target (as opposed to clutter returns) if it paints in the same place for at least 5 out of 10 radar scans (50% paint). This definition of detection is also used by an ARPA (automatic radar plotting aid) to both detect and maintain track of a target.

The parameters often quoted as meaningful measures of the performance and suitability of a marine radar for a particular application include transmitter power, horizontal beamwidth, pulse length and pulse repetition frequency (PRF). These are discussed further in the following paragraphs:

Transmitter Power Output - A high power output level increases the chances that the radar will detect targets within its range in poor weather conditions (e.g. due to rain attenuation) compared to a low power radar; it will also be able to detect smaller objects at longer ranges (within its maximum unambiguous range).

Beamwidth – the radar horizontal beamwidth depends on the size of the antenna; the larger the horizontal aperture of the antenna, the narrower the beamwidth. Typical horizontal beamwidth ranges from 7 degrees for the smallest ship radars down to less than a degree for a large ships' radar set. The ability of the radar to distinguish between two targets close together on the same bearing, the angular resolution, also depends on the horizontal beamwidth, the narrower the beamwidth the better the resolution; it also shows land mass contours and inlets with much greater resolution.

Pulse length **-** has a similar effect when it comes to discriminating between objects that are on the same bearing but slightly separated in range. Short pulses give better definition, but unfortunately a "long" (up to about a microsecond!) pulse may be required to transmit enough energy at the target to produce an echo from small or distant targets. Manufacturers solve the problem by making radars that automatically change the pulse length to suit the range scale in use.

PRF – the pulse repetition frequency (number of pulse transmitted per second) determines the maximum unambiguous range of the radar. A long range radar has a low PRF (this allows time for the radar energy to be reflected from the target and return to the radar antenna before the next pulse is transmitted) whereas a short range radar has a high PRF. The radar PRF and the pulse length are interrelated; for short ranges requiring high range resolution, high PRFs and short pulse lengths are employed; for longer ranges where the resolution need not be as high, longer pulse lengths can be used.

Navigation radars normally operate in one of two frequency bands, X-Band (9 GHz) and S-Band (3 GHz) in accordance with ITU recommendations. Each frequency band has different characteristics which make them suitable for different purposes and size of vessels.

X-band radars are used on all vessels above 300 tonnes and have a very short, short and medium range operating modes. Typically an X-band radar being higher frequency than S-band, has narrower beamwidths, wider bandwidths, better angular and range resolution than an S-band radar. This makes it more suitable in areas of high vessel concentration, in and around harbours, coastal areas, busy shipping routes and inland waterways, whereas S-band is more suitable for the longer range applications and when X-band is affected by weather and seaclutter conditions. Vessels of 30,000 tonnes and above must carry an S-band radar in addition to an X-band radar (unless Administrations allow a second X-band radar). X-band is better for coastal/harbour use and S-band radar better for sea going. X-band radars tend to be smaller/lightweight compared to S-band whereas the components at S-band tend to be more readily available and cheaper than at X-band.
An important advantage of radar is that it does not require cooperating targets.
The Table below show typical parameters of such radars:

Parameter	**X-Band (9.4GHz)**	**S-Band (3GHz)**
Transmitter Power	10kW/25kW	30kW
Pulse Length (PRF)	0.05 (1760Hz) 0.25 (1760Hz) 0.75 (785 Hz)	0.05 (1760HZ) 0.25 (1760Hz) 0.75 (785Hz)
Hor. Beamwidth	1.3 deg/6ft antenna 1.0 degf/8ft antenna	2 deg/12 ft antenna
Antenna Rotation Rate	30 RPM	30 RPM

Conventional radar displays used a PPI (Plan Position Indicator) rotating raster type of display presentation, the raster scan following the rotating antenna position; present day displays utilize TV-type raster scans and up-to-date flat screen displays. Typical sizes of display range from 12 inches to 26 inches.

Present day radar displays are capable of displaying ENC chart information as an underlay to the synthetic radar display and most radars are now capable of accepting and displaying AIS data (which is entirely independent of radar derived data) on the display. The radars also provide an output of data to a Vessel Data Recorder (VDR).

The displays are capable of presenting a true or relative motion picture and can be used in a head-up or north-up mode. It is usual for both radar and ECDIS displays to be used in a head-up mode. The main purpose of the radar is collision avoidance and position fixing. In relative motion mode, the display is very useful for anti-collision purposes and does not need own ship's geographical position.

6.1.3 Radar Limitations

Radar operators should be aware of the constraints and inherent limitations of radars such as:

1. radar energy travels in straight lines along the line-of sight to a target; consequently, it cannot 'see' beyond obstructions such as may be present near and within harbours and along coastlines.
2. radars cannot 'see' beyond the radar horizon irrespective of transmitter power and its unambiguous range
3. radars can only detect targets which reflect electromagnetic power and cannot detect wood and fibreglass vessels hence the need for such vessels to carry radar reflectors
4. the limited detection range on small targets
5. the performance of radars is affected by the weather (e.g. precipitation and rain clutter). This is more so for X-band radars than S-band radars
6. the ability of radars to detect small surface targets is affected by seaclutter (backscatter reflections from the sea surface). The probability of detection at close ranges deteriorates as the incident sea state increases. X-band suffers more than S-band radars
7. the need to select the appropriate range scales/pulse lengths/PRFs for the task in hand
8. antenna rotation rate of conventional marine radars is 30 rpm; higher speeds if available could improve the detection of small targets in heavy seas and high sea clutter.

6.1.4 References

Relevant Documents

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2. IMO resolution A.278(VII) Supplement to the recommendation on PS for navigational radar equipment.
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5. IEC 62388 Radar Test Standard (replacing 60872 and 60936 series of test standards).
6. IEC 60945 Maritime navigation and radio communication equipment and systems – General requirements – Methods of testing and required test results.

7. IEC 61162 Maritime navigation and radio communication equipment and systems – Digital interfaces.
8. IEC 62288 Presentation and display of navigation information.
9. IMO A.813 (19) General requirement for electromagnetic compatibility (EMC) for all electrical and electronic ship's equipment
10. IMO A.820 (19) Performance standards for navigational radar equipment for HSC
11. IMO MSC.64 (67) Annex 4 Recommendation on performance standards for radar equipment
12. IEC 60936-1: 2002 Ship-borne radar performance requirement and unwanted emissions of radar systems
13. IEC 60936-2: 1998 Performance requirement for High-Speed Craft (HSC) radar
14. IEC 60945: 2002 General requirements for maritime navigation and radio communication equipment
15. IEC 61162-1 Ed. 2: 2000 for digital interface
16. IEC 61162-2 Ed. 1: 1998 for digital interface
17. RESOLUTION MSC.192(79) (adopted on 6 December 2004) ADOPTION OF THE REVISED PERFORMANCE STANDARDS FOR RADAR EQUIPMENT (MSC 79/23/Add.2 ANNEX 34)

Websites

1. www.imo.org – The International Maritime Organisation
2. www.iala-aism.org – The International Association of Lighthouse Authorities
3. www.itu.int – International Telecommunications Union
4. www.iec.ch – International Electrotechnical Commission

6.2. Automatic Radar Plotting Aid (ARPA)

6.2.1. ARPA Requirements

A navigator's assessment of collision risk depends upon his/her knowledge about own ship's motion and other ships' motion. The available means for assessing the other ships' motion include visual sighting, voice communication with other ships, radar, AIS and ARPA (or other radar plotting aids).

The IMO have defined three levels of radar plotting and target tracking aid:

1. Electronic Tracking Aid (ETA) - To be incorporated in Radar equipment on ships of 300 gt. and over, but less than 500 gt
2. Automatic Tracking Aid (ATA) - To be incorporated in Radar equipment on ships of 500 gt. and over (replacing the requirement for an EPA). On ships of 3000 gt. and over the second radar must also be equipped with an ATA. The two ATAs must be functionally independent of each other.

3. Automatic Radar Tracking Aid (ARPA) - To be incorporated in one radar equipment on ships of 10000 gt. and over. The second unit must incorporate ATA if not ARPA.

The EPA provides basic plot with manual target acquisition and tracking while the ARPA is completely automatic in operation and can cope with multiple target tracks and will calculate the closest point of approach of own ship to other vessels and will enable various collision avoidance manoeuvres to be set-up and be checked. The functionality in each of the above is defined in more detail in Section 6.2.2.

The IMO has laid down performance requirements for each of the three levels of plotting and tracking aids. These are defined in IMO, Solas Chapter V Regulation 19; Carriage Requirements for ship-borne navigational systems and equipment

1. Electronic Plotting Aid (EPA) - EPA equipment enables electronic plotting of at least 10 targets, but without automatic tracking.
   NOTE – The wording of the Regulation in the case of EPA includes "..or other means to plot electronically the range and bearing of targets to determine collision risk." Therefore manual plotting equipment is no longer acceptable except for existing vessels still complying with SOLAS V/74.
2. Automatic Tracking Aid (ATA) - ATA equipment enables manual acquisition and automatic tracking and display of at least 10 targets.
3. Automatic Radar Plotting Aid (ARPA) - ARPA equipment provides for manual or automatic acquisition of targets and the automatic tracking and display of all relevant target information for anti-collision decision making. For vessels of less than 500gt it should cater for tracking 20 targets, for vessels between 500 and 10,000gt it should cater for tracking 30 targets and for vessels over 10,000gt it should provide for tracking a minimum of 40 targets with automatic target acquisition. ARPA facilities should also enable trial manoeuvres to be executed.

6.2.2 ARPA Description

An Automatic Radar Plotting Aid (ARPA) is essentially a radar processing unit which at present is normally an integral part of radar or it can be a standalone device. The ARPA takes in radar video from the radar's signal processing unit and enables radar target data to be displayed as synthetic plot and track data on a radar display. The latter may be a conventional PPI type of display using a radial scan type of presentation or more frequently in new systems, a raster scan display format similar to that used in TV display unit.

A typical ARPA gives a presentation of the current situation and predicts future situations. An ARPA assesses the risk of collision, and enables an operator to see proposed maneuvers by own ship. Vessels being tracked are easily identified with a

number and vector line. Detailed information such as CPA/TCPA (Closest Point of Approach/Time to Closest Point of Approach), speed and course can also be displayed.
Targets may be acquired manually or by setting up an automatic acquisition zone such as an annular or polygonal automatic acquisition zone of variable depth and provide protection over any arc up to and including a full circle around own ship. When target tracking, the operator is able to display target data on any chosen target.

While many different models of ARPAs are available on the market, the following functions are typical of what is provided:

- True or relative motion radar presentation.
- Automatic acquisition of targets plus manual acquisition.
- Digital read-out of acquired targets which provides course, speed, range, bearing, closest point of approach (CPA, and time to CPA (TCPA).
- The ability to display collision assessment information directly on the PPI, using vectors (true or relative) or a graphical Predicted Area of Danger (PAD) display.
- The ability to perform trial maneuvers, including course changes, speed changes, and combined course/speed changes.
- Automatic ground stabilization for navigation purposes. ARPA processes radar information much more rapidly than conventional radar but is still subject to the same limitations. ARPA data is only as accurate as the data that comes from inputs such as the gyro and speed log.

Vessels being tracked are easily identified with a number and vector line. Detailed information such as CPA (Closest Point of Approach), speed and course is also displayed.

6.2.3 ARPA Limitations

The accuracy of plots and tracks output from an ARPA are sensitive to the errors inherent in the outputs of the sensors which provide data to the ARPA such as radar, log, speed, position etc. The following aspects can affect the performance of an ARPA and must be checked to ensure that the ARPA output is within the accuracy requirements specified by the relevant IMO regulation:

1. the performance of the radar is at its optimum
2. Serious errors of output data can arise if automatic heading and speed inputs to the ARPA/ATA are incorrect.
3. Correct speed input, where provided by manual setting of the appropriate ARPA/ATA controls or by an external input, is vital for correct processing of ARPA/ATA data. .

4. Users should be aware of possible hazards of using ground stabilised mode with ARPA/ATA when assessing risk of collision with approaching vessels, particularly in areas where significant tidal streams and/or currents exist. When course and speed inputs are derived from electronic position fixing systems (eg LORAN, GPS and DGPS) the display is ground-stabilised. The output data of tracked targets will relate to their ground track and, although accurate, may be highly misleading when assessing target aspect and determining collision-avoidance manoeuvres.
5. In cases of gyro failure when heading data is provided from a transmitting magnetic compass, watch-keepers should remember to determine and apply the errors of the magnetic compass.
6. Mis-alignment of the heading marker, even if only slight, can lead to dangerously misleading interpretation of potential collision situations, particularly in restricted visibility when targets are approaching from ahead or fine on own ship's bow
7. The use of more than one ARPA display for anticollision purposes by one officer is likely to lead to increased scope for error.

6.2.4 References

Relevant Documents

1. IMO, SOLAS Chapter V, Regulation 19, Carriage Requirements for ship-borne navigation equipment and systems, Annex 16, Radar Equipment
2. IMO, SOLAS Chapter V, Annex 9, Performance Standards for Navigational Equipment
3. IMO, MSC 64(67) Annex 4, Recommendations on Performance Standards for Radar Equipment
4. IMO, Resolution A694, General Requirement for Shipborne Equipment Forming Part of the GMDSS and for Electronic Navigational Aids (adopted on 6 November 1991)
5. IEC 60872-1, Maritime navigation and Radiocommunication equipment and systems - Radar plotting aids - Part 1: Automatic radar plotting aids (ARPA) – Methods of Testing and Required Test Results
6. IEC 60872-2, Marine Navigation and Radiocommunication Equipment and Systems - Radar Plotting Aids - Part 2: Automatic Tracking AIDS (ATA) - Methods of Testing and Required Test Results
7. IEC 60872-3, Maritime Navigation and Radiocommunication Equipment and Systems - Radar Plotting Aids - Part 3: Electronic Plotting Aid (EPA) - Performance Requirements - Methods of Testing and Required Test Results
8. IEC 60945, Maritime Navigation and Radio communication Equipment and Systems - General Requirements – Methods of Testing and Required Test Results
9. EN60872-1, Maritime navigation and radiocommunication equipment and systems - Radar plotting aids - Part 1: Automatic radar plotting aids (ARPA)

10. EN 60872-2, Maritime navigation and radiocommunication equipment and systems. Radar plotting aids. Automatic tracking aids (ATA).
11. EN 60872-3, Maritime navigation and radiocommunication equipment and systems. Radar plotting aids. Electronic plotting aid (EPA).
12. EN60945, Maritime Navigation and Radio communication Equipment and Systems - General Requirements – Methods of Testing and Required Test Results
13. EN 61162, Maritime navigation and radiocommunication equipment and systems - Digital interfaces - Part 1: Single talker and multiple listeners
14. IMO, RESOLUTION A.823(19) (adopted on 23 November 1995) PERFORMANCE STANDARDS FOR AUTOMATIC RADAR PLOTTING AIDS (ARPAs)

Websites:

1. www.imo.org – The International Maritime Organisation
2. www.itu.int – International Telecommunications Union
3. www.iec.ch – International Electrotechnical Commission

7. Electronic Chart Display and Information System (ECDIS)

7.1 Requirements

ECDIS is a navigation information system which is approved by the International Maritime Organisation (IMO) as a paper chart equivalent. SOLAS Chapter V Regulation 19 *Carriage requirements for ship-borne navigational systems and equipment* allows an electronic chart display and information system (ECDIS) to be accepted as meeting the chart carriage requirements of the regulation.

The regulation requires all ships, irrespective of size, to carry nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. The ship must also carry back-up arrangements if electronic charts are used either fully or partially. A second ECDIS, connected to an independent power supply and a separate GPS position input or an appropriate up-to-date folio of official paper charts for the intended voyage is acceptable.

For an ECDIS to meet a minimum level of reliability and functionality, the International Maritime Organization (IMO) has developed a performance standard for ECDIS. This standard specifies how an ECDIS must work in order that it serves as an adequate replacement for the paper nautical chart. The IMO Performance Standards permit National Maritime Safety Administrations to consider ECDIS as the functional equivalent to charts required by Regulation V, Chapter 20 of the 1974 SOLAS Convention. IMO has specifically requested that member governments encourage their National Hydrographic Offices produce electronic navigational charts (ENCs) and provide the associated updating service as soon as possible, and ensure that manufacturers conform to the performance standards when designing and producing ECDIS.

The IMO minimum requirements for ECDIS systems (ECDIS Performance Standard) are defined in IMO Resolutions A.817(19), MSC.64(67) and MSC.86(70).

ECDIS Performance Standard defines functional minimum requirements:

- Use of official digital chart data in standardised formats (S-57, RCDF),
- Presentation of chart data according to the Colours and Symbol Specification (S52),
- Support of essential navigational functions (VRM, EBL, Route planning, Route monitoring),
- Handling of data received from other navigational equipment (e.g. GPS, Gyro),
- Performance tests, alarms and indications for e.g. Anti-Grounding or for malfunctions of e.g. navigational interfaces,
- Power supply
- Back up arrangements.

IEC 61174 is used as the basis for type-approval/certification by Maritime Safety Administrations for an IMO-compliant ECDIS. Type approval is normally conducted by recognized organisations or by marine classification societies nominated by Flag States.

To ensure that ECDIS equipment intended for onboard use is seaworthy, it must pass type approval and test procedures developed by the International Electrotechnical Commission (IEC) based on the ECDIS Performance Standards of IMO and applying the IHO requirements, S-52 and S-57 in particular.

At the IMO Sub-Committee on Safety of Navigation (NAV), 54th session: 30 June – 4 July 2008 an implementation schedule for mandatory ECDIS was agreed; it is anticipated that this will be adopted by the Maritime Safety Committee in May 2009. There will be a scaled implementation period, with staggered dates for different vessel classes as indicated below:

- passenger ships of 500 gross tonnage and upwards constructed on or after a proposed date of [1 July 2012];
- tankers of 3,000 gross tonnage and upwards constructed on or after a proposed date of [1 July 2012];
- cargo ships, other than tankers, of 10,000 gross tonnage and upwards constructed on or after a proposed date of [1 July 2013];
- cargo ships, other than tankers, of 3,000 gross tonnage and upwards but less than 10,000 gross tonnage constructed on or after a proposed date of [1 July 2014];
- passenger ships of 500 gross tonnage and upwards constructed before [1 July 2012], not later than the first survey on or after a proposed date of [1 July 2014];
- tankers of 3,000 gross tonnage and upwards constructed before [1 July 2012], not later than the first survey on or after a proposed date of [1 July 2015];
- cargo ships, other than tankers, of 50,000 gross tonnage and upwards constructed before [1 July 2013], not later than the first survey on or after a proposed date of [1 July 2016];
- cargo ships, other than tankers, of 20,000 gross tonnage and upwards but less than 50,000 gross tonnage constructed before [1 July 2013], not later than the first survey on or after a proposed date of [1 July 2017];
- cargo ships, other than tankers, of 10,000 gross tonnage and upwards but less than 20,000 gross tonnage constructed before [1 July 2013], not later than the first survey on or after a proposed date of [1 July 2018].

7.2 ECDIS Description

The Electronic Chart Display and Information System (ECDIS) is a ship-borne real-time electronic navigational system that is capable of integrating navigational positioning system and ship sensors with the electronic navigational charts (ENCs). It is an automated decision aid capable of continuously determining a vessel's position in relation to land, charted objects, aids-to-navigation, and unseen hazards. It is able to provide 24-hour and all-weather information, as well as anti-grounding and anti-collision warnings (CPA/TCPA etc), and other information and also has the capabilities to carry out route planning, route monitoring and estimated time of arrival (ETA) computation.

ECDIS has two official modes of operation: ECDIS mode when Electronic Navigational Chart (ENC) data is available and Raster Chart Display System (RCDS) mode when ENC data is unavailable. The full functionality of ECDIS is unachievable when operating ECDIS in the RCDS mode and therefore it can only be used together with an appropriate portfolio of paper charts. This report considers the ECDIS mode of operation.

ECDIS comprises three main components:

- ECDIS Software (to read ENC for display on the monitor)
- ECDIS Hardware
- Electronic Navigational Chart (ENC)

The ENC contains chart information necessary for safe navigation and may contain supplementary information to those in the paper chart. Official ENC data is produced by national hydrographic offices. The ENC data is produced in accordance with the International Hydrographic Organisation (IHO) S57 standard. An ENC (Electronic Navigational Chart) is a database, standardized as to content, structure and format, issued for use with ECDIS on the authority of government authorized Hydrographic Offices (HOs). It contains all chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart (e.g. Sailing Directions), which may be considered necessary for safe navigation.

The electronic chart can be overlaid with a variety of navigation data such as radar echo images, ship's position, heading, speed and others to facilitate safe and efficient vessel operation. Radar echo image overlay can also be made available. This function gives the exact match in scale and presentation of the chart and radar echo image.

ENC database stores the chart information in the form of geographic objects represented by point, line and area shapes, carrying individual attributes, which make any of these objects unique. Appropriate mechanisms are built into the system to query the data, and then to use the obtained information to perform certain navigational functions (e.g. the anti-grounding surveillance). ECDIS displays are available in various sizes and configurations, 19 inch and 23 inch being typical. Operators are provided with controls over adjustment of the presentation which can include radar imagery/synthetic radar information, AIS information as well as electronic chart information.

Unlike the paper chart, ECDIS is a highly sophisticated system which, besides the navigational functions, includes components of a complex, computer-based information system. In total, the system includes hardware, operating system, ECDIS software (kernel and user interface), sensor input interfacing, electronic chart data, rules for presentation and display, status and parameters of alarms and indications, etc. It is essential that officers remember to cross check the information displayed by all other means available; especially by looking out the window and watching the radar! Bridge-procedures must be adapted appropriately and appropriate training must be carried out.

7.3 Updating ECDIS Information

Electronic Nautical Charts and other information held in ECDIS require updating in line with the paper versions as more accurate or new information becomes available. Updating of ENCs is automatic in ECDIS. Possible ways of providing the information for transfer to the ECDIS are:

- CD-ROM
- Landline
- Port-wide wireless network
- Mobile phone technology (GSM)
- Broadband link (terrestrial or satellite)

The conventional way of updating electronic nautical charts is by the use of CD-ROM done when the ship is in port, the information being provided by the ship's agent. The information could also be provided by land line to the ship or by using port-wide wireless networks which are becoming available in larger ports. It is not currently normal practice for ECDIS charts to be update while the ship is at sea although this could be the case in future. At present, the expense of using satellite communication links for updating ECDIS is prohibitive and the legal situation regarding ship insurance where there is a broadband link to ECDIS is unclear.

The EC funded MarNIS Project has investigated the existing and planned broadband updating methodologies, both satellite and terrestrial, for updating the Electronic Navigational Charts (ENCs) as used in ECDIS. It has concluded that, while the cost of using satellite communications is too expensive for most users at present, this is likely to change in the future as systems having higher transmission speeds/lower costs come on line. The Project Deliverable Report (D2.5.D) covers the state-of-the- art and the capabilities/limitations of available and future updating methods.

7.4 ECDIS Limitations

One of the biggest problems with a transition to ECDIS is an over-reliance on the information provided. Some of the inherent limitations of ECDIS are listed below:

- lack of official Electronic Navigational Charts (ENC)
- accuracy is affected by poor GPS performance
- ECDIS is complex and installation setup may not be optimised
- There could be errors in the compilation of ENC (e.g. datum) or other chart errors (omissions, out-dated);
- There may be survey errors inherent in the ENC;
- The standards are not finalized and could affect existing ship installations.

7.5 References

Relevant Documents

1. IMO SOLAS Chapter V, Regulations 18.1, 19.2.1.4, 19.2.1.5
2. IMO Resolutions A.817(19), MSC.86(70), Performance standards for electronic chart display and information systems;
3. Resolution MSC.64(67) - Adoption of New and Amended Performance Standards (Adopted on 4 December 1996)
4. Resolution MSC.232(82) - Adoption of the Revised Performance Standards for Electronic Chart Display and Information System (ECDIS) (Adopted on 5 December 2006), Revised Performance Standards for Electronic Chart Display and Information System (ECDIS))
5. IHO S52, Specifications for chart content and display aspects of ECDIS
6. IHO S52 appendix 1, Guidance on updating the electronic navigational chart;
7. IHO S52 appendix 2, Colour and symbol specifications for ECDIS;
8. IHO S52 appendix 3, Glossary of ECDIS-related terms;
9. IHO S57, Transfer standard for digital hydrographic data;
10. IEC 61174, Electronic chart display and information system (ECDIS)
11. IEC 61174 (2001-10): Electronic chart display and information system (ECDIS) – Operational and performance requirements, methods of testing and required test results
12. IEC 60945: Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results;
13. IEC 61162: Navigation interfaces – Methods of testing and required test results
14. IALA Navguide, Edition 5, 2006
15. MarNIS, Deliverable reference number: D2.5.D. Title: Research report on Chart updates, 1-05-06

Websites

1. www.imo.org – The International Maritime Organisation
2. www.iala-aism.org – The International Association of Lighthouse Authorities
3. www.iho.org – The International Hydrographic Organisation
4. www.iec.ch – International Electrotechnical Commission
5. www.marnis.org – European Commission Funded MarNIS project

8. Global Satellite Navigation Systems (GNSS)

8.1 GNSS Requirement

The IMO's SOLAS Chapter V Regulation 19, 2.1.6, Carriage Requirements for ship-borne navigational systems and equipment states that:

All ships irrespective of size are required to be fitted with a GNSS receiver. This will probably be a GPS receiver using the US Global Positioning System which may or may not be equipped to provide differential correction (DGPS). The Russian GLONASS system or a terrestrial navigation system receiver will also meet the requirements of SOLAS V/19.

Particular attention should be paid to the correct data inputs / outputs. Particular attention should be paid to the antenna and its connections.

GNSS receivers also calculate speed over the ground. Surveyors should ensure that speed input to the radar is not generated by GNSS, as the radar requires water-track speed.

8.2 GNSS Background

A Global Navigation Satellite System is a satellite navigation system that provides autonomous geo-spatial positioning with global coverage. A GNSS allows users with compatible receivers to determine their location (longitude, latitude and altitude) to within a few metres using time signals transmitted along a line of sight by radio from satellites.

Several countries are developing their own global navigation satellite systems but currently, the US Global Positioning System (GPS) is the only fully operational system. This was originally developed for military purposes and this is still its main purpose but the facility is available for commercial use. The only other system available is the Russian GLONASS which is being restored to full operation and should be operational again by 2010. In Europe, the EU is developing the GALILEO positioning system which is scheduled to be operational in 2013. Other programmes worldwide include:

- China: Beidou navigation system, which may be expanded globally
- Indian Regional Navigation Satellite System (IRNSS) which is intended to be a regional system aimed for operation in 2012.

Satellite Navigation Systems pinpoint a location by measuring the distances from at least .three known satellite locations. The distance to one satellite defines a sphere of possible locations; combining three such spheres defines a common area containing the unknown position. The accuracy of the distance measurements determines how small the common area is and thus the accuracy of the final location. In practice a receiver at the location captures time signals from three satellites and converts them into the respective distances.

The position accuracy depends on the accuracy of the time measurement. Only atomic clocks can provide the required accuracy, of the order of nanoseconds and the necessary stability of the order of 10 nanoseconds per day.

This report concentrates on GALILEO as this is the GNSS intended for maritime navigation applications in the future. A short description of the US GPS is included as this is the system generally in use at present and until GALILEO is operational.

Satellite navigation benefits all maritime applications including leisure boats, commercial vessels, and unregulated and SOLAS-regulated ships.

8.3 GPS and DGPS

8.3.1 GPS

The US Global Position System (GPS) originally used a constellation of 24 satellites; continuously more satellites are launched to modernise the system and to include new functions or a better accuracy. There are currently 29 satellites in orbit. Position calculations are made in the World Geodetic System (WGS-84). New developments include a second frequency for civil use to improve accuracy and to eliminate some atmospheric disturbances.

GPS when used for civilian purposes has several shortcomings:

- A mediocre and changing degree of position according to place and time, sometimes being inaccurate to several dozen metres
- Variable atmospheric refractive index causes degradation in performance which results in an excessive range measurement
- Reliability leaves something to be desired, coverage of regions in extreme latitudes is not dependable nor is signal penetration in dense areas and town centres
- GPS's main purpose is for military applications and hence there is always a risk of civilian users being cut off in the event of a crisis. Signal interruptions can have disastrous consequences especially if there is no warning

There is no guarantee of service and responsibility for performance and reliability GPS is currently used for many civilian applications including maritime navigation.

8.3.2 Differential GPS (DGPS)

Over several years, the accuracy of GPS for civilian users was degraded compared to the accuracy available for military purposes by disturbing the accuracy of the timing signals. To improve the accuracy under these circumstances in limited areas, GPS reference receivers were installed in exact known locations. By comparing the position of the reference receiver and the received and calculated positions of the GPS

receiver, the difference in signals was known for each of the received satellites. However, degrading the accuracy is no longer employed.
Both GPS and DGPS are used for maritime purposes.

8.4 European Geostationary Navigation Overlay Service (EGNOS)

GPS has revolutionised navigation and positioning over the last two decades but there are shortfalls. Some users need firm commitments on civil control, others need much better accuracy than GPS alone can provide. Many need to know the state of health of the system (e.g. malfunction of a satellite) and need warnings of this to support safety critical applications. Satellite based augmentation systems (SBAS) assist in achieving these functions.

EGNOS is a European Satellite Based Augmentation System (SBAS) and is being deployed to provide regional satellite based augmentation services to aviation, maritime and land users in Europe. Consisting of three geostationary satellites and a network of ground stations, EGNOS achieves its aim by transmitting a signal containing information on the reliability and accuracy of the positioning signals sent out by the Global Positioning System (GPS) and the Global Orbiting Navigation Satellite System (GLONASS). It allows users in Europe and beyond to determine their position to within 2 metres, compared with about 20 metres for GPS and GLONASS alone.

It augments the GPS system making it suitable for safety critical applications such as flying aircraft or navigating ship’s through narrow channels. It is designed to meet the requirement for landing aircraft which is the most stringent and so meets most other user’s requirements such as:

1. Availability improvement by broadcasting GPS look alike signals from up to three geostationary satellites
2. Accuracy improvement to 1-2 metres horizontally (compared to about 20 metres previously) and 3-5 metres vertically
3. Improvements to integrity and safety by alerting users within 6 seconds if a GPS malfunction occurs

Without such a system, it can take up to 3 hours for a warning signal if a satellite should malfunction but with SBAS an alert message can be sent within 6 seconds when a GPS malfunctions thus helping to maintain performance.

EGNOS entered its pre-operational phase in 2006. It is progressively being brought into service and will undergo certifications for safety-of-life applications.

8.5 GALILEO

8.5.1 Background

GALILEO is the first satellite positioning and navigation system designed for civilian purposes. It will offer state-of-the-art services with outstanding performance in accuracy and continuity and availability. It will be more advanced, more efficient and more reliable than the current US GPS. GALILEO is a European Union funded project and the system is scheduled to be operational in 2013.

GALILEO will provide several levels of service:

1. A basic, free of charge service for the final user such as consumer applications and general services (GPS also provides this service free)
2. Restricted access service for commercial and professional applications that require superior performance (there will be several levels going up to a very restricted service for applications which in no event must be disturbed))

Restricted access services will require payment which will contribute to economics of the system.

GNSS operate within the frequency range 1100 MHz -1600 MHz.

8.5.2 Description

GALILEO will consist of a constellation of 30 satellites placed in orbit at an altitude of 24000 km and covering the entire surface of the earth together with a network of ground stations. Each satellite is equipped with an atomic clock providing extremely precise time measurements making it possible to determine a location of any stationary or moving target to within one metre.

GALILEO offers superior and constant accuracy due to the structure of its satellite constellation and ground relay system. Guaranteed accuracy to one metre is needed for certain applications, for example to avoid a collision when a vessel enters or manouvres in harbour. GALILEO is expected to achieve this accuracy.

GALILEO will offer a safety of life service for most transport applications where lives could be endangered if the performance of the navigation system is degraded without real time notices. There will be a worldwide high integrity level for safety critical applications such as maritime, aviation and rail where guaranteed accuracy is essential. Safety of Life services will operate in specific frequency bands reserved for Aeronautical Radio-Navigation Services.

8.5.3 Maritime Navigational Applications

The efficiency, safety and optimisation of maritime transportation are key issues. GALILEO will be a fundamental tool for bringing innovation and progress in navigation and many other marine activities such as navigation, fishing, oceanography and oil and gas exploration.

The accuracy and integrity requirements vary significantly between different phases of marine navigation. Generally, 3 major phases are identified: oceanic navigation (distance to the nearest obstacle greater than 50 nautical miles), coastal navigation (distance to the nearest obstacle between 3 and 50 miles) and pilotage navigation (distance to the nearest obstacle less than 3 miles). Within harbour approaches and in harbours, the accuracy requirements are much higher.

GALILEO will be used on-board ship in every phase of marine navigation: ocean, coastal, port approach and port manoeuvres and on inland waterways, under all weather conditions and will contribute to vessel activities as follows:

- The high accuracy and signal availability are ideal for navigation in the open sea and the integrity information contained in the GALILEO signal adds confidence to the calculated position of the vessel
- It will be an additional means of implementing the regulations on AIS which depends on satellite navigation and currently uses GPS. GALILEO will provide improved reliability and thus contribute to increased safety and vessel traceability.
- GALILEO with its localised elements in harbours will provide high positional accuracy and will enable vessels to enter and carry out precision manouvres in harbours under all weather conditions
- The use of high accuracy and reliable satellite navigation will assist with vessel navigation in estuaries and inland waterways
- GALILEO will contribute to search and rescue services. The positioning accuracy of the current system is poor (typically a few kilometres and the alert is not always issued in real time. The GALILEO SAR service will drastically reduce the time to alert and the position of the distress signal will be determined to a few metres.

85.4 GPS, EGNOS and GALILEO

Neither GPS (nor GLONASS) offer the performance required for safety of life applications in terms of accuracy, integrity, continuity and availability. This has to some extent been remedied by introducing differential services (dGPS) and Satellite Based Augmentation Services (SBAS) such as EGNOS in some parts of the world. However, ship positioning is highly dependent on the availability of GPS and GLONASS, both systems being under military control. GALILEO will provide an independent mean for ship positioning with availability guaranteed by a civil authority and will offer superior and constant high accuracy and a global high integrity level compared to the existing GPS currently in use, due to the structure of its satellite constellation and ground relay system.

GALILEO, GPS and EGNOS are compatible and will not interfere with each other. More importantly from the user point of view is the GPS, EGNOS, GALILEO interoperability. The performance of receivers will be improved thanks to the use of

both constellations. A combined GPS-EGNOS-GALILEO receiver will be the common solution for the majority of applications, especially in the mass market.
By integrating GALILEO with other technologies the following benefits can be achieved:

- A reliable safe and accurate tool for maritime navigation in any phase
- Integrity information for Safety-of-Life
- Increased performance with integrated receivers (e.g. combined GPS/GALILEO receivers)
- Improved Search and Rescue Services

8.5.5 GALILEO Related European Commission Funded Projects

GALILEO is a European Union funded project which is nearing successful launch of the GALILEO satellite navigation system. Much work has been done in European Commission funded R&D programmes related to GALILEO and its applications. A comprehensive list of projects relevant to maritime navigation is provided in section 10.5.7 courtesy of the MarNIS (Maritime Navigational Information Systems) Project. This particular project has carried out studies into the use of GNSS (and GALILEO in particular) to assist in ship navigation at present and how it can be used in the future. An essential part of this study has been a review of European Commission funded projects and a comparison of the various GNSSs in relation to ship navigation. References to these projects and associated reports are included in the following Section.

8.6 References

Relevant Documents

1. IMO, SOLAS Chapter V Regulation 19 (2.1.6) Carriage requirements for ship-borne navigational systems and equipment
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9. Long Range Aid to Navigation (LORAN) and eLORAN

9.1 LORAN-C

LORAN (**LO**ng **R**ange **A**id to **N**avigation) is a long range terrestrial radio navigation system that can be used for land sea and air navigation. It is based on a system of terrestrial transmitters and was developed by the US during the 1960s to meet US Department of Defence requirements. The latest version in operation is LORAN-C. The Russian Federation operates a similar navigation system called CHAYKA. There are currently about 24 LORAN-C and CHAYKA chains operating around the world. LORAN-C is a hyperbolic radionavigation system using triangulation techniques to determine the position of a receiver.

A LORAN-C chain consists of between 3 and 5 stations having a spacing of 600 to 1000 nm. The signal format is a structured sequence of pulses at a carrier frequency within the band 90 – 110KHz. One of the stations is designated as the 'master' and transmits bursts of 9 pulses; the other stations are called 'secondaries' and these transmit bursts of 8 pulses. The pulse spacing is a characteristic unique to each chain of transmitters and is referred to as the Group Repetition Interval (GRI).

LORAN-C operates over long range, up to 1,200 nm and can provide positional accuracy typically of 0.25nm or better.

9.2 eLORAN

The EC's views and intentions regarding the future availability of the European coverage of LORAN is that there should be a terrestrial long term service which should provide a viable back-up to GNSS in view of the perceived vulnerability of GNSS and their propagation limitations. It is considered essential to provide a terrestrial alternative source of position, navigation and time information to reduce dependence on GNSS. In the UK, the General Lighthouse Authority has been awarded a 15 year contract to provide a state-of-the-art enhanced LORAN (eLORAN) service to improve the safety of mariners in the UK and Western Europe which will be operational until at least 2022.

Enhanced LORAN, or eLORAN, comprises an advancement in receiver design and transmission characteristics which increase the accuracy and usefulness of traditional LORAN. With reported accuracy as high as 8 meters, the system becomes competitive with unenhanced GPS. eLoran also includes additional pulses which can transmit auxiliary data such as DGPS corrections. eLoran receivers now use "all in view" reception, incorporating signals from all stations in range, not solely those from a single GRI, incorporating time signals and other data from up to 40 stations. These enhancements in LORAN make it adequate as a substitute for scenarios where GPS is unavailable or degraded.

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10. Automatic Identification System (AIS)

10.1 Requirements

Regulation 19 of the IMO SOLAS Chapter V - Carriage requirements for ship borne navigational systems and equipment - sets out navigational equipment to be carried on board ships, according to ship type. In 2000, the IMO adopted a new requirement (as part of a revised new chapter V) for ships to carry automatic identification systems (AISs) capable of providing information about the ship to other ships and to coastal authorities automatically.

The regulation states that AIS is to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004.

The regulation requires that AIS shall:

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

10.2 Description

10.2.1 System Overview

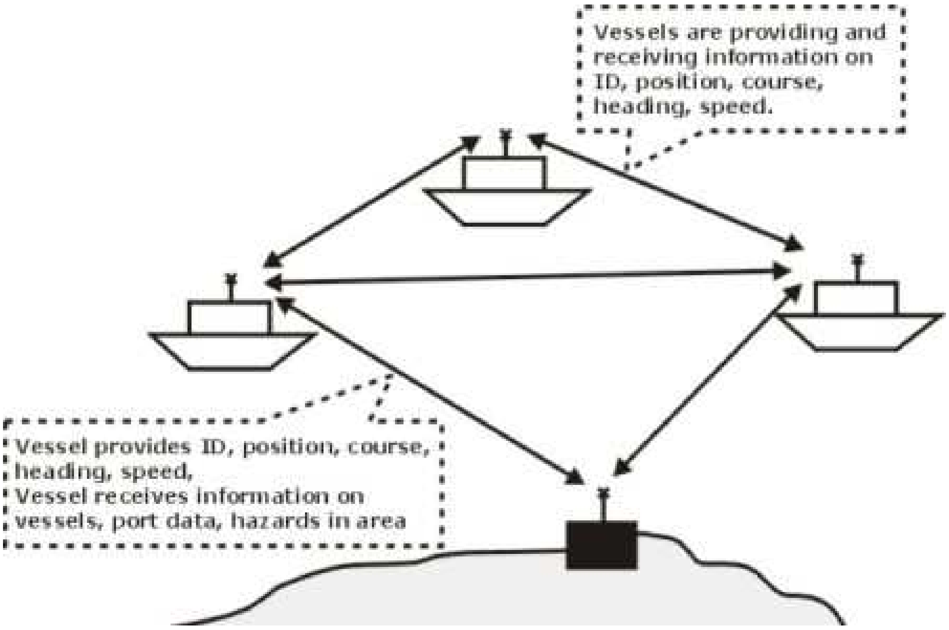
The AIS equipment has the following functions***:***

- Ship to Ship communication
- Ship to Shore communication, including long range applications
- Automatic and continuous operation
- Provide information messages

Performance Standards for AIS require that the system should be capable of operating:

- In the ship-to-ship mode, to assist in collision avoidance
- As a means for littoral States to obtain information about a ship and its cargo
- As a VTS tool, i.e. ship-to-shore (traffic management)

A simplified overall AIS system overview is shown in the following diagram for the reader. However, this report concentrates on the ship-borne equipment required to provide the onboard AIS facilities which enables the ship to cooperate with other AIS carrying vessels and shore based authorities and facilities (e.g. VTS).



AIS system overview *(Source: IMO SOLAS Ch. V, Annex 17 Fig. 1)*

10.2.2 Ship-borne AIS

A typical on-board AIS subsystem configuration is shown in the diagram below:

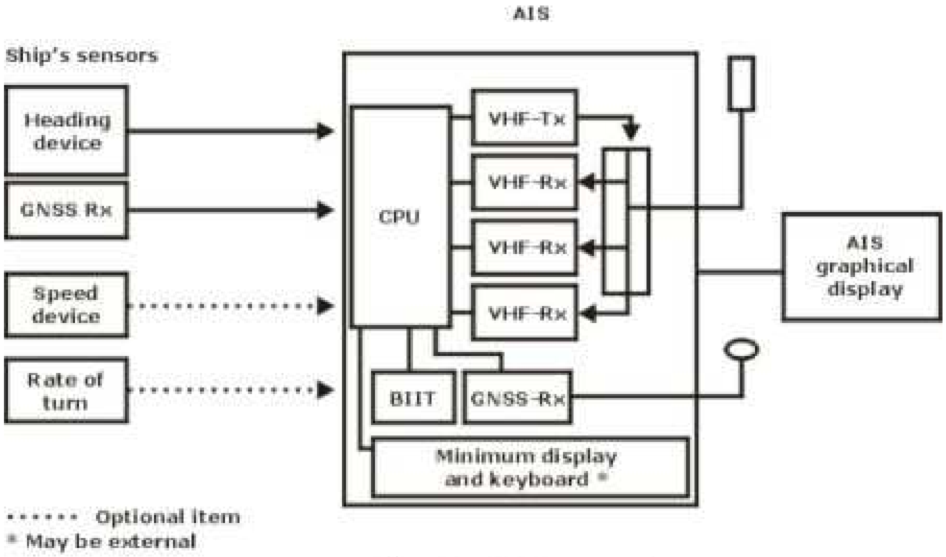


Figure 2 - AIS Components

(Source: IMO SOLAS CH. V, Annex 17 Fig. 2)

The onboard equipment essentially consists of:

- antennas
- one VHF transmitter
- two multi-channel VHF receivers
- one channel 70 VHF receiver for channel management
- a central processing unit (CPU)
- an electronic position fixing system, Global Navigation Satellite System (GNSS) receiver for timing purposes and position redundancy
- interfaces to heading and speed devices and to other ship-borne sensors
- interfaces to radar/Automatic Radar Plotting Aids (ARPA), Electronic Chart System/Electronic Chart Display and Information System (ECS/ECDIS) and Integrated Navigation Systems (INS) – only provided on the latest systems
- BIIT (Built In Integrity Test
- minimum display and keyboard to input and retrieve data.

The basic equipment enables the AIS to operate as a stand-alone system. The integration of the received AIS data into other devices such as INS, ECS/ECDIS or a radar/ARPA display would significantly increase the effectiveness of AIS, when achievable. However, minimum fit AIS equipment may not have this capability. (see Section 18 on e-Navigation)

The AIS relies on data from other ship's sensors and hence the accuracy of such data will affect the accuracy of the position and heading data transmitted by the AIS.

10.2.3 AIS Operation

The on-board equipment:

- continuously transmits ship's own data to other vessels and VTS stations
- continuously receives data of other vessels and VTS stations
- displays this data on its own display unit

AIS operates primarily on two dedicated international VHF channels (AIS1 - 161,975 MHz and AIS2 - 162,025 MHz). Where these channels are not available regionally, the AIS is capable of being automatically switched to designated alternate channels by means of a message from a shore facility.

The AIS is able to detect ships within VHF/FM range and around bends and behind islands, if the landmasses are not too high. A typical value to be expected at sea is 20 to 30 nautical miles depending on antenna height. With the help of repeater stations, the coverage for both ship and VTS stations can be improved. In practice, the capacity of the overall system is unlimited allowing for a great number of ships to be accommodated at the same time.

Information from ship-borne AIS is transmitted continuously and automatically without any intervention. An AIS shore station might require updated information from a specific ship by "polling" that ship, or alternatively, might wish to "poll" all ships within a defined sea area. However, the shore station can only increase the ships' reporting rate but not decrease it.

10.2.4 AIS Information Sent By Ships

The IMO requirement defines the information to be supplied and sent by ships as:

- fixed, or static information, which is entered into the AIS on installation and need only be changed if the ship changes its name or undergoes a major conversion from one ship type to another
- dynamic information, which, apart from 'Navigational status' information, is automatically updated from the ship sensors connected to AIS equipment
- voyage-related information, which might need to be manually entered and updated during the voyage such as:
    - Ship's draught

- hazardous cargo;
- destination and ETA;
- route plan (way-points);
- the correct navigational status; and
- safety related short messages.

The update data rates of the information sent differs in that dynamic information is sent at higher rates than static and voyage related data; the latter is updated at 6 minute intervals or on request whereas dynamic information rates depend on the speed of the vessel ranging from every 3 minutes at anchor to every 2 seconds at speeds greater than 23 knots and with changing course.

10.2.5 AIS on Vessels Smaller Than 300 tonnes

Whilst AIS is mandatory for all ships of 300 tonnes and upwards and all passenger ships falling under the SOLAS Chapter V convention, other ships, as pleasure craft and inland navigation vessels may carry AIS on a voluntary basis. For pleasure crafts Class B CSTDMA has been developed. Other, professional, users may use Class A or derivative Class A stations. For inland navigation a dedicated Inland AIS is under development.

10.2.6 Long Range AIS

AIS can be provided with a two-way interface for connecting to long range radiocommunication equipment. Initially, it is not envisaged that AIS would be able to be directly connected to such equipment. There is a Long-Range option in Class A stations (SOLAS ships) that can operate in combination with any long-range data communication system. Inmarsat-C is proposed because this communication system forms a part of the GMDSS, already available on almost every ship of interest. The only thing missing is the mandatory connection between AIS and the Inmarsat-C terminal.

A shore station would first need to request that the ship makes a long range AIS information transmission. Any ship-to-shore communication would always be made point-to-point, and not broadcast, and once communication has been established, the ship would have the option of setting its AIS to respond automatically to any subsequent request for a ship report from that shore station.

10.3 Limitations

1. Because AIS is normally operating on VHF frequencies, the range of communication is limited to 25-30 nautical miles.
2. Multiple AIS base station around the coast may result in interference between stations, ships, ships to shore etc.

3. Where AIS information can be displayed on combined displays there may be incompatibilities between Radar and AIS symbologies which need to be resolved in order to provide the navigator with an unambiguous and intuitive picture.
4. Specific types of ships, and in particular leisure craft, fishing boats and warships, and some coastal shore stations including Vessel Traffic Service (VTS) centres might not be fitted with AIS.
5. Other ships, fitted with AIS as a mandatory carriage requirement, might switch off AIS under certain circumstances.
6. The accuracy of AIS information received is only as good as the accuracy of the AIS information transmitted; in particular, manually inputted data may not be updated as necessary.
7. Poorly configured or calibrated ship sensors (position, speed and heading sensors) might lead to incorrect information being transmitted. Incorrect information about one ship displayed on the bridge of another could be dangerously confusing.
8. The ship may be within a reporting system but out of VHF range of the coastal station.
9. AIS positions are derived from the vessels GNSS position. (GNSS = Global Navigation Satellite System, usually GPS). This may not coincide with the radar target.
10. It could be very easy to falsify AIS data onboard and this could therefore pose a security risk.
11. AIS information is publicly available for all with an AIS receiver and may be open to miss use.

10.4 Future developments -Space-Based AIS

Maritime vessels larger than 300 gross tonnes are required to carry AIS transponders which give vessel name, position, speed, course and cargo to ships and shore based stations within range. However, due to the curvature of the earth, such systems operating in the VHF band have limited range, typically 20 -30 nautical miles, together with the other limitations outlined in the previous Section.

Satellite-borne standard AIS equipment can easily receive AIS transmissions from ships for satellite altitudes of up to 1000 Km. A single satellite will be able to receive and report AIS data form AIS-equipped ships from anywhere within the satellite coverage area. This provides the opportunity, using a suitable satellite constellation of providing global surveillance and reporting of all maritime vessels equipped with AIS transponders. A reliable satellite-based collection system would eliminate the short range limitations of conventional AIS and potentially reduce the need to build large numbers of coastal stations along the world's coastlines. However, shore-based AIS facilities will need suitable satellite communication equipment to receive, process and display the information received from the space-based AIS satellite constellation.

The potential of space-based AIS is being investigated by several organisations and companies. For example research is being undertaken in Norway and Canada into the viability of space based AIS. There are several limitations which need to be overcome such as the density of ships reporting within single satellite coverage and the likelihood of system saturation. Parameters to be taken into consideration include ship information and satellite reporting update rates, individual satellite coverage, number of satellites required, detection probabilities, ship densities. Advanced filtering techniques will be required to distinguish between the multitude of signals received from ship transponders within satellite coverage area.

It has been suggested that that with adequate funding and need, space-based AIS could become viable by 2020.

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11. Global Maritime Distress and Safety System (GMDSS)

11.1 GMDSS Requirements

GMDSS is an automated ship to shore distress alerting system that relies on satellite and advanced terrestrial communications links. The system also provides some limited ship to ship communications capabilities, as well as items specific to Search & Rescue activities such as emergency position indicating radio beacons (EPIRBs) and search and rescue transponders (SARTs).

The requirement for fitting a Global Maritime Distress and Safety System (GMDSS) is specified in Chapter IV of the SOLAS Convention. All passenger ships and all cargo ships of 300 gross tonnage and upwards on international voyages are required to carry equipment designed to improve the chances of rescue following an accident, including satellite emergency position indicating radio beacons (EPIRBs) and search and rescue transponders (SARTs) for the location of the ship or survival craft. Regulations in Chapter IV cover undertakings by contracting governments to provide radiocommunication services as well as ship requirements for carriage of radiocommunication equipment. The Chapter is closely linked to the Radio Regulations of the International Telecommunication Union.

11.2 GMDSS Description

The basic concept of GMDSS is that search and rescue (SAR) authorities ashore, as well as shipping in the immediate vicinity of the ship in distress, will be rapidly alerted to a distress incident so that they can assist in a co-ordinated SAR operation with the minimum delay. The system also provides for agency and safety communications and the promulgation of Maritime Safety Information (MSI) - navigational and meteorological warnings and forecasts and other urgent safety information to ships. GMDSS utilises traditional radio communications, but integrates them into a coordinated system, adding satellite communications.

Every ship should be capable, irrespective of the area in which it operates, to perform those communication functions which are essential for the safety of the ship itself and of other ships operating in the same area. GMDSS consists essentially of three main components: communication satellites to detect and locate emergency beacons carried by ships, the emergency beacons and a network of ground stations and search and rescue centres. When an emergency beacon is activated, the signal is relayed via a satellite to the nearest available ground station where it triggers a search and rescue action on the part of the responsible agency.

11.2.1 System Configuration

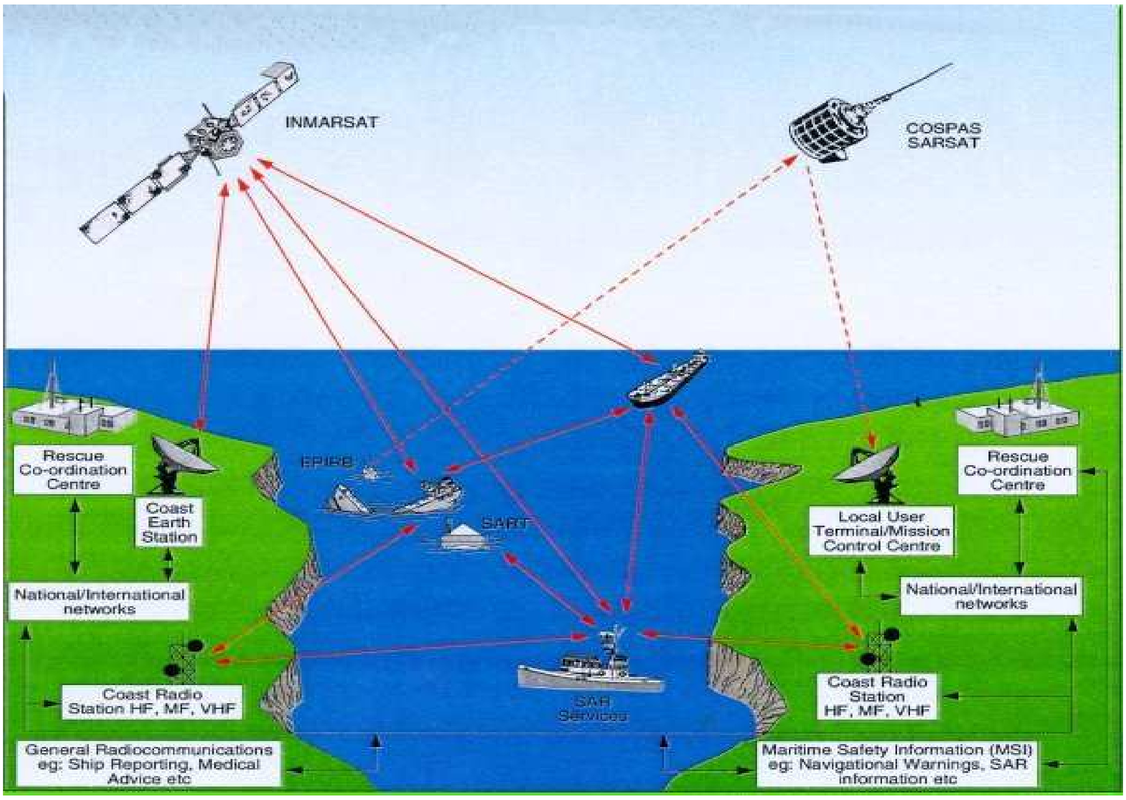
As can be seen from the pictorial view of the infrastructure involved in providing a GMDSS capability, the main components include both terrestrial and satellite communication links between the stricken ship and the major players such as shore based rescue centres. There are also networks providing national and international rescue coordination and information flow.

The GMDSS makes extensive use of communication satellites for rapid and reliable communications. There are two main satellite communication systems involved in the provision of GMDSS, the INMARSAT system and the COSPAS-SARSAT system. Both systems are capable of receiving distress signals from maritime EPIRBs which operate at 406 MHz. These two systems are briefly described in the following paragraphs.

INMARSAT owns and operates a global satellite network and offers mobile satellite communications services for users in the maritime, land and aeronautical sectors. It provides the space segment for the GMDSS for the maritime community and it offers three satellite communications systems designed to provide most of the GMDSS medium- and long-range functions: Inmarsat B, Inmarsat C and Inmarsat Fleet 77. These systems typically provide for ship/shore, ship/ship and shore/ship telephone, telex and high-speed data services, including a distress priority telephone and telex service to and from rescue coordination centres.

The Inmarsat C provides ship/shore, shore/ship and ship/ship store-and-forward data and telex messaging, the capability for sending preformatted distress messages to a rescue coordination centre, and the SafetyNET service. The Inmarsat C SafetyNET service is a satellite-based worldwide maritime safety information broadcast service of high seas weather warnings, navigational warnings, radionavigation warnings, ice reports and warnings generated by the International Ice Patrol, and other similar information not provided by NAVTEX. SafetyNET works similarly to NAVTEX in areas outside NAVTEX coverage.

The COSPAS-SARSAT satellite system is designed to provide distress alert and location data to assist search and rescue (SAR) operations, using spacecraft and ground facilities to detect and locate the signals of distress beacons (EPIRBs, ELTs, PLBs) and a network of control centres to process and distribute data to SAR authorities. It has been developed and is operated by organisations from the former USSR, USA, Canada and France. The space component of the system comprises 4 low altitude earth orbiting satellites (LEOSARs) and three geostationary satellites (GEOSARs) at an altitude of 36,000km to provide global coverage.



(Source: http://www.icselectronics.net/GMDSS.php)

11.2.2 GMDSS Ship Equipment

Specific equipment requirements for ships vary according to the sea area (or areas) in which the ship operates. The GMDSS combines various subsystems which all have different limitations with respect to coverage, into one overall system, and the oceans are divided into four sea areas:

1. **Area A1**. Within range of VHF coast stations with continuous DSC (Digital Selective Calling) alerting available (about 20 - 30 miles).
2. **Area A2.** Beyond area A1, but within range of MF coastal stations with continuous DSC alerting available (about 100 miles).
3. **Area A3.** Beyond the first two areas, but within coverage of geostationary maritime communication satellites (in practice this means Inmarsat). This covers the area between roughly 70 deg N and 70 deg S.
4. **Area 4.** The remaining sea areas. The most important of these is the sea around the North Pole (the area around the South Pole is mostly land). Geostationary satellites, which are positioned above the equator, cannot reach this far.

Coastal vessels, for example, only have to carry minimal equipment if they do not operate beyond the range of shore-based VHF radio stations, but they may carry satellite equipment. However, some coasts do not have shore-based facilities, so although the ship is close to shore, the area counts as Area A2 or A3. Ships which do go beyond Sea Area A1 have to carry MF equipment as well as VHF or Inmarsat satellite equipment. Ships which operate beyond MF range have to carry Inmarsat satellite equipment in addition to VHF and MF. Ships which operate in area A4 have to carry HF, MF and VHF equipment.

11.2.2.1 Digital Selective Calling (DSC)

DSC is, basically, a paging system that is used to automate distress alerts sent over terrestrial (ie: non-satellite) VHF, MF and HF marine radio systems. Digital selective calling (DSC) has been introduced on VHF, MF and HF maritime radios as part of GMDSS. DSC is primarily intended to initiate ship/ship, ship/shore and shore/ship radiotelephone and MF/HF radiotelex calls. DSC calls can also be made to individual ships or groups of ships. DSC distress alerts, which consist of a pre-formatted distress message, are used to initiate emergency communications with ships and rescue co-ordination centres.

DSC eliminates the need for persons on a ship's bridge or on shore to continuously guard radio receivers on voice radio channels used for distress, safety and calling. GMDSS DSC equipment is normally comprised of a stand alone control unit, with an alpha-numeric display screen and a keyboard on which to compose messages.

(Source: http://www.gmdss.com.au/dsc.htm)

The DSC system supports a number of call categories. These categories mirror the standard maritime prioritisation of message traffic, i.e.: *DISTRESS, URGENCY, SAFETY, ROUTINE.*

At the press of a button, a ship can send its identity, position and nature of distress by either satellite or terrestrial communication.

12.2.2.2 NAVTEX

This is an international, automated system for instantly distributing maritime navigational warnings, weather forecasts and warnings, search and rescue notices and similar information to ships. A small, low-cost and self-contained "smart" printing radio receiver installed in the pilot house of a ship or boat checks each incoming message to see if it has been received during an earlier transmission, or if it is of a category of no interest to the ship's master. If it is a new and wanted message, it is printed on a roll of adding-machine size paper; if not, the message is ignored. A new ship coming into the area will receive many previously-broadcast messages for the first time; ships already in the area which had already received the message won't receive it again. No person needs to be present during a broadcast to receive vital information.

11.2.2.3 EPIRBs

Emergency Position Indicating Radio Beacons and other radio systems are used to 'raise the alarm' in an emergency, and some EPIRBs also provide approximate location information. There are two types of Emergency Position Indicating Radio Beacons (EPIRBs) that are designated for use in the GMDSS:

1. 406MHz EPRIBs using the Cospas-Sarsat polar orbiting satellite network.
2. There is also available a VHF DSC EPIRB that uses VHF Channel 70 (156.525MHz). This type of EPIRB is intended only for vessels that sail within GMDSS Sea Area A1.

The transmission of an EPIRB signal is considered to be a distress alert. The essential purpose of an EPIRB signal is to help determine the location of survivors during a distress incident. A Rescue Co-ordinating Centre (RCC) receiving an EPIRB transmission would consider that the vessel in distress is unable to transmit or receive a distress message so a Distress Alert Relay would normally be transmitted to ships in the area by any suitable means, e.g. SafetyNET, DSC or NAVTEX

All EPIRBs have the facility for manual activation or "float-free" release and self-activation. Remote activation from the navigating bridge, while the EPIRB is still mounted in the "float-free" cradle mounting, may also be provided. The equipment, mounting and hydrostatic release mechanism must be reliable and able to operate under the most extreme conditions likely to be met at sea. Manual distress alert initiation requires at least two independent actions. The latest EPIRBs are capable of receiving GPS information and transmitting their position as part of the distress information

11.2.2.41 SARTs Search and Rescue Transponders

Search and Rescue Transponders greatly improve the ease and speed of locating and rescuing the survivors, by displaying an internationally recognized signature on the radar screens of passing vessels or aircraft. No specialist equipment needs to be carried by the receiving craft, so any passing vessels or aircraft will be able to react to the SART's signal, reducing the all-important time-to-rescue dramatically. GMDSS rules state that all registered vessels above 300 gross tonnes must carry at least one SART, and those above 500 gross tonnes at least two SARTs.

11.3 Reference

Relevant Documents

1. List of Resolutions adopted by the Assembly, Council, FAL, LC, LEG, LP, MEPC, MSC, and TC Committee according to subject headings (12 November 2008), Section 4, Maritime Safety
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11. INTRODUCTION TO THE COSPAS-SARSAT SYSTEM, GC/S G.003 Issue 5 - Revision 1, October 1999
12. IEC 60945, Maritime navigation and radiocommunication equipment and systems – General requirements –Methods of testing and required test results, October 2002
13. IEC 61097-4, Global maritime distress and safety system (GMDSS) – Part 4: Inmarsat C ship earth station and Inmarsat enhanced group call (EGC) equipment – Operational and performance requirements, methods of testing and required test results, November 1994
14. IEC 61097-5, Global maritime distress and safety system (GMDSS) – Part 5: Inmarsat E Emergency position indicating radio beacon (EPIRB) operating through the Inmarsat system – Operational and performance requirements, methods of testing and required test results, November 1997

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16. IEC 61907-13, Global maritime distress and safety system GMDSS) – Part 13: Inmarsat F77 ship earth station equipment – Operational and performance requirements, methods of testing and required test results, May 2003

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3. www.cospas-sarsat.org – Cospas-Sarsat Consortium
4. www.inmarsat.com – Inmarsat
5. www.iec.ch – International Electrotechnical Commission

12. Voyage Planning and Weather Routing

12.1 Voyage Planning

12.1.1 Overview

Voyage planning is becoming increasingly important in today's maritime scenario and the need to plan a vessels voyage from berth-to-berth whether it be for short sea shipping or Long Distance Ocean crossings is well understood. The voyage plan covers all stages of the voyage from leaving dockside, harbour manouevring, the en-route portion, to final docking at journeys end. Optimised voyage planning is recognized as an essential requirement for cost effective, efficient and safe maritime operations.

A vessel's voyage plan should identify a route which: takes into account any relevant ships' routing systems, ensures sufficient sea room for the safe passage of the ship throughout the voyage, anticipates all known navigational hazards and adverse weather conditions, takes into account the marine environmental protection measures that apply and avoids, as far as possible, actions and activities which could cause damage to the environment.

The generation and execution of a voyage plan consists of four components:

1. Appraise – all available information: weather, tide, boat, crew, route, hazards en route, passage times, aids to navigation
2. Plan – departure and arrival, constraints, critical times such as tide gates, pilotage plans, ports of refuge
3. Execute – make the passage according to the plan, taking into account the prevailing conditions.
4. Monitor – progress against the plan continuously, particularly weather forecast, tides and position

.

The need for accurate estimated time of arrival (ETA) planning in order for the ship owners to satisfy customers demanding information on where their cargo is, arrival time, and where and when it can be picked up and the need for “just-in-time” logistics has generated a requirement for accurate voyage planning and updating. Optimised voyage planning can also contribute to improvements in fuel consumption.

Satellite communications enable vessels to provide details of their voyage plans to coastal VTS centers when they come within their sphere of influence. While not current practice, in future this information could be used by VTS centers to significantly improve maritime traffic control.

12.1.2 Requirements

The IMO, Resolution A.893(21), Annex 2, adopted on 25 November 1999, has laid down guidelines for the development of a plan for voyage or passage, as well as the close and continuous monitoring of the vessel's progress and position during the execution of such a plan, are of essential importance for safety of life at sea, safety and efficiency of navigation and protection of the marine environment.

The need for voyage and passage planning applies to all vessels. There are several factors
that may impede the safe navigation of all vessels and additional factors that may impede the
navigation of large vessels or vessels carrying hazardous cargoes. These factors will need to be taken into account in the preparation of the plan and in the subsequent monitoring of the execution of the plan.

Annex 24, Voyage Planning, of SOLAS, Chapter V, includes guidelines for/defines the four components of voyage planning.

12.2 Weather Routing

12.2.1 Overview

Ship routing on the basis of the weather forecast is also of growing importance in shipping and more and more ship owners have realised the advantages of using weather routing to ensure smoother and safer sea passages. Accurate weather routing to avoid bad weather can provide the possibility of cost savings on sea-fastening and cargo reinforcements and damage to cargo; delays due to cargo salvage can also be minimised.

The use of satellite communications with high speed data transfer rates and the availability of GNSS provide the facilities to enable instant updates on weather conditions and enable fast updates to a vessel's voyage plan. Optimised weather routing can contribute to improvements in fuel consumption.

12.2.2 Requirements

The IMO require that Contracting Governments provide and promulgate meteorological information and warnings to shipping. (SOLAS, Chapter V, Regulation 5, Meteorological Services and Warnings).

In particular, Contracting Governments undertake to warn ships of gales, storms and tropical cyclones by the issue of information in text and, as far as practicable graphic form, using the appropriate shore-based facilities for terrestrial and space radiocommunications services.

12.3 References

Relevant Documents

1. IMO, SOLAS Chapter V, Annex 24, Voyage Planning, MCA Guidance Notes
2. IMO, SOLAS Chapter V, Annex 25, Voyage Planning, IMO Resolution A.893
3. IMO, SOLAS Chapter V, Regulation 34, Safe navigation and avoidance of dangerous situations
4. IMO, SOLAS Chapter V, Regulation 10, Ship's Routing

Website:

www.imo.org

13. Voyage Data Recorder (VDR)

13.1 VDR Requirements

13.1.1 Overview

Passenger ships and ships other than passenger ships of 3000 gross tonnage and upwards constructed on or after 1 July 2002 must carry Voyage Data Recorders (VDRs) to assist in accident investigations, under regulations adopted in 2000, which entered into force on 1 July 2002. VDRs enable accident investigators to review procedures and instructions in the moments before an incident and help to identify the cause of any accident.

The mandatory regulations are contained in the IMO’s Chapter V on Safety of Navigation of the International Convention for the Safety of Life at Sea, 1974 (SOLAS).

13.1.2 Specific VDR Requirements

Under Regulation 20 of SOLAS Chapter V on Voyage Data Recorders (VDR), the following ships are required to carry VDRs:

- passenger ships constructed on or after 1 July 2002;
- Ro-Ro passenger ships constructed before 1 July 2002 not later than the first survey on or after 1 July 2002;
- passenger ships other than Ro-Ro passenger ships constructed before 1 July 2002 not later than 1 January 2004; and
- ships, other than passenger ships, of 3,000 gross tonnage and upwards constructed on or after 1 July 2002.

Performance standards for VDRs were adopted in 1997 and give details on data to be recorded and VDR specifications. They state that the VDR should continuously maintain sequential records of preselected data items relating to status and output of the ship's equipment and command and control of the ship. The VDR should be installed in a protective capsule that is brightly coloured and fitted with an appropriate device to aid location. It should be entirely automatic in normal operation.

Administrations may exempt ships, other than ro-ro passenger ships, constructed before 1 July 2002, from being fitted with a VDR where it can be demonstrated that interfacing a VDR with the existing equipment on the ship is unreasonable and impracticable.

Regulation 18 of SOLAS Chapter V on Approval, surveys and performance standards of navigational systems and equipment and voyage data recorder states that:

The voyage data recorder (VDR) system, including all sensors, shall be subjected to an annual performance test. The test shall be conducted by an approved testing or servicing facility to verify the accuracy, duration and recoverability of the recorded data. In addition, tests and inspections shall be conducted to determine the serviceability of all protective enclosures and devices fitted to aid location. A copy of a the certificate of compliance issued by the testing facility, stating the date of compliance and the applicable performance standards, shall be retained on board the ship.

From 1st July this year, the SOLAS Convention will require all existing RO-RO ferries with international trading patterns to have a VDR installed on or by their first survey after that date. In addition, new vessels whose keels are laid on or after 1st July 2002 of over 3,000 registered gross tonnes will also be obliged to carry a VDR. Passenger ships must comply by 1st January 2004.

The European Union has also brought out a directive which covers the carriage requirements, use and performance of a ship-borne VDR; this is in accordance with the IMO directive and IEC regulations.
Article 10 of Directive 2002/59/EC requires that Member States shall monitor and take all necessary and appropriate measures to ensure that ships calling at a port of a Member State are fitted with a voyage data recorder (VDR) system in accordance with the performance standards of IMO Resolution A.861(20) and the testing standards set by Standard No 61996 of the International Electronics Commission (IEC).

Annex 11 of the directive requires that data which have been collected from a VDR system shall be made available to the Member State concerned in the event of an investigation following a casualty occurring within the waters under the jurisdiction of a Member State. Member States shall ensure that such data are used in the investigation and are properly analysed. Member States shall ensure that the findings of the investigation are published as soon as possible after its conclusion.

To satisfy these requirements, investigating authorities in the Member States need to acquire and continually update the knowledge and skills necessary for autonomous retrieval and, where possible, immediate playback of data from the VDR systems that they are likely to encounter.

13.1.3 Simplified VDRs

The MSC at its 79th session in December 2004 adopted amendments to Regulation 20 of SOLAS chapter V (Safety of Navigation) on a phased-in carriage requirement for a ship-borne simplified voyage data recorder (S-VDR). The amendment entered into force on 1 July 2006. The new rules stipulate that existing cargo ships on international voyages shall be fitted with an S-VDR.

The phase-in is as follows:

“20,000 gross tonnage and upwards constructed before 1 July 2002, at the first scheduled dry-docking after 1 July 2006 but not later than 1 July 2009”

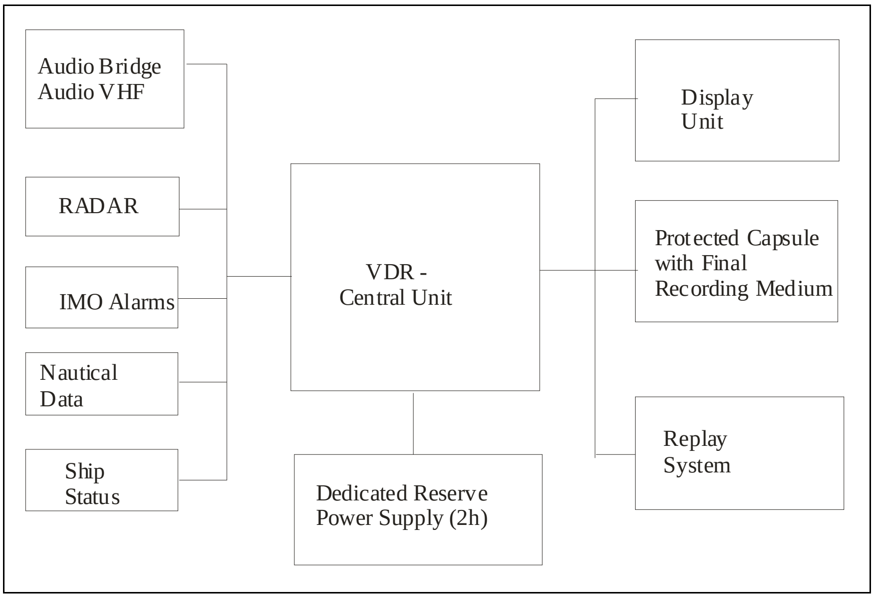
“3,000 gross tonnage and upwards but less than 20,000 gross tonnage constructed before 1 July 2002, at the first scheduled dry-docking after 1 July 2007 but not later than 1 July 2010”

"Administrations may exempt cargo ships from the application of the requirements when such ships will be taken permanently out of service within two years after the implementation date

The S-VDR is not required to store the same level of detailed data as a standard VDR, but nonetheless should maintain a store, in a secure and retrievable form, of information concerning the position, movement, physical status, command and control of a vessel over the period leading up to and following an incident.

13.2 VDR Equipment Description

The purpose of a VDR is to maintain continuously recorded sensor data to reconstruct in case of an accident what was happened before a collision, grounding or any other casualty. The data that has to be recorded and stored include information concerning the position, movement, physical status, command and control of the vessel .The generic structure of a VDR is depicted in the following figure (MARNIS Deliverable D2.4.C). The replay system is not normally installed on a ship and is not regarded as part of a VDR. However, investigations have shown that when a replay system is installed the crew use it for purposes of on board training and ISM documentation also uses it.



Principle structure of a full Voyage Data Recorder

(Source: MarNIS, Deliverable report number D2.4.C, Research report on ship-borne equipment for enhanced performance and capabilities, Page 44, Fig. 25)

The VDR collects data from various sensors on board the ship and stores the information digitally, in an externally mounted protective storage unit which is a tamper-proof unit designed to withstand the extreme shock, impact, pressure and heat, which could be associated with a maritime incident (e.g. fire, explosion, collision). This protective storage unit may be in a retrievable fixed unit or free float unit when the ship is sunk in a marine incident – only about 4-5% of incidents result in the a vessel being sunk.

The last 12 hours of stored data in the protected unit can be recovered and replayed by the authorities or ship owners for incident investigation. Beside the protective storage unit, the VDR system consists of a recording control unit and data acquisition unit, which is connected to the various equipment and sensors on board a ship.

A pictorial example, showing a physical unit configuration of a typical S-VDR is shown below:

(Source: www.kelvinhughes.co.uk)

An S-VDR is a reduced version of the VDR required for new vessels and is specifically aimed at the retrofit of cargo vessels. The Simplified Voyage Data Recorder (S-VDR), as defined by the requirements of IMO Performance Standard MSC.163(78), is a lower cost simplified version VDR with only basic ship's data recorded.

The different requirements are summarised in the Table below:

Interface	VDR	S-VDR
Date and Time	⍰	⍰
Ship’s Position	⍰	⍰
Speed	⍰	⍰
Heading	⍰	⍰

Bridge Audio	✓	✓
Communications Audio	✓	✓
Radar Data – post-display selection	✓	Unless ‘impossible’
AIS	✓	If no Radar
Echo Sounder	✓	Only if the data is available in accordance with the international digital interface standard (IEC 61162)
Main Alarms	✓	
Rudder Order and Response	✓	
Engine Order and Response	✓	
Hull Openings (doors) status	✓	
Watertight and fire door status	✓	
Accelerations and Hull Stresses	✓	
Wind Speed and Direction	✓	

Data Types:

- Date and time: Referenced to UTC with an indication of the source. The source could be the GPS
- Ship’s position: In latitude and longitude with the datum used. The source could be the GPS
- Speed: Through water or speed over ground with indication of which it is. The source could be the speed log
- Heading: As indicated by the ship’s compass. The source could be the gyro compass
- Bridge audio: As picked up by one or more microphones positioned on the bridge so that conversation at or near the conning stations, radar displays, chart tables, etc., is adequately recorded. As far as practicable, the positioning of microphones should also capture intercom, public address systems and audible alarms on the bridge
- VHF communications: Relating to ship operations should be recorded
- Radar data: Electronic signal information from within one of the ship’s radar installations with recording of all the information which was actually being presented on the master display of that radar at the time of recording

- AIS data: If it is impossible to obtain radar data by using a commercially available interface then AIS target data should be recorded as a source of information regarding other ships. If radar data is recorded, AIS information may be recorded additionally as a beneficial secondary source of information on both other and own ship. AIS data is not mandatory, but an option when it is impossible to obtain radar data by means of a commercially available interface
- Additional data: Items listed by IMO with the requirements set out in resolution A.861(20) should be recorded when the data is available in accordance with the international digital interface standard NMEA0183 using approved sentence formatters. The additional data listed by IMO with the requirements in resolution A.861(20)are:
  – Echo sounder
  – Main alarms
  – Rudder order and response
  – Engine order and response
  – Hull openings status
  – Watertight and fire door status
  – Accelerations and hull stresses
  – Wind speed and direction

Definition of the data items to be recorded is provided in IMO Performance Standard (Res. A.861(20)) and IEC Information format (IEC 61996).

Although the primary purpose of the VDR is for accident investigation after the fact, there can be other uses of recorded data such as for preventive maintenance, performance efficiency monitoring, heavy weather damage analysis, fleet management, accident avoidance and reduction of running cost. Data stored in the replay unit can be used for training and evaluation purposes and to improve safety. The data collected can be transmitted via the ships communication systems to shore based facilities or command centres.

The ship owner will, in all circumstances and at all times, own the VDR and its information. However, in the event of an accident the following guidelines would apply. The owner of the ship should make available and maintain all decoding instructions necessary to recover the recorded information.

13.3 References

Relevant Documents

1. IMO, Chapter V on Safety of Navigation of the International Convention for the Safety of Life at Sea, 1974 (SOLAS)

2. IMO, SOLAS chapter V (Safety of Navigation) Regulation 20 on Voyage Data Recorders (VDRs)
3. IMO, SOLAS Chapter V, Regulation 18 –Approval, survey and performance standards for navigational systems and equipment and voyage data recorders
4. MSC/Circ.1024 Guidelines on voyage data recorder (VDR) ownership and recovery
5. IMO. Resolution A.861(20) Performance Standards for Ship-borne Voyage Data Recorders. London 1997
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7. IMO Annex 9: IMO Performance Standards for Navigational Equipment
8. IMO Annex 10 EU requirements for VDRs on passenger ships on domestic voyages
9. IMO Annex 20: Inspection and survey of VDRs – guidance on inspection and survey of VDRs
10. MARNIS Project Deliverable Reference Number D2.4.C, Research report on ship-borne equipment for enhanced performance and capabilities, 12/9/06
11. Marine Guidance Note: VOYAGE DATA RECORDER'S (VDRs) - PERFORMANCE TESTING MGN 272(M)
12. IEC 61996 Maritime navigation and radiocommunication equipment and systems –Shipborne (VDR) –Part 1: Voyage data recorder (VDR) – Performance requirements, methods of testing and required test results
13. DIRECTIVE 2002/59/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, 27 June 2002, establishing a Community vessel traffic monitoring and information system.

Websites

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3. www.mcga.gov.uk Maritime Coastguard Agency
4. www.marnis.org - European Commission funded MarNIS project
5. www.nmea.org/pub/0183 - National Marine Electronics Association
6. http://www.elna.de/en - S-VDR supplier
7. www.kmkongsberg.com –VDR supplier

Projects

The EMDM project aims to study and develop new applications, functionalities and proposals for specifications and standards for enhanced, interactive VDRs and electronic logbooks, in order to face to the challenge of the intermodal, safe and secure European transport development .

http://www.euroqualityfiles.net/emdm

14. Integrated Bridge System/Integrated Navigation System (IBS/INS)

14.1 Requirements

The IMO defines an Integrated Bridge System (IBS) as a combination of systems which are interconnected in order to allow centralised access to sensor information or command/control from work stations, with the aim of increasing safe and efficient ship's management by suitably qualified personnel. An Integrated Navigation System (INS) is a composite system which performs at least the functions of collision avoidance and route planning/monitoring thus providing added value for the operator to plan, monitor and safely navigate the progress of the vessel.

Performance standards for integrated bridge systems were adopted by IMO in 1996 and essentially state that:

Integrated Bridge Systems shall be so arranged that failure of one sub-system is brought to immediate attention of the officer in charge of the navigational watch by audible and visual alarms and does not cause failure to any other sub-system. In case of failure in one part of an integrated navigational system, it shall be possible to operate each other individual item of equipment or part of the system separately.

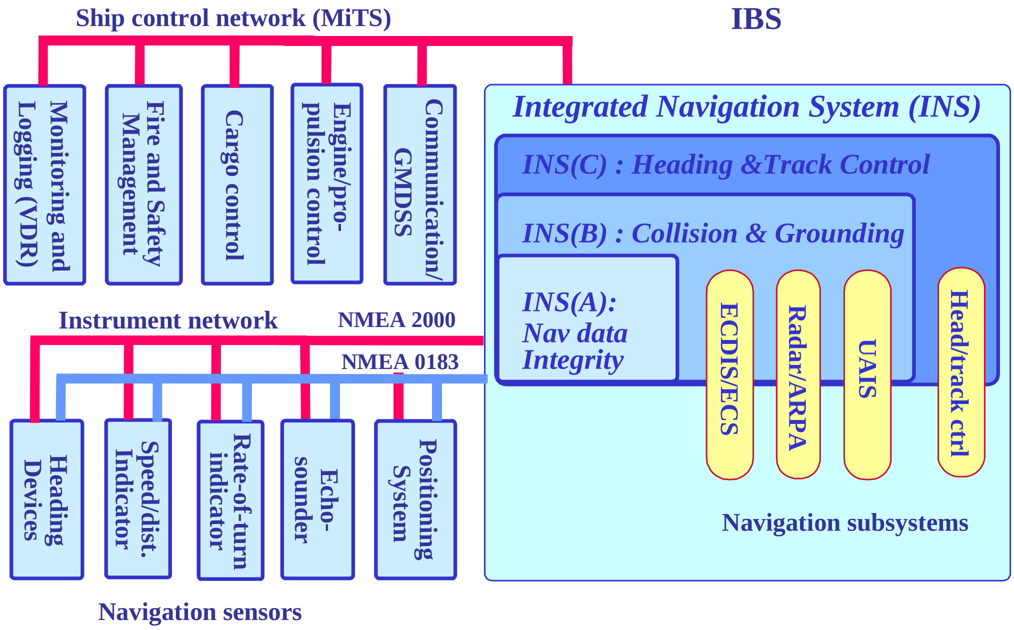
In terms of carriage requirements, fitting requirements and performance standards relate to Integrated Bridge Systems fitted to all classes of ships from 300 tonne upwards.

14.2 IBS Description

The current state-of-the-art in on-board navigation systems, fitted in the latest ships, involves the use of Integrated Bridge Systems (IBS) which take in data from various ship navigation sensors such as GPS, gyrocompass, radar, speed log, depth sounders etc. to enable the overlay of the ship's position, movement and route on a digital representation of a nautical chart on an electronic display. The aim of such systems is to increase the situation awareness and the automation of most of the time consuming duties associated with traditional bridge navigation activities. It also includes control and monitoring of ship equipment such as engines, power generation, etc.

The inventory for a standard integrated bridge system encompasses radars, electronic chart display, GMDSS and communications console, shipboard monitoring systems, navigation sensors, including echo sounder, GPS, DGPS, gyro compass, track and heading control system (autopilot), engine control systems as well as safety monitoring and annunciation systems.

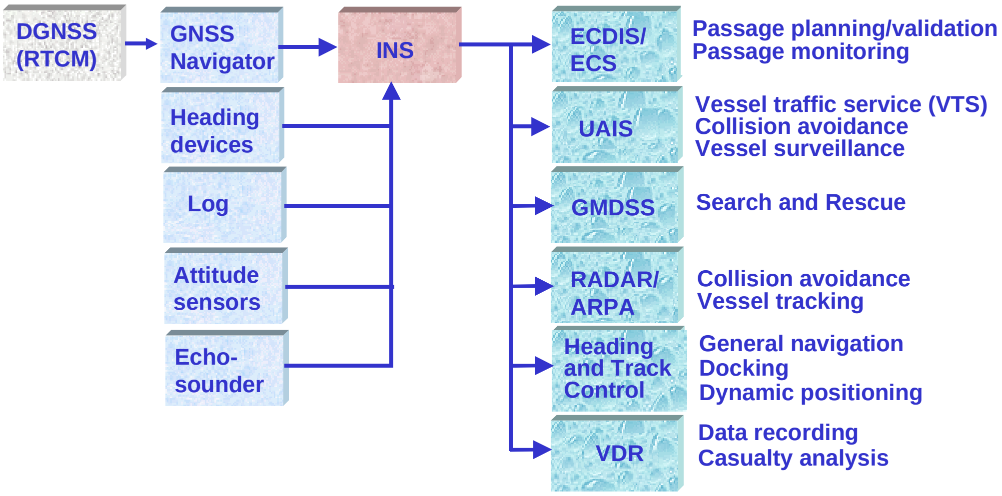
A typical overall system configuration of a state-of-the-art Integrated Bridge System - IBS is shown below:



(Source: MarNIS, Deliverable reference number: D2.4.E part 2, Enhanced Reliability and Safety for shipping using GALILEO, Page 47, Fig 0-1)

Integrated Navigation Systems are an integral part of an Integrated Bridge System. The purpose of the Integrated Navigation System (INS) is to provide 'added value' to the functions and information needed by the officer on watch to plan, monitor or control the progress of the ship.

The INS supports safety of navigation by evaluating inputs from several independent and different sensors, combining them to provide information giving timely warnings of potential dangers and degradation of integrity of this information. Integrity monitoring is an intrinsic function of the INS. This is depicted in the diagram below:



Source: MarNIS, Deliverable reference number: D2.4.E part 2, Enhanced Reliability and Safety for shipping using GALILEO, Page 49, Fig.0-3)

Quite a few of the onboard systems shown above have been introduced only during the last two decades and have had a significant importance in enhancing the navigational safety.

The functions of the watchkeeper on the bridge, can include:

- The safe conduct of navigation and collision avoidance, through the use of charts (both paper and electronic), a plethora of publications and relevant QMS manuals, compasses, echo sounders, speed logs, electronic positioning systems, radars, visual and aural senses, and ultimately AIS.
- Monitoring and operating a range of communications equipment, both external and internal, including GMDSS, VHF, Navtex, Inmarsat, cellular phones, weather fax, internal telephones, talkback systems, ships broadcast systems and VHF.
- The monitoring of cargo, fire fighting and engineering systems, and CCTV
- Knowledge of vessel operations, including manoeuvring characteristics, port operations, cargo operations, daily maintenance routines.
- Receiving, compiling and sending weather reports.
- The processing of paper checklists

Information Technology aboard ships has increased the level of information, thus increasing the task of managing the information. The information on the bridge of a ship can include information pertaining to navigation, collision avoidance, communication, cargo, engineering, ship management, vessel safety and security. It is also not uncommon for bridges to have in excess of 200 alarms

An important aspect of an Integrated Bridge System is the layout of the bridge itself. Although some form of performance standards exist, many bridge systems, engineering consoles and cargo systems vary greatly in their user interface (layout of controls, displays and symbology) and functionality beyond what is required as a minimum (added features requiring extra controls, menu options or customised symbology). The result of non-standardised controls and displays is an increase in the amount of training needed to make a seafarer familiar with and effective in the use of the equipment.

System integration brings with it the opportunity to maximise efficiency while providing significantly more information for the crew to enable them to carry out their duties. There is a need to standardize on the functionality and facilities provided so as to enable where possible a common approach to the operational procedures to be adopted. This also applies to formats of the various display presentations. To date, many of these aspects have been decided by the system providers and can be particular to a supplier's system. With the rapid developments in ICT, commonality has to be the key to future applications.

14.3 IBS Limitations

The rapid advancement in ICT and the complexity resulting from the increased number of equipments and their evolvement into an integrated system bring with it potential problems some of which are mentioned below:

1. System and equipment vulnerability, in the event of an equipment failure
2. the lack of 'graceful' degradation in the event of malfunction or failure of a subsystem or software
3. the industry is tending towards 'technology push' rather than 'market pull' such that very advanced technology and integrated systems are being put onto the bridge with the risk of over-saturating the untrained
4. the plethora of alarms and the potential for distracting the officer of the watch from his main purpose of conducting the safe navigation of the ship
5. the lack of standardisation in terms of switches and control keys;
6. An increase in the amount of training needed to make a seafarer familiar with and effective in the use of the different types of IBSs fitted to ships
7. issues of illumination levels from equipment during periods of darkness
8. The increased use of technology aboard vessels brings with it new demands for training, even if that technology has been designed to automate an existing task.

14.4 References

Relevant Documents

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2. IMO resolution MSC.116(73) Performance standards for marine transmitting Heading devices (THD).
3. MSC.86(70), annex 3 - Performance standard for Integrated navigational systems.
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5. IMO, SOLAS Chapter V Regulation 15, Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures
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7. GUIDELINES ON ERGONOMIC CRITERIA FOR BRIDGE EQUIPMENT AND LAYOUT, MSC/Circ.982, 20 December 2000
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10. Issues for training seafarers resulting from the implementation of onboard technology Submitted by IFSMA.to the IMO Subcommittee, STW 34/INF.6, 2 January 2003, SUB-COMMITTEE ON STANDARDS OF TRAINING AND WATCHKEEPING, 34th Session
11. Integrated Bridge and Navigation Systems (IBS/INS) - User Enhanced Designs - Official Report (© 2002 The Nautical Institute. From The Nautical Institute's IBS/INS conference held on 13-14 November 2002, London
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5. www.iec.ch – International Electrotechnical Commission
6. www.iso.ch – International Organisation for Standardisation
7. http://waterborne.balport.com – European Commission funded WATERBORNE Technology Platform
8. www.marnis.org - European Commission funded MarNIS project

15. Vessel Traffic Services (VTS)

15.1 VTSC Requirements

Vessel Traffic Services (VTS) are provided world-wide to improve navigational safety and efficiency, safety of life at sea and protection of the marine environment. The IMO define two types of VTS: Port and Coastal. There is a clear distinction between the two:

1. A Port (or river) VTS is a service provided when entering or leaving ports or harbours or when sailing along rivers or through waters which restrict the manoeuvring of ships.
2. A Coastal VTS is mainly concerned with vessel traffic passing through a sea area.

IMO Resolution A.857 (20), Nov, 1997, defines VTS as:
Shore-side systems which range from the provision of simple information messages to ships, such as position of other traffic or meteorological hazard warnings, to extensive management of traffic within a port or waterway.
Generally, ships entering a VTS area report to the authorities, usually by radio, and may be tracked by the VTS control centre.
Ships must keep watch on a specific frequency for navigational or other warnings, while they may be contacted directly by the VTS operator if there is risk of an

incident or, in areas where traffic flow is regulated, to be given advice on when to proceed.
SOLAS Chapter V (Safety of Navigation) states that governments may establish VTS when, in their opinion, the volume of traffic or the degree of risk justifies such services.

In practice, vessel traffic services are shore-side systems and for this reason are not covered by this report which deals with ship technology. VTS is briefly described here as VTS and its operators interface with the ship's navigation and communication systems and the bridge personnel.

15.2 VTS Description

15.2.1 System Overview

Vessel Traffic Services range from the provision of simple information messages to ships, such as position of other traffic or meteorological hazard warnings, to extensive management of traffic within a port or waterway. Generally, ships entering a VTS area report to the authorities, usually by radio, and may be tracked by the VTS control centre.
Ships must keep watch on a specific frequency for navigational or other warnings, while they may be contacted directly by the VTS operator if there is risk of an incident or, in areas where traffic flow is regulated, to be given advice on when to proceed.
The primary aim and function of Vessel Traffic Services, from the point of view of the ship's captain, is to assist, and possibly enhance the safe and timely passage of the ship through and within the VTS area of interest.

A vessel traffic management system is designed to provide complete surveillance coverage to a specified area of interest by the use of appropriate sensors. The primary sensor is the marine radar of which there may be several in a complex system; both X-band and S-band radars are used. This may be backed up by the use of electro-optics (daylight TV, lowlight TV), Infrared Cameras, millimetric wave devices etc as required.

In addition to the surveillance sensors, VTS will also include other shore based systems such as AIS, terrestrial and satellite communication systems, direction finding systems, etc.

Operations rooms may have several operator positions each having high resolution colour raster scan displays which can accept inputs from the available sensors. Facilities provided at operator positions will include similar but more comprehensive facilities to those provided on-ship such as radar/chart display presentations, ECDIS type presentations, target tracking facilities plus a host of other facilities particular to the shore based VTS operator tasks to enable the control and monitoring of vessels in their area.

15.2.2 VTS services

A vessel traffic management system is essentially a data gathering, handling and management system that collects, evaluates and disseminates selected data. The information is utilised to provide a range of services such as:
Information Service **-** to ensure that essential information concerning the area, the governing circumstances and the traffic situation is, in time, available to the shipboard navigational decision making process
Navigational Assistance Service **-** to contribute or participate in the navigational decision making process on board and to monitor the effects. The extent to which navigational assistance can, and may, be given from the shore depends to a large degree upon national legislation and the qualifications of the VTS operator.

Traffic organisation service - **t**o provide for the safe and efficient movement of traffic and to prevent the development of dangerous situations within the VTS area by the forward planning and monitoring of movements.
Co-operation with allied services and adjacent VTS **-** to integrate the effects of VTS and to coordinate the information flows for the collection, evaluation and dissemination of data.

15.3 References

Relevant Documents

1. IMO Resolution A.578(14), Guidelines for Vessel Traffic Services, 1985
2. IMO Resolution A.857 (20)), which offers guidance on design and operation of VTS systems
3. IMO Regulation 12, Vessel Traffic Services
4. The IALA VTS Manual (2nd edition, 1998) Vessel Traffic Services, IALA NAVGUIDE - Edition 5, 2006

Websites

1. www.imo.org – International Maritime Organisation
2. www.iala-aism.org – International Association of Lighthouse Authorities
3. www.mcga.org.uk – Maritime Coastguard Agency

16. Long Range Identification and Tracking System (LRIT)

16.1 LRIT Requirement

The initial purpose of long-range identification and tracking of ships is to enhance security for Contracting Governments, without undue impact to the security of ships, by providing ship identity and current location information in sufficient time for a Contracting Government to evaluate the security risk posed by a ship off its coast and to respond, if necessary, to reduce the risk. The Long-Range Identification and Tracking (LRIT) system provides for the global identification and tracking of ships.

An active and accurate long-range identification and tracking system also has potential safety benefits, most notably for maritime search and rescue. Accurate information on the location of the ship in distress as well as ships in the vicinity that could lend assistance will save valuable response time to affect a timely rescue as well as marine environment protection purposes

The MSC has made a number of decisions to ensure the timely implementation of the LRIT system. SOLAS regulation V/19-1 on LRIT entered into force on 1 January 2008 and will apply to ships constructed on or after 31 December 2008 with a phased implementation schedule for ships constructed before 31 December 2008. The LRIT system is intended to be operational with respect to the transmission of LRIT information by ships from 30 December 2008.

The SOLAS regulation on LRIT establishes a multilateral agreement for sharing LRIT information for security and search and rescue purposes, amongst SOLAS Contracting Governments, in order to meet the maritime security needs and other concerns of such Governments.

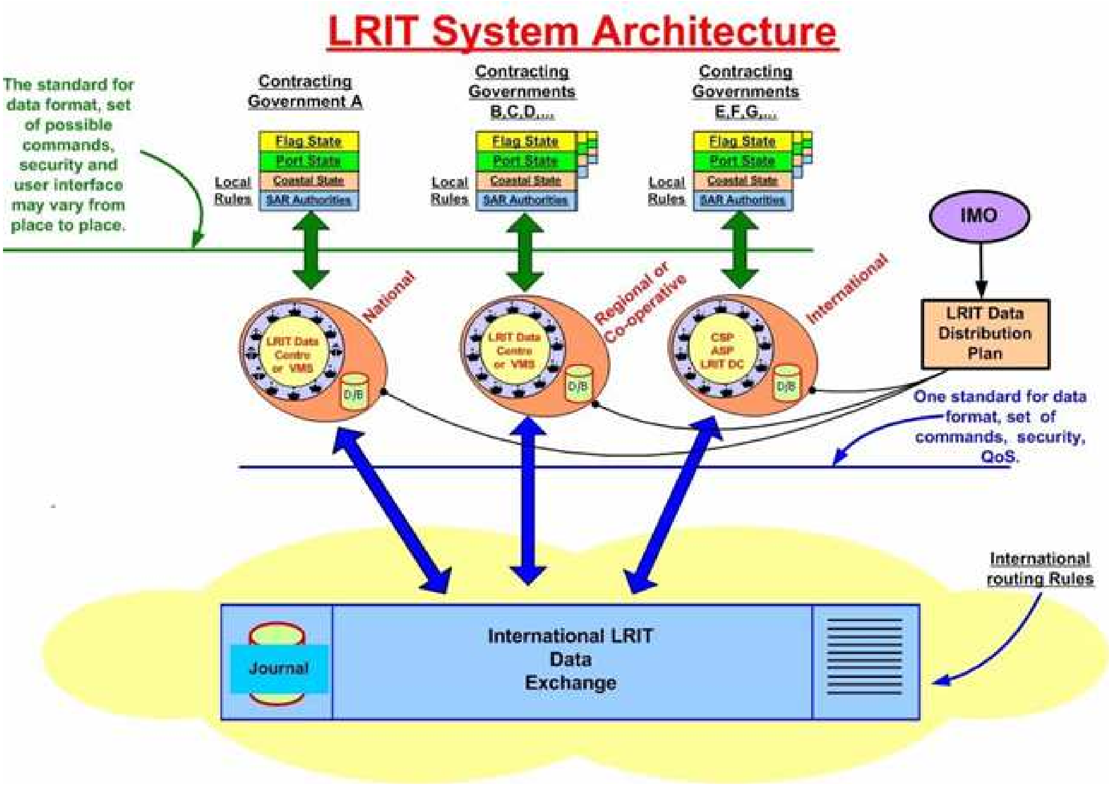
The LRIT information that ships will be required to transmit include the ship's identity, location and date and time of the position. There will be no interface between LRIT and AIS. Data derived through LRIT will be available only to the recipients who are entitled to receive such information and safeguards concerning the confidentiality of those data have been built into the regulatory provisions. SOLAS Contracting Governments will be entitled to receive information about ships navigating within a distance not exceeding 1000 nautical miles off their coast.

16.2 LRIT Description

16.2.1 LRIT System Architecture

The primary function of LRIT is to provide a facility to enable flag states, coastal states, port states and search/rescue services of contracting governments to receive ship information for security and safety purposes from the LRIT operational organisation. For this purpose, the vessels will need to cooperate and provide specific ship information when interrogated by the LRIT operating service provider. The intention is to set up European and International LRIT ship databases in order to monitor the progress of LRIT compatible ships.

The following paragraphs are included to provide a brief description of the overall LRIT system architecture envisaged by the IMO to enable the reader to put ship-board technology and its usage into context. Relevant references provide sources of further information on the overall system and its operation. A block diagram illustrating the international and national nature of the envisaged architecture is shown below:



(Source: www.imo.org)

LRIT information is provided to Contracting Governments and Search and Rescue Services entitled to receive the information, upon request, through a system of National, Regional, Co-operative and International LRIT Data Centres, using where necessary, the LRIT International Data Exchange.

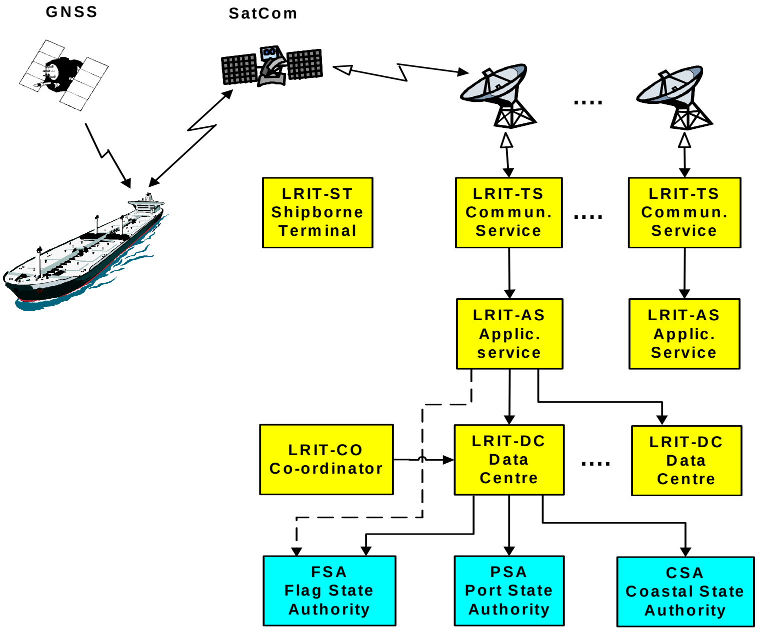
Each Administration should provide to the LRIT Data Centre it has selected, a list of the ships entitled to fly its flag, which are required to transmit LRIT information, together with other salient details and should update, without undue delay, such lists as and when changes occur.

Ships should only transmit the LRIT information to the LRIT Data Centre selected by their Administration. The obligations of ships to transmit LRIT information and the rights and obligations of Contracting Governments and of Search and Rescue Services to receive LRIT information are established in regulation V/19-1 of the 1974 SOLAS Convention.

The present situation regarding the setting up of the LRIT facilities is that the European Maritime Safety Agency (EMSA), the coordinating agency plans to outsource the Application Service Provider (ASP) / Communication Service Provider (CSP) functionality, the development of the EU LRIT Data Centre and also the invoicing and billing system through public tender procedures. It will therefore be some time before an international LRIT facility is operational.

16.2.2 Ship Equipment and Interfaces

As can be seen from the system diagram below, the envisaged information flow through the LRIT system is via the ship-borne LRIT information transmitting equipment, the Communication Service Provider(s), the Application Service Provider(s), the LRIT Data Centre(s), and the International LRIT Authority.



(Source: MarNIS, Deliverable reference number: D2.1.B, WP2.1 Integration of AIS functionalities – Technical Progress Report first year, Page12, Fig.1)

The LRIT service will use existing infrastructures in terms of satellite communication and global positioning systems but will require dedicated LRIT terminals both on-ship and at shore facilities at the Application Service Provider’s Operations Centres.

The ship-borne equipment should comply with the following minimum requirements:

- be capable of automatically and without human intervention on board the ship transmitting the ship's LRIT information at 6-hour intervals to an LRIT Data Centre
- be capable of being configured remotely to transmit LRIT information at variable intervals
- be capable of transmitting LRIT information following receipt of polling commands
- interface directly to the ship-borne global navigation satellite system equipment, or have internal positioning capability;
- be supplied with energy from the main and emergency source of electrical power.

16.3 LRIT Limitations

The following aspects should be taken into consideration in terms of the operational capability of LRIT and the ship-borne equipment:

1. The overall international system will not be fully operational for some years although the EU LRIT system may be operational sooner – the IMO resolution states that a system should be available by December 2008
2. LRIT is a cooperative system and requires that ships will have the appropriate ship-borne terminals and utilise appropriate GNSS and Satellite Communication Systems
3. LRIT requires that shipboard equipment will be switched on and operating when required
4. The usefulness of LRIT information is only as good as the information input into the ship-borne LRIT terminal.

16.4 References

Relevant Documents

1. Resolution MSC.263(84), Revised performance Standards and functional requirements for the LRIT of ships (revoking MSC.210(81), MSC.254(83)), 16/05/2008
2. Resolution MSC.242(83), Use of LRIT for Maritime Safety and Environment protection purposes, 12/10/2007
3. Resolution MSC.254(83), Adoption of amendments to Resolution MSC.210(81), 12/10/2007
4. 2821st EU Council meeting, EU Council Resolution dated 2 October 2007, 02/10/2007
5. Resolution MSC.202(81), Adoption of amendments to the international convention for safety of life at sea, 1974, as amended, 19/05/2006

6. Resolution MSC.210(81), Performance standards and functional requirements for the long-range identification and tracking of ships, 19/05/2006
7. Resolution MSC.211(81), Arrangements for the timely establishment of the long-range identification and tracking system, 19/05/2006
8. Resolution A.887(21), Establishment, updating and retrieval of the information contained in the registration databases for the global maritime distress and safety system (GMDSS), 25/11/1999
9. Regulation V/19-1 of the 1974 SOLAS Convention
10. MARNIS, Deliverable Ref. No. D2.1.B, WP 2.1 Integration of AIS functionalities – Technical Progress Report first year

Websites

1. www.mcga.gov.uk –The UK Maritime Coastguard Agency
2. http://emsa.europa.eu – European Maritime Safety Agency
3. www.imo.org – International Maritime Organisation
4. www.marnis.org – European Commission Funded MarNIS Project

17 Portable Pilot Unit (PPU)

17.1 Requirements

When pilots guide ships into busy tide-bound ports, or dock alongside quay walls, extremely precise navigation is essential. Minimizing under-keel clearance enables ships to enter and exit port earlier than normal. Accurate navigation is also vital in avoiding costly damage to own ship/other ships and to port infrastructure. Absolute precision is required in terms of horizontal and vertical positioning, bow and stern speed, heading, and rate of turn. It is essential that pilots are provided with the necessary facilities to enable them to perform these accurate navigation tasks and port maneuvers.

17.2 Portable Pilot Unit (PPU)

Pilots make a significant contribution to the safety of navigation in the confined waters and port approaches of which they have up to date knowledge and are increasingly using their own portable equipment, with which they are fully conversant, and familiar, to assist them in their tasks. A Portable Pilot Unit (PPU) can be described as a portable, computer-based system that a pilot brings onboard a vessel to use as a decision-support tool for navigating in confined waters. A PPU helps the pilot to safely navigate into and out of harbours and other areas where obstacles could impede the progress of the vessel. A PPU provides the pilot with accurate, real-time, reliable navigational information to make critical decisions and to provide early detection of variations from the planned route and to take corrective action quickly.

The latest PPUs are ruggedized lightweight notebook computers with screen sizes of between 10” to 15” with 12” screens being the most popular. Most run Windows XP, have typically 1 Gbyte of RAM with the capability of interfacing with a variety of shipboard navigational equipment. PPUs utilize electronic charts; the International Maritime Organisation (IMO) recommends the use of S-57 standard charts.

Interfaced to a positioning sensor such as GPS/DGPS and using an electronic chart display, a PPU is capable of showing the vessel’s position/movement in real-time. In addition, PPUs provide information about the location/movement of other vessels via an AIS interface. Increasingly, PPUs are being used to display other types of navigation-related information such as soundings/depth contours from recent hydro surveys, dynamic water levels, current flow etc.

Most PPUs can interface with the ship’s equipment, for example:

- GNSS - GPS/DGPS/RTK which can usually be accessed via the AIS Plug although some PPUs have their own DGPS units and choose whether to deploy it or use the ship’s information
- Heading and rate of turn– can be obtained via the ship’s Pilot Plug
- AIS - accessed via the Pilot Plug.

PPU set-up time is usually 2-3 minutes but may take a little longer if own DGPS has to be deployed.

The European Commission has funded a research project, Innovative Portable Pilot Aid (IPPA) to develop and validate an advanced prototype pilot equipment capable of receiving data from a wide range of sources, including other vessel's and shorebased AIS, River Information Services (RIS) centre, Vessel Traffic Service (VTS) centre, and other relevant authorities. Using the track, environmental and other data, together with its stored data, it should be able to display a comprehensive traffic image. With a variety of communications interfaces, the equipment will also be capable of transmitting back to a VTS centre data required for traffic and port management.

A PPU is expected be used in nearly all pilot assisted operations within a few years

17.3 Portable Operational Approach and Docking Support System (POADS)

The European Commission funded MarNIS project has carried out research-into and the development-of a Portable Operational Approach and Docking Support System (POADS), which is an enhancement of the PPU concept. POADS will act as a pilots tool for advanced decision support in the tactical sense on board the vessels and in the strategic sense in VTS Centres. The main functions of POADS are:

- To improve the safety and efficiency in ports and approaches;
- To improve fairway usability for vessels with maximum dimensions for the fairway;
- Exchange of information with the VTS and others port actors;
- Preparation of the Dynamic passage planning;
- Execution of the Dynamic passage planning.

On a strategic level POADS should enable information exchange between operational users (vessels - masters/maritime pilots) and Vessel Traffic Support Centres, Meteorological and Hydrographical Offices, Locks, Bridges, Terminals and other sources in the approaches, rivers, canals, docks and basins to and within European ports with respect to the safe and most efficient use of these fairways.

The POADS system is envisaged to consist of two subsystems, an onboard subsystem on a vessel and a shore based subsystem which will typically be based in a VTS centre. The on board system will consist essentially of User Interface and an Instrumented Unit.

The User Interface, which will be a PC Notebook, will provide a:

- Graphical Interface for the display of data obtained direct or indirect via the Instrument Unit, in an ECDIS/ENC environment;
- Keyboard to edit all commands;

- Interface to the vessels AIS unit;
- Serial link interface for onboard radar system.

The Instrumented Unit will house the interfacing, processing and communications equipment and will include three DGPS antennas and an inertial navigation unit for measuring the vessels position, heading, course over ground (COG), speed over ground (SOG), pitch, roll and other dynamic parameters.

The POADS Ashore System will consist of:

- Dedicated Workstation or Server as Communication Front end to the onboard system. The server will be equipped with two network interfaces, the VTS data (direct and indirect) and the Long Range WLAN Access Points;
- Long Range WLAN Access Points with omni-directional antennas;
- RTK/DGPS double frequency Reference Station(s).

Further information on the requirements, functionality, detailed specification and status of POADS can be obtained from the MarNIS deliverable report on the subject, referenced below.

17.4 References

Relevant Documents

MarNIS, Deliverable reference number: D4.2.D, Interim technical research report, 15-11-06

Website

www.marnis.org

18. e-Navigation

18. 1 Overview

e-Navigation is an International Maritime Organisation (IMO) led concept based on the harmonisation of marine navigation systems and supporting shore services driven by user needs. e-Navigation is a concept which encompasses human factors, standards, procedures etc and is more than a system comprising of integrated subsystems and equipments.

e-Navigation, as defined by the IMO (and IALA and other organisations) is as follows: 'e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and to protect the marine environment.'

The core objectives of an integrated e-Navigation have been identified by IALA as "Using electronic data capture, communication, processing and presentation, to:

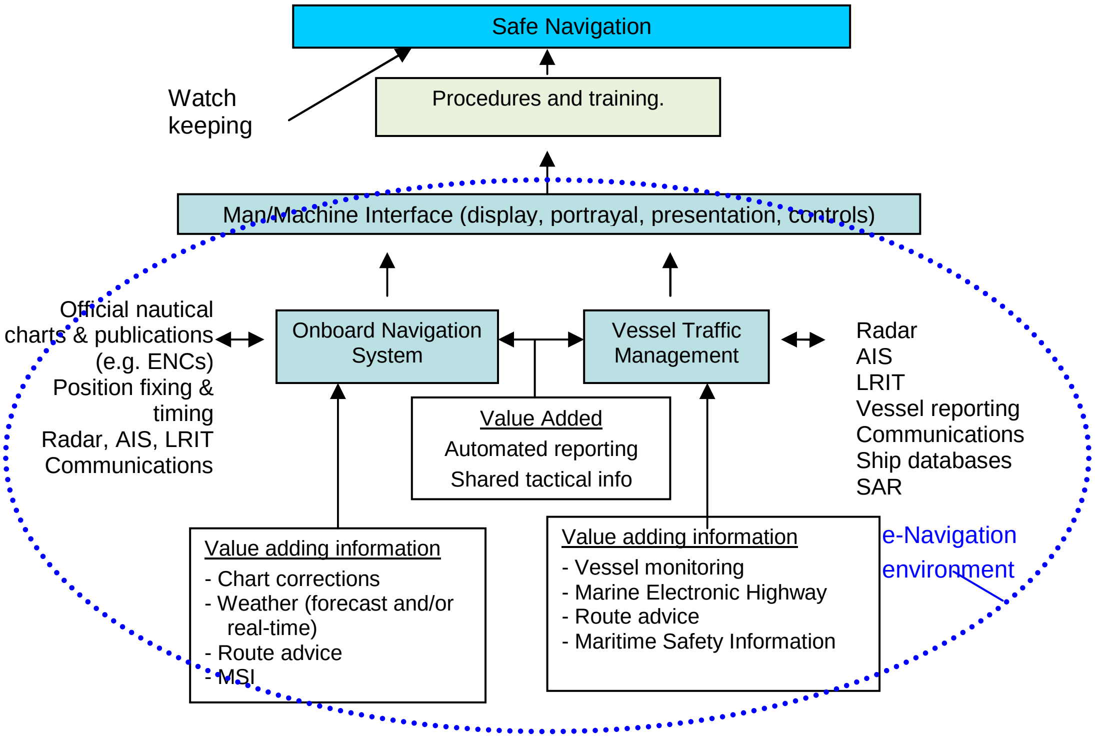
1. facilitate safe and secure navigation of vessels having regard to hydrographic and navigational information and risks (e.g. coastline, seabed topography, fixed and floating structures, meteorological conditions and vessel movements)
2. facilitate vessel traffic observation and management from shore/coastal facilities where appropriate, for example in harbours and approaches
3. facilitate ship-to-ship, ship-to-shore, shore-to-ship and shore-to-shore communications, including data exchange, as needed, to achieve the above points
4. provide opportunities for improving the efficiency of transport and logistics
5. facilitate the effective operation of distress assistance, search and rescue services and the storage and later use of data for the purposes of traffic and risk analysis and accident investigation
6. integrate and present information onboard and ashore in a format, which, when supported by appropriate training for users, maximizes navigational safety benefits and minimizes risks of confusion or misinterpretation; and
7. facilitate global coverage, consistent standards and mutual compatibility and interoperability of equipment, fitment, systems, operational procedures and symbology, so as to avoid potential conflicts between vessels or between vessels and navigation/traffic management agencies

Many of the electronic building blocks of navigational technologies are already available, are being developed, or are capable of development, which can be integrated to provide an accurate, secure and highly cost-effective e-Navigation system, with potentially global coverage. The same technologies should be scalable for use by larger and smaller vessels. In addition to reducing navigational errors, these technologies can deliver benefits in areas such as search and rescue, pollution incident response, national and international security and the protection of critical marine resources such as fishing grounds.

The future of e-Navigation will rely heavily on the integration of latest state-of-the-art navigation systems and the incorporation of global navigational satellite systems for communication, positioning information and surveillance – specifically, GALILEO. The European commercial satellite system scheduled for operation and service in 2008. This GNSS is intended specifically for civil and commercial purposes and will provide increased accuracy, service guarantees, and increased availability of signals in demanding environments over the current US operated GPS service. However, the introduction of new technologies and associated operational procedures will result in the need for adequate training; this will be an important aspect in developing the e-Navigation concept.

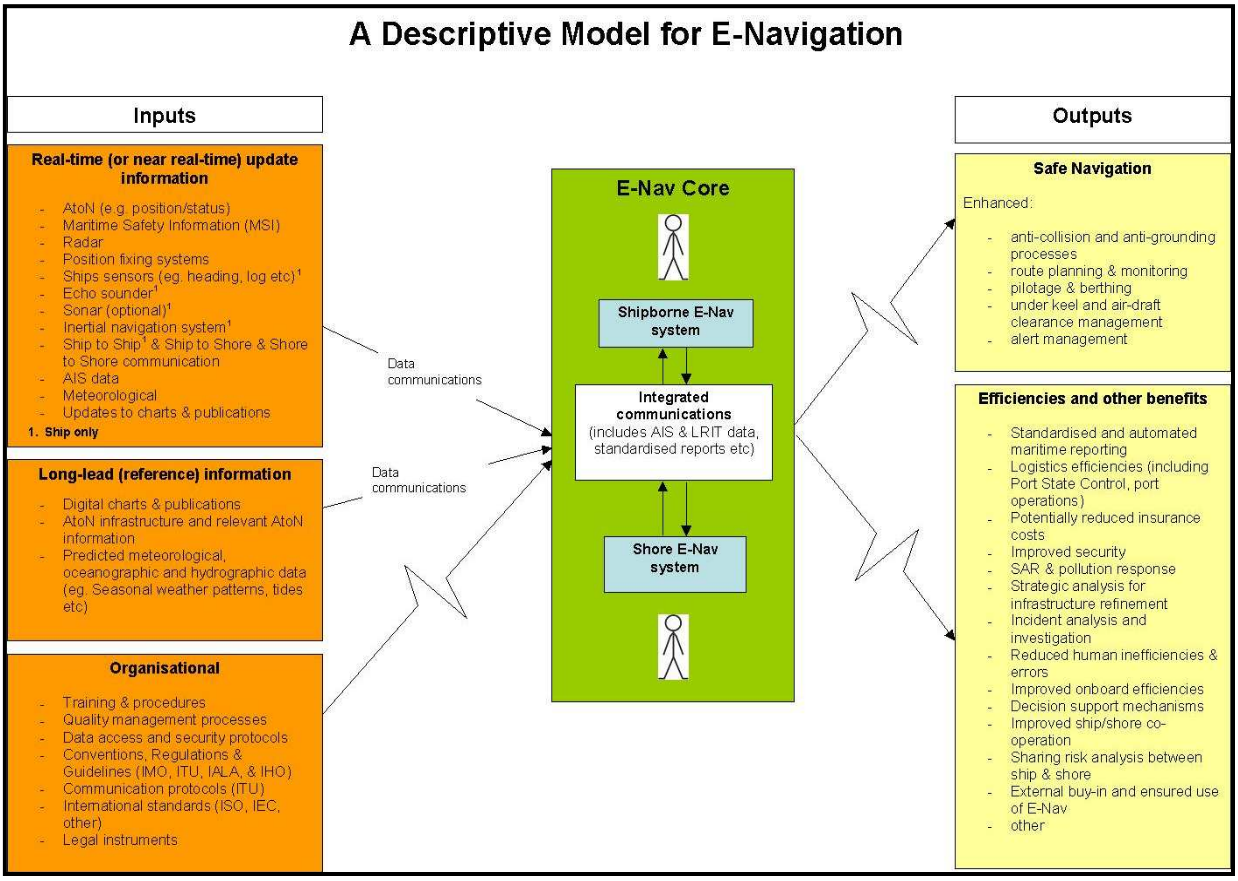
18.2 Description of e-Navigation

e-Navigation is a concept that encompasses far more than a system comprising of integrated subsystems and equipment. A diagrammatic representation of what the e-Navigation concept is considered to encompass is shown below.



(Source: IALA Vision of e-Navigation, Nordic Institute of navigation, E-Navigation, Oct 16th 2007, Oslo)

A descriptive view of the concept of e-Navigation which defines the inputs and outputs of an e-navigation system is shown below:



(Source: IALA Vision of e-Navigation, Nordic Institute of navigation, E-Navigation, Oct 16th 2007, Oslo)

18.3 Integration AIS/ECDIS/GALILEO/RADAR/VDR for e-Navigation

18.3.1 Overview

The rapid increase in the number of vessels travelling through European waters and ports results in congestion in shipping lanes and more particularly in European ports. There is therefore a need for further improvements in the control and safety of shipping particularly when approaching and manoeuvring and docking in congested harbours. To ensure satisfactory control of shipping there is need for new technologies, systems, processes and operational procedures both ashore and onboard vessels. On-board, future navigation systems will be required to provide ships crews with the ability to control their vessels under these demanding conditions with a greater degree of accuracy than possible at present and under all weather conditions.

This Section addresses the on-board integration of the latest equipments and systems described in previous Sections of the Report and how this can provide an enhanced shipboard navigation system. Many of the latest versions of AIS, Radar/ARPA, ECDIS equipments have been designed to include IMO approved digital interfaces and signal formats to enable them to be interfaced and work together. For example, as described in Section 10, the latest AIS equipments will accept inputs from various ships reference sensors and will provide outputs to radar/ARPA and ECDIS equipments for data fusion/display purposes and to the ship's VDR for recording purposes provided that the formats are compatible with IMO requirements.

A study on the integration of Radar, AIS, ECDIS, GALILEO and VDR and the possibility for fusion of these information sources has been performed as part of the MarNIS (Marine Navigation and Information Systems) project funded as part of the EC's Framework VI programme.. Within the study, operational as well as technical aspects of overlapping information were taken into account. The human factor related operational aspects were especially addressed by an empirical study on the mariners view on the integration. The technical aspects were investigated in detail within the frame of a demanding and exhausting experimental field study on the reliability of and the deviations between AIS and ARPA data. The relevant project reports are included in the list of relevant documents. A short summary of the findings and the conclusions reached is included in this Section.

18.3.2 Integrated Bridge Improvements

As explained in Section 4.1, the standard bridge set of equipment, in the past, has consisted of several discrete equipments, often provided by different manufacturers (e.g. radar, communications, engine control equipment) to provide the basic functions to enable ship control and navigation to be conducted. The current state-of-the-art in on-board navigation systems, fitted in the latest ships, involves the use of Integrated Bridge Systems (IBS) which take in data from various ship navigation sensors such as GPS, gyrocompass, radar, speed log, depth sounders etc. to enable the overlay of the ship's position, movement and route on a digital representation of a nautical chart on an electronic display. The aim of such systems is to increase the situation awareness and the automation of most of the time consuming duties associated with traditional bridge navigation activities. Performance standards for integrated bridge systems were adopted by IMO in 1996.

However, the information from different navigation equipments is still often presented on separate displays and the operator has to divide his attention between these presentations. For example the bridge may include both radar and ECDIS displays; sometimes the displays may be multifunction to enable the operator to carry out his tasks at any display position. Crew members are still faced with an overload of information and have simultaneously to carry out other duties.

The MarNIS project concluded that integration of equipment leads to a high complexity of functions and functionalities. The number of warnings, alerts and alarms triggered increases rapidly with the number of integrated subsystems. The more complex a navigation system is the better should be the skills and knowledge of the OOW (Officer of Watch) on the bridge of a ship. MarNIS recommended, that the EU should support the activities started by the IMO to establish new standards for Integrated Navigation and Integrated Bridge Systems respectively. Efforts should be undertaken to improve the alarm management and alarm handling on board sea-going vessels, because the present situation is not satisfactory according to the preliminary results of the investigations performed under MarNIS.

The MarNIS project concluded that for the integration of the techniques into one system there is a need for improvements regarding simplification, management and generally effective and sustainable human machine interfaces. From a field study it was identified that navigators stressed the importance of increased focus on human/machine interaction when designing navigational aids and developing rules.

The key principles recommended in order to get better solutions to the existing problems are to have a human factors approach to the design of the interface. It is important that:

- The different information is handled comprehensively in an integrated view
- The presented information is minimal and sparse
- Essential information should be easy accessible
- System behaviour is visible to the operator
- Other sensory alternatives like audio conceptions, should be considered in addition to graphics and text

18.3.3 Integation of AIS, Radar/ARPA and ECDIS

The MarNIS recommendations and conclusions regarding how AIS and Radar data is used on ECDIS and Radar displays are reproduced below (detailed discussion and results of studies are included in the relevant dolcumentation):

- Concerning the integration of AIS the studies performed under MarNIS WP 2.4 proved again the findings of former studies, that MKD (Minimum Keyboard Display) is only a very poor measure. It is only installed to fulfil required mandatory carriage requirement but is of less use to navigators. If at all, then it is only a temporary solution. The Commission should undertake measures to improve the present standards so that MKD installations may substitute as soon as possible.

- The radar is the most important instrument on the bridge and seems at present as one main subject for integration of information. The commission should promote activities that ensure the integration of navigation systems that is added to radar to compensate shortcomings of this navigation sensor but not to substitute it. Integration of information from AIS, GNSS and ECDIS should be integrated as far as useful to mariners. Standards for integration should be based on results of proved scientific studies taking also into account human factor related subjects.
- It is strongly recommended that AIS targets should be displayed on the radar or the ECDIS together with radar targets
- Recommendations or operational guidelines for the fusion of symbols of AIS and Radar/ARPA data of one target are missing. Implemented solutions are not harmonised and differ with the manufactures.
- Investigations performed have shown that there are obviously a great number of unreliable AIS installations, which leads to transmission of unreliable or even false target information. It was studied that update rates are not according to the defined standards. It is recommended to take policy measures to enhance the certification and control procedures of the specific navigational equipment.
- Integration of AIS into the navigation process also needs guidance to mariners how to suitably apply AIS to the COLREGS. To avoid misuse and ensure effective and most beneficial use for maritime safety, it is recommended that corresponding guidance should be provided on a harmonised policy level.
- Appropriate integration of AIS targets, bearings, headings, speeds etc. will increase the value for navigation and safety purposes
- Sparse ECDIS chart information is recommended to be presented in the radar and sparse radar information may be presented in the ECDIS to keep some attention of both systems simultaneously.
- Although ECDIS provides a lot of information and is a major tool due its potential for integration, ECDIS is not the ultimate solution for all problems of integration and presentation of information, further development of the HMI to the different tasks and needs of OOW is needed.

- Simulator tests using a combined ARPA/AIS display were carried out in the MarNIS project. The conclusion from this test is that there is a considerable improvement in the time to detect manoeuvres of other ships when using AIS compared to radar/ARPA. There was also a considerable difference in misinterpretation of manoeuvre detection.

- AIS update rates (e.g. at 3 second intervals) need to be optimised if the info is to be presented together with the associated radar targets especially on short range displays where the AIS target will not keep up with the radar target.

18.3.4 Benefits by combined use of AIS and VDR

The VDR, which records all the important navigation and ship performance related data in real time (see Section 11), is a relatively new equipment fitted onboard vessels. This real time data is stored in the VDR for the purposes of assessment should an incident such as a collision or grounding occur. The fact that all this real time data is gathered and stored in the VDR presents the opportunity of using it for other purposes such as:

1. Crew Training
2. Enhancement of navigation functionality onboard.

However, at present, the information in the VDR is not available to any other real time processors or used for any other real time processes. This data is potentially valuable in terms of enhancing navigation but will require suitable processing and algorithms to maximise the use of the information. The following sections discuss the possibility of using VDR information in e-Navigation systems.

Crew Training:

The facilities provided on naval defence vessels quite often include onboard inbuilt training facilities as standard. Such facilities include a data logging equipment which is used to log essential sensor and situation assessment data during naval exercises which can then be played back onto the displays in the operations room for training purposes for crew training in periods of low activity. The VDR, if provided with a playback facility could similarly provide a navigational training facility.

Enhancement of navigational functionality:

The main sensor for use in navigation is the navigation radar which provides target information to the ARPA; the latter can be used to track a number of targets (as described in Section 6.2). Guard zones can be set-up around own ship such that warnings are given when targets enter these zones. The ARPA is also capable of calculating the closest point of approach, and the time to reach the closest point of approach to selected targets. This calculation takes into consideration the direction/speed of own ship and of the target.

The accuracy of this calculation can be improved if the manoeuvring performance of own ship and the target can be taken into account – a knowledge of these will improve the accuracies of the CPA/TCPA calculations. The availability of AIS information (including a target's course intentions) together with a knowledge of the manoeuvring performance of own ship taking into account factors such as engine condition and performance will enhance the CPA calculations. The VDR historical data related to vessel movement can be used to derive a vessel's manoeuvring characteristics and performance.

The VDR also stores information related to the ship's state of health derived from the ship's control and condition monitoring systems; this data can be used to optimise and rationalise the alarm system provided on the Bridge for the Officer of the Watch (OOW). Research has shown that there is an overload in terms of the number of alarms on Integrated Bridge Systems. The VDR data provides a means of rationalising and reducing the workload in this respect.

The AIS information can enhance the target information provided by the radar/ARPA and help to build up a more accurate picture. This together with the VDR information can enable ships to manoeuvre closer to other vessels while still maintaining a low risk of collision. Such a capability will be very useful in congested waterways and shipping lanes. However, the reliability and integrity of data is essential for this to be achieved.

The MarNIS project suggests that where the additional AIS and VDR information is available that there is the potential to have additional levels of alarms related to the CPA/TCPA calculations to take account of the increased accuracy and allow ship's to pass closer than at present.

The MarNIS project has studied the impact of combining AIS data and VDR data. and the main conclusions can be summarised as:

1. VDR voyage data can be used for improving methods presently in use and implemented in navigation equipment.
2. Although AIS provides a lot of additional and supporting information, collisions still happen, further research work, investigations are needed in the fields Human Factor, in technical but also operational aspects.
3. Scenario studies show, that there are faulty as well as missing parts of dynamic AIS information such as Heading and ROT of a targets
4. Beside the technical shortcomings, until now, there has been no clear harmonised procedure on how to handle transmissions of faulty AIS data
5. There is still a need for the development of technical solutions to support the update of AIS data to be inserted in the system manually.
6. Recorded motion data, available in VDR systems on board, are presently not used for on-line processes. There is a great potential for valuable online support of decision making of OOW on basis of such data especially in combination with additional AIS target information for collision avoidance.

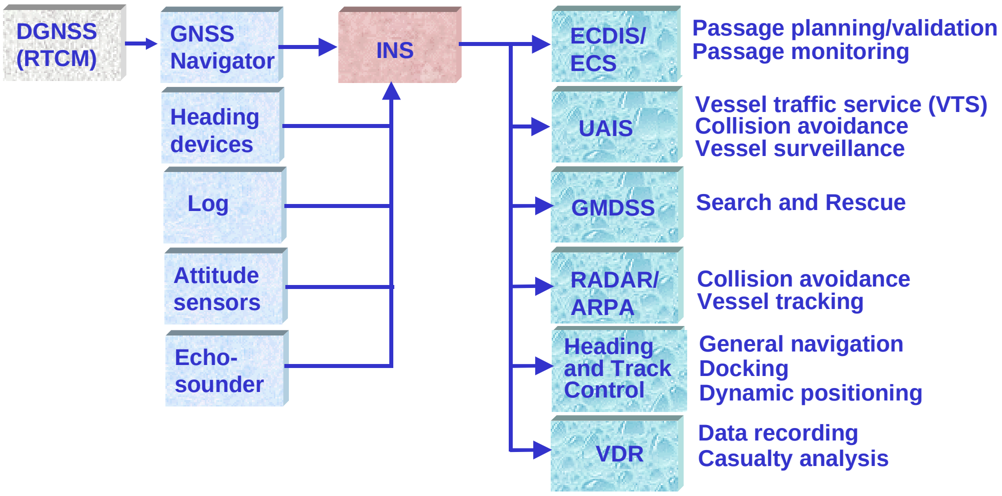
7. New potential for harmonisation of thresholds and limit values for alarming is indicated by the new technologies come into operation for navigation of a ship.
8. Due to quick developments and changes in standardisation and regulation processes, the recordings of VDRs and S-VDRs respectively are only with respect to the situation of information available on board during the course of accidents. The most impressive item is, that AIS information is not yet subject to the IMO Performance Standards of the recording equipment, but should as soon as possible added, so that an obligation is stated for recording of AIS information.
9. The format of data streams recorded by VDRs is not harmonised. There are differences between the VDRs of different manufacturers. This leads to additional efforts for bodies and institutions responsible for investigation of accidents.
10. One of the most important issues before introducing such new innovative solutions is to ensure a sufficient reliability of the data and information provided by AIS and VDR as well.

The MarNIS project concluded that ‘Combination of AIS and VDR information is possible on a new basis. Combination and pre-processing of information allows for the development of enhanced safety related warnings. In the field of collision and grounding avoidance it is now possible to provide also more COLREG-related warnings. The potential integrated use of own ship information basing on VDR recordings also allow for enhanced information to support decision making for manoeuvres to avoid dangerous situations’.

18.4 Integration of GALILEO into On-board Navigation Systems

There is an increasing reliance on GNSS for maritime navigation and the future on-board component of e-Navigation systems involving integrated bridge/integrated navigation subsystems. These systems can utilise the increased accuracy and improved availability of GNSS information than has been acceptable to date.

The extent to which on-board e-Navigation functionality relies on GNSS data is best illustrated by the following diagram:



Source: MarNIS, Deliverable reference number: D2.4.E part 2, Enhanced Reliability and Safety for shipping using GALILEO, Page 49, Fig.0-3)

GALILEO will play an important role in many of the processes of future on-board navigation; the main functions, such as general navigation, collision avoidance, docking, search and rescue are depicted in the above diagram. GALILEO will provide an independent means for ship positioning with availability guaranteed by a civil authority and will offer superior and constant high accuracy and a global high integrity level compared to the existing GPS.

The maritime requirements for GALILEO have been laid down by the IMO and take account the most critical needs in maritime navigation such as when vessels are approaching harbours, manoeuvring within harbours and docking. It also specifies the requirements for search and rescue and the GMDSS service. Two resolutions form the backbone of IMO’s requirements for future Maritime Radionavigation Systems:

- A.953(23) which gives the present-day formal requirements and procedures for accepting new systems as ‘components of the World-Wide Radionavigation System (WWRNS)’
- A.915 (22) which is a ‘positioning’ document related to requirements for future developments of GNSS to be considered within the framework of A.953(23).

GALILEO performances are expected to be compliant with far more restrictive requirements than GPS performances; this is not only due to its enhanced accuracy, but also to the GALILEO capability to provide integrity information on a global basis. The MarNIS project has carried out a detailed study into the use of GALILEO in the maritime sector including a comparison against the two IMO requirements and also in comparison with the existing GPS and EGNOS facilities. The main conclusions are summarised in the following paragraphs; for details of the reasoning behind the conclusions, the reader is referred to the relevant MarNIS document.

With respect to the present, IMO Res. A.953 (23) operational requirements the preliminary conclusion is that:

1. The single frequency Open Service meets the IMO operational requirements for navigation in Ocean areas
2. The dual frequency Open Service will meet the IMO operational requirements for navigation in harbour entrances, harbour approaches and coastal waters with low traffic and/or risk.
3. None of the combinations of constellations and signals are able to meet the IMO requirements for navigation in harbour entrances, harbour approaches and coastal waters with high traffic and/or risk in terms of continuity of service over the required period (3 hours).

With respect to the future requirements as stated in the Res. A.915 (22) the preliminary conclusion is that:

1. Neither the GALILEO single frequency Open Service nor the combined GALILEO/GPS constellation using L1 will meet the IMO future requirements for satellite navigation.
2. The GALILEO dual frequency Safety of Life Service will meet the IMO future requirements for navigation in ocean and coastal waters.
3. None of the combinations of GALILEO and GPS constellations and signals are able to meet the IMO future requirements for navigation in port approaches, ports and inland waterways
4. Port navigation will require local augmentation

There is a need for further discussions regarding the requirements in terms of the integrity and continuity of service required, particularly in relation to the IMO's future navigation requirements in harbour approaches, harbour entrances and similar confined spaces where vessels are required to manoeuvre.

Discussions between the IMO, associated maritime organisations and the various stakeholders with the aim to provide a consistent and rational set of integrity and continuity requirements for maritime applications should be encouraged.

It should be noted that GALILEO is a new GNSS and is not yet fully operational. It will be the only civil system of its kind providing high accuracy and integrity on a global basis for present and future applications. This accuracy and integrity can be further enhanced by the use of localised augmentation. GALILEO is intended as the maritime GNSS for the future

18.5 References

Relevant Documents

1. Marine eNavigation – paper by Brian Wadsworth, Director, Logistics and Maritime Transport, Department of Transport, UK, July 2005
2. MSC.64(67) Annex 1: Performance Standards for Navigational Equipment (Integrated Bridge Systems) for equipment fitted after 01/01/1999
3. Presentation to the IALA 2. Marine eNavigation – paper by Brian Wadsworth, Director, Logistics and Maritime Transport, Department of Transport, UK, July 2005
4. GALILEO, The European Programme for Global Navigation Services, BR 185 (2nd Edition, English) June 2005, ISBN 92-9092-738-0, Published by ESA Publications Division, Netherlands
5. MSC/Circ.1091 - ISSUES TO BE CONSIDERED WHEN INTRODUCING NEW TECHNOLOGY ON BOARD SHIP, issued by IMO, Ref. T2/444.01, 6th June 2003
6. The IALA Vision for e-Navigation, Nordic Navigation Conference, Oslo 16/17 October 2007
7. MarNIS, Deliverable reference number: D2.4.C, Research report on ship-borne equipment for enhanced performance and capabilities, 12-09-06
8. MarNIS, Deliverable reference number D2.4.E, Part 2, Enhanced Reliability and Safety for shipping using GALILEO, 27-04-07
9. MarNIS, Deliverable D2.4.E, Part 1, Final report on overlapping Radar. AIS and ECDIS, 22-04-07
10. IMO, The Convention on the International Regulations for Preventing Collisions at Sea (COLREGS)

Websites

1. www.imo.org – International Maritime Organisatio
2. www.marnis.org – European Commission Funded MarNIS Project
3. www.iala-aism.org – International Association of Lighthouse Authorities
4. www.emsa.eu – European Maritime Safety Organisation

19. Role of the IMO and Standards/Regulatory Bodies

19.1 Overview

International maritime bodies have for a number of years taken initiatives to strengthen maritime safety for international shipping and for protection of the sea environment. This section provides a brief overview of the current activities of international and national organisations and the main regulations and standards which apply to maritime navigation and which have relevance to e-navigation.

At the international level, navigation is controlled through the rules and standards of the International Maritime Organization (IMO). IMO member states must ensure a regulatory framework is in place to require vessels comply with appropriate IMO standards, and to enforce compliance with these standards.

In addition to IMO policy, a member state can apply additional control over the navigation of vessels operating within its jurisdiction as it sees fit, i.e., as part of a national risk management strategy.

In Europe for example, the European Commission (EC) has adopted a range of additional directives to control aspects of navigation in European Union (EU) waters These directives, while being compatible with the IMO rules and standards, must be implemented into the regulatory framework of each EU member state.

The main three IMO regulations which apply to the navigation and operation of vessels are:

1. The Convention on the International Regulations for Preventing Collisions at Sea (COLREGS)
2. Aspects of Chapter V (Safety of Navigation) of the International Convention on the Safety of Life at Sea (SOLAS) in respect of voyage planning, life-saving signals, assistance to other craft and misuse of distress signals
3. Aspects of The International Convention for the Prevention of Pollution from Ships (MARPOL) in respect of dumping of refuse and other technical provisions such as the use of anti-fouling paint.

19.2 International Maritime Organisation (IMO) and e-Navigation

The IMO has embraced the concept of e-Navigation and, through its Maritime Safety Committee (MSC), decided in 200? to include a high priority item on ‘Development of an e-navigation strategy’ in the work programme of its NAV and Radio Communications and Search and Rescue (COMSAR) Sub-Committees with the NAV Sub-Committee acting as co-ordinator.

It was also decided that the IMO should take the lead in the development of a strategic vision/concept of e-navigation but that other organisations should be invited to participate and provide an input. The main contributors involved are:

- International Association of Lighthouse Authorities (IHO)
- International Hydrographic Organization (IHO)

Other international and national organisations and bodies have contributed through participation in formal Working Groups of the above on e-Navigation for example in the UK, the Nautical Institute and Royal Naval Architects Association (RINA). One of the first steps taken by the IMO in developing its e-Navigation strategy is to identify and define user needs.

A report to be issued at the end of 2008 which should address the following aspects of e-navigation:

- the definition and scope of the concept of e-navigation in terms of its purpose, components and limitations, with the aim of producing a system architecture;
- the identification of the key issues and priorities that will have to be addressed in a strategic vision and a policy framework on e-navigation;
- the identification of both benefits and obstacles that may arise in the further development of the strategic vision and policy framework;
- the identification of the roles of the Organization, its Member States, other bodies and industry in such development
- the formulation of a related work programme, including an outline migration plan (to give timescales for the phased roll out of the proposed system) and the roles of the NAV and COMSAR Sub-Committees and the input of other parties concerned.

19.3 Standards and Regulations

In order to achieve the global vision of e-navigation it will be necessary to ensure commonality in procedures and standards both on-ship and on-shore at national and international level. This will apply to all navigational related technology, its functionality and associated operational procedures. It will be necessary to set standards for the performance and operation of equipment and to ensure compatibility between equipments and the use of standard interfaces and protocols in the transmission of data. Major obstacles in the evolvement of e-navigation are seen to be human factors related (e.g. training, how the data is displayed to personnel and how they react to it, standardisation of displays etc.).

These aspects require addressing if the vision of e-Navigation is to be achieved. The IMO has already been active in regulating the main building blocks for e-Navigation such as AIS and ECDIS and is therefore well placed to lead and set the standards for e-Navigation. The most appropriate body to co-ordinate and lead the initiative is therefore the IMO but in conjunction with other international and national stakeholders. There will also be a need to involve other stakeholders such as ship owners, port authorities, coastal states, ship owners, equipment manufacturers, navigational service providers (see section 3.1 for a detailed list).

The main stakeholders in Europe, have been invited to join and are involved in the European Commission' s WATERBORNE Technology Platform which was launched in January 2005; this forum is well placed to contribute to setting the quality standards for safe and sustainable maritime operations.

Much work has already been done on standards and regulations in other EC funded projects (COMPRIS and MARNIS) which is a good starting point in defining the needs of e-Navigation in terms of regulations and standards. A comprehensive list of organisations and institutions which are involved in setting standards in the maritime industry, together with their specific roles and interests is included in the COMPRIS and MarNIS reports on Standards included in 19.4.

19.4 References

Relevant Documents

1. IMO, Chapter V (Safety of Navigation) of the International Convention on the Safety of Life at Sea (SOLAS) in respect of voyage planning, life-saving signals, assistance to other craft and misuse of distress signals
2. Inventory and guide to standards and recommendations for COMPRIS and RIS, Appendix 1: Standardisation organisations, institutions and legal entities
3. Aspects of The International Convention for the Prevention of Pollution from Ships (MARPOL) in respect of dumping of refuse and other technical provisions such as the use of anti-fouling paint.
4. D-HA3C Interim Report 0n Standards, MARNIS Deliverable Report, SINTEF

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3. www.iho.org – The International Hydrographic Organisation
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5. www.itu.int – International Telecommunications Union
6. www.iec.ch – International Electrotechnical Commission
7. www.iso.ch – International Organisation for Standardisation
8. www.cordis.lu – European Union

9. http://waterborne.balport.com – European Commission funded WATERBORNE Technology Platform
10. www.enavigation.org – annual e-navigation conferences organised by Pacific Maritime Magazine in the USA
11. www.euro-compris.org Website for the EC funded COMPRIS project
12. www.marnis.org – Website of the EC funded MARNIS project

20. Overall Conclusions

The present state-of-the-art subsystems currently on-board ship forming part of such systems as Automatic Identification Systems, Integrated Bridges, Electronic Chart Displays, Automatic Radar Plotting Aids, Long Range Identification Systems, Global Maritime Distress and Safety Systems, Voyage Data Recorders, and Global Satellite Navigation Systems will be the building blocks for e-navigation systems of the future. The key challenge is how they can be integrated together to form future onboard e-navigation systems.

Assessments of operator requirements have concluded that there will be a need to review and optimise the human/machine interfaces and to ensure that the training needs match the e-navigation bridge of the future.
The study suggests that the rapid pace of technology and the increased functionality which will be provided on the e-navigation bridge will bring with them a need to examine and update the regulations and standards which apply to on-board navigation systems.

The design of future onboard e-navigation systems must be considered as an integral part of the overall e-navigation concept which relies on a sound organisational and functional approach and gives equal weight on communications from the shore (and vice versa) as well as on integration and human factors on-board.