SEAFARERS TRAINING CENTER INC

OPERATIONAL USE OF ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM (ECDIS)

(Regulation II/1, Section A-II/1 and table A-II/1)

COURSE FRAMEWORK

SCOPE

This course intends to provide the knowledge, skills and understanding of EDIS and electronics charts to the thorough extent needed to safely navigate vessels whose primary means of navigation is ECDIS. The course emphasizes both the application and learning of ECDIS in a variety of underway context.

The course is designed to meet the STCW requirements in the use of ECDIS, AS REVISED BY THE 2010 Manila Amendments, specifically as these apply to Tables A-II/1, A-II/2 and A-II/3, and also to revised guidelines pertaining to training and assessment in navigational watchkeeping, and evaluation of competence, both in Table B-II.

It should be understood that this is a generic course which requires a structured and complementary on board ship specific ECDIS familiarization for each shipboard ECDIS system on which the navigating office serves.

OBJECTIVE

Those who successfully complete this course should be able to demonstrate sufficient knowledge, skill and understanding of ECDIS navigation and electronic charts to undertake the duties of a navigational watch officer defined by STCW Code, as amended. This knowledge, skills and understanding should include Column 1 ECDIS competencies of Tables A-II, but is not limited to:

- Knowledge of the capability and limitations of ECDIS operations, and all indicated sub-topics
- Proficiency in operation, interpretation, and analysis of information obtained from ECDIS, and all indicated sub-topics.
- Management of operational procedures, system files and data, and all indicated sub-topics.

ENTRY STANDRDS

It is assumed the trainees undertaking this course have accomplished some formal instruction is Terrestrial Navigation, have at minimum some familiarization with visual navigation, have accomplished a period of supervised bridge watch-keeping duties, and have prior completion of basic RADAR/ARPA (MC1.07). Trainees should also have considerable familiarization with personal computing operating systems, keyboards and mice or trackballs.

COURSE CERTIFICATE, DIPLOMA OR DOCUMMENT

Documentary evidence should be issued to those who have successfully completed this course indicating that holder has completed training in the navigational use and operation of Electronic Chart Display and Information Systems (ECDIS) based on this model course.

COURSE DELIVERY

The outcome of this course may be achieved through various methods, including simulation-based classroom and laboratory training, or in-service training, or combinations of these methods, such that each trainee is provided access to an ECDIS with ENC data for all required hours of practice and assessment in a controlled visual underway navigational environment.

Methods of distance learning or computer-based training may be used to supplement the familiarization stages of this course, but should not be substituted for the underway assessment of proficiency

COURSE INTAKE LIMITATIONS

The maximum number of trainees should be 10 persons.

The instructor – trainee ratio should be limited 1:12. When a class size exceeds 12 trainees, an assistant instructor is required.

STAFF REQUIREMENTS

The following are the minimum qualifications recommended for instructors delivering a course that follows the IMO Model Course 1.27. The instructor in charge should:

1. Hold relevant certificate of competency in the deck department or other qualification or experience at the discretion of the administration approving the course;
2. Have successfully completed an approved ECDIS course;
3. Have completed type specific familiarization relevant to the equipment used for training;
4. Have a detailed knowledge of the requirements of SOLAS chapters V/2, V/9, and V/20-27, as amended;
5. Have an up-to-date knowledge of the IMO ECDIS Performance Standards currently in force and knowledge of relevant STCW requirements and guidance;
6. Have an up-to-date knowledge of ENCs.
7. Be fully aware of current ENC data transfer standards and presentation libraries

of the IHO, methods of ENC licensing and updating and current IMO recommendations on ECDIS software and other issues;

8. Have a current relevant teaching qualification or have successfully completed a Train-The-Trainer course, including the application of simulators in training and meets the requirements of STCW regulations I/6 and I/12.

Assistant instructors should have relevant knowledge of ECDIS operation.

TEACHING FACILITIES AND EQUIPMENT

ECDIS simulation equipment. In simulator NAUTIS vs Version 1-3.

ECDIS Classroom/Lab

The lecture portion of the course can take place in a classroom with desk/seating space for all trainees. Standard classroom facilities must be available such as whiteboard/chalkboard, appropriate projection system, etc.

The practical demonstration and assessment portion of the course must take place in a space equipped to provide a suitable ECDIS simulator work station for each individual trainee. The necessity of mounting display monitors on the desk surfaces requires careful placement of all equipment and projection screens to maintain good visibility for all trainees.

In addition to the trainee work stations there must be an instructor station with dedicated projection system that will allow projection of the exercises and lecture materials. It is strongly recommended that there be display(s) networked to the instructor station, thereby allowing display(s) of ARPA and ECDIS information (or other training material) for the benefit of the trainees.

Note that the lecturing may take place in the same room as the simulation if the space is suitable. This would require adequate visibility around/over the workstations to the whiteboard/chalkboard and projection screens, and adequate work space for taking notes and written examinations.

TEACHING AIDS (A)

A1 Instructor Manual (Part C of the course)
A2 Audiovisual aids: Video/DVD player, visual presentation, document project, etc.
A3 Simulator providing ownship functionality in an underway navigational context
A4 ECDIS workstation including ENC data, deriving inputs from simulation or live sensors
A5 Electronic Navigational Chart (ENC) data, various, including permits, and update

files
A6 Raster Navigational Chart (RNC) including permits and updates

BIBLIOGRAPHY (B)

B1 NMEA Interface Standard 0183 v.3.01 (Severna Park, MD, National Marine Electronic Association, 1/2002)
B2 Facts about electronic charts and carriage requirements, 2nd Ed. (Finnish Maritime Administration: Primar Stavanger and IC-ENC, 5/2007)
B3 Gale, H. (2009) From Paper Charts to ECDIS. London: Nautical Institute
B4 Bole, et al. (2005) The Radar/ARPA Manual, 2nd ed., Chapter 10 "Ancillary Equipment". Burlington, MA: Elsevier
B5 American Practical Navigator (Browditch, Pub. No. 9), 2002 Ed., Chapter 14 "Electronic Charts"
B6 Simulator reference manual (Manufacturer, Date)
B7 User's manual accompanying the ECDIS software utilized during the training course
B8 IEC 61174 – Maritime navigation and radiocommunication equipment and system – Electronic chart display and information system (ECDIS) – Operational and performance requirements, methods of testing and required test results, edition 3.0, International Electrotechnical Commision
B9 IHO S-66, Facts about electronic charts and carriage requirements, Edition Jan 2010
B10 IHO S-61, Product specifications for Raster Navigation Charts, Edition 1.0
B11 IHO S-52, Specification for chart content and display aspects of ECDIS, 5th ed., as amended (IHB, 12/2001)
B12 IHO S-100 Universal Hydrographic Data Model, Ed. 1.0.0 (Monaco: IHB, 1/2010)
B13 IHO S-57, Electronic Navigational Chart (ENC), Edition 3.1

ELECTRONIC MEDIA (E)

E1 ECDIS, Seagull CBT, CD #64
E2 AIS, Seagull CBT, CD # 109 v.A, 8/2003
E3 ECDIS Training Course, Videotel CBT #871, 5/2008

IMO REFERENCES

R1 Standard of training, Certification and Watchkeeping for Seafarers (STCW Convention)
R2 1974 SOLAS Convention, Regulations V/19, V/20 and V/27, as amended 2009, IMO Res. MSC 282(86)
R3 Revised ECDIS Performance Standards, MSC.232 (82), IMO, 12/2006

R4 ECDIS Performance Standards, IMO Resolution A.817 (19) as adopted 11/1995, including Appendices 1 – 5, Appendix 6 as adopted 11/1996 Res. MSC. 64 (67), and Appendix 7 as adopted 12/1998 Res. MSC. 86 (70)

R5 IMO MSC. 1/ CIRC.1391, Operating anomalies identified within ECDIS

R6 IMO SN. 1/ CIRC. 266/Rev. 1, Maintenance of Electronic Chart Display and Information System (ECDIS) Software

R7 Guidelines for Voyage Planning, IMO Res. A. 893 (21)

R8 COLREGS – International Regulations for Preventing Collisions at Sea, 1972, as amended

TEXTBOOKS (T)

T1 Norris, A. (2010) ECDIS and Positioning. London: The Nautical Institute

T2 Weintrit, A. (2009) The Electronic Chart Display and Information System (ECDIS): An Operational Handbook. Gydnia: Gydnia Maritime University, Poland, Balkema Book, CRC Press, Taylor & Francis Group

T3 Hecht, et al. (2001) The Electronic Chart, Fundamentals, Functions, Data and other Essentials A textbook for ECDIS Use and training (3rd Revised Edition) Lemmer, The Netherlands: Geomares Publishing

T4 The ECDIS Manual, ECDIS Ltd, Witherby Seamanship International, Edition 2012

PART B: COURSE OUTLINE AND TIMETABLE
COURSE OUTLINE

SUBJECT AREA AND TOPICS	HOURS
ELEMENT OF ECDIS 1. Course introduction & familiarization plan 2. Purpose of ECDIS 3. Value to navigation 4. Correct & incorrect use 5. Workstation start, stop & layout 6. Vessel position 7. Position source 8. Basic navigation 9. Heading & drift vectors Ex.1 Simulator exercise – open sea (basic integrate navigation) 10. Understanding chart data 11. Chart quality & accuracy 12. Chart organization	9.5
WATCHKEEPING WITH ECDIS 13. Sensors 14. Ports & data feeds 15. Chart selection 16. Chart information 17. Changing the settings 18. Chart scaling 19. Information layers Ex.2 Simulator exercise – coastal waters (charts display settings) 20. System & position alarms 21. Depth & contour alarms	9.0
ECDIS ROUTE PLANNING AND MONITORING 22. Vessels maneuvering characteristics 23. Route planning by table 24. Route planning by chart 25. Track limits 26. Checking plan for safety Ex.3 Simulator exercise – coastal & restricted waters (navigation alarms & route scheduling) 27. Additional Navigational Information 28. Route schedule 29. Use charts in route planning	9.0

SUBJECT AREA AND TOPICS	HOURS
ECDIS TARGET, CHARTS & SYSTEM 30. ARPA/RADAR overlay 31. AIS functions 32. Procuring & installing chart data 33. Installing chart corrections Ex.4 Simulator exercise – restricted waters (advanced integrated navigation with ECDIS) 34. System reset & backup 35. Archiving ECDIS data and data logging	6.5
ECDIS RESPONSIBILITY & ASSESSMENT 36. Responsibility 37. Effective navigation with ECDIS Ev.1 Written evaluation EV.2 Simulator exercise – coastal & restricted waters (underway ECDIS navigation assessment)	6.0
TOTAL	40.0

COURSE TIMETABLE

DAY/PERIOD	1st period (2.0 hours)	2nd Period (2.0 hours)	3rd Period (2.0 hours)	4th Period (2.0 hours)
DAY 1	Elementary of ECDIS 1. Course introduction & familiarization plan 2. Purpose of ECDIS 3. Value to navigation 4. Correct & incorrect use	5. Workstation start, stop &layout 6. Vessel position 7. Position source	8. Basic navigation 9. Heading & drift vectors 10. Understanding chart data	Ex1 Simulator exercise- open sea (basic integrated navigation)
DAY 2	11. Chart quality & accuracy 12. Chart organization WATCHKEEPING WITH ECDIS 13. Sensor 14. Ports & contour alarms	15. Chart selection 16. Chart information	17. Changing the settings 18. Chart scaling 19. Information layers	Ex.2 Simulator exercise - coastal waters (chart display settings)
DAY 3	20. Systems & position alarms 21. Depth & contour alarms	ECDIS ROUTE PLANNING AND MONITORING 22. Vessel maneuvering characteristics 23. Route planning by table	24. Route planning by chart 25. Tracks limits 26. Checking plan for safety	Ex.3 Simulator exercise - coastal & restricted waters (advanced integrated navigation with ECDIS)
DAY 4	27. Additional navigational information 28. Route schedule 29. User charts in route planning	ECDIS TARGET, CHARTS & SYSTEM 30. ARPA/RADAR overlay 31. AIS functions	32. Procuring & installing chart data 33. Installing chart corrections	Ex4. Simulator exercise –restricted waters (advanced integrated navigation with ECDIS)
DAY 5	34. System reset & backup 35. Archiving ECDIS data and data logging	ECDIS RESPONSIBILITY & ASSESSMENT 36. Responsibility	37. Effective navigation with ECDIS Ev.1 written evaluation	EV.2 Simulator exercise – coastal & restricted waters (underway ECDIS navigation assessment

MANUAL

ELECTRONIC NAVIGATION SYSTEMS

Since the earliest days of navigation, seafarers have sought to keep track of their direction and position. The earliest forms of the magnetic compass date back to the 12th century while the crude "dead reckoning" system involved measuring the course and distance sailed from a known position.

By the end of the 15th century navigators were using the quadrant and astrolabe to find latitudinal position from the position of the sun, moon or stars and the horizon, while the chronometer, invented in the 18th century, enabled navigators to find their longitudinal position.

The introduction of radio and wireless technology in the late 19th century permitted the development of more sophisticated navigation systems. Wireless time signals, which were first broadcast from Paris in 1910, enabled more accurate determination of longitude, while the Italians Ettore Bellini and Captain Tosi in 1906 developed a direction finding system used to determine the direction from which wireless signals were transmitted.

After the end of World War Two, the development of radar led to the possibility of ships being able to fix their position, when within 48 to 60 miles of the shore, by making reference to coastal features or responder beacons (Racons) installed on the shore. Further out to sea, hyperbolic radio systems soon enabled accurate position fixing with a range of at least 250 miles.

These early radio navigation systems - including Decca Navigator and Loran A - involved a ship's radio receiver measuring transmissions from groups of radio transmitters transmitting signals simultaneously or in a controlled sequence. By measuring the phase difference between one pair of transmissions a position line can be established, a second measurement from another pair of stations gives a second line and the intersection of the two lines gives the navigating position.

By the 1970s, Loran C and Differential Omega radio navigation systems were also becoming operational in major areas of the world's oceans and they were combined with early computer technology to provide electronic print outs of the ship's position. The Soviet Tchaika system also became operational. Meanwhile, the world's first satellites had been launched and their potential for accurate position finding was being actively researched.

IMO and navigation systems

The importance of using navigation systems in maritime safety and preventing marine pollution, for example as an aid to avoiding hazards, was recognized by IMO in the late 1960s, and in 1968 it adopted resolution A.156(ES.IV) on *Recommendation on the Carriage of Electronic Position-Fixing Equipment*.

That resolution recommended that ships carrying oil or other noxious or hazardous cargoes in bulk should carry "an efficient electronic position-fixing device".

Performance Standards for Shipborne Receivers for use with Differential Omega (resolution A.479(XII) were adopted in 1981, while in 1983 the Assembly adopted resolution A.529(13) on *Accuracy Standards for Navigatio*n.

Resolution A.529(13) is aimed at providing "guidance to Administrations on the standards of navigation accuracy for assessing position-fixing systems, in particular radio-navigation systems, including satellite systems". It notes that "the navigator needs to be able to determine his position at all times".

Accuracy of navigation systems in areas such as harbour entrances and approaches depends on local circumstances, but in other waters, the resolution established that navigation systems should provide accuracy within the order of 4% of the distance from danger with a maximum of 4 nautical miles (for a ship proceeding at not more than 30 knots).

Also in 1983, IMO began a study into a world-wide radio-navigation system, in view of the need for such a system to provide ships with navigational position-fixing throughout the world - but recognizing that itwas not considered feasible for IMO to fund a world-wide radio-navigation system.

The objective of the study was to provide a basis by which Regulation 12 (covering shipborne navigational equipment) of SOLAS Chapter V might be amended to include a requirement for ships to carry equipment to receive transmissions from a radio navigation system throughout their intended voyage.

SOLAS Chapter V Regulation 12 includes a requirement for ships on international voyages over 1,600 gross tonnage to be fitted with radio direction-finding apparatus. This requirement dates back to the 1948 SOLAS Convention, while in 1988 IMO adopted an amendment which allowed ships the possibility to carry instead radionavigation equipment suitable for use throughout the intended voyage.

World-wide radio navigation system

In 1985, IMO initiated a study into a world-wide satellite position-fixing system for the safety of navigation and a report, *Study of a World-Wide Radionavigation System*, was adopted by the IMO Assembly in 1989 (resolution A.666(16).

The report gave a detailed summary of the different terrestrial-based radio navigation systems then in operation (Differential Omega, Loran-C, Chayka), and also the satellite systems which were being developed - Global Positioning System (GPS) Standard Positioning Service (SPS), which was being developed by the United States air force; and GLONASS (Global Navigation Satellite System), being developed by the then Soviet military (now managed for the Government of the Russian Federation by the

Russian Space Agency.

The 1989 report said that it was not considered feasible for IMO to fund a world-wide radionavigation system, so existing and planned systems provided and operated by Governments or organizations were studied to ascertain whether they could be recognized or accepted by IMO.

When a radio-navigation system is accepted by IMO, it means the system is regarded as capable of providing adequate position information and that the carriage of receiving equipment satisfies the relevant SOLAS requirements.

The report notes that shipborne receiving equipment should conform to the general requirements for navigational equipment in resolution A.574(14) (later updated by A.694(17) and that detailed requirements for receivers for GPS, differential GPS, GLONASS, differential GLONASS, Loran-C, Chayka, Omega combined with differential Omega and Decca Navigator systems were available to manufacturers to enable them to construct the equipment.

The report set operational requirements for world-wide radionavigation systems: they should be general in nature and be capable of being met by a number of systems. All systems should be capable of being used by an unlimited number of ships. Accuracy should at least comply with the standards set out in resolution A.529(13) *Accuracy of Standards for Navigatio*n.

1995 update

The report was updated in 1995 by resolution A.815(19), *World-Wide Radionavigation syste*m, which takes into account the requirements for general navigation of ships engaged on international voyages anywhere in the world, as well as the requirements of the Global Maritime Distress and Safety System (GMDSS) for the provision of position information.

The revised report also addresses the development of high speed craft, such as fast ferries, noting that ships operating at speeds above 30 knots may need more stringent requirements.

The report states that provision of a radionavigation system is the responsibility of governments or organizations concerned and that these should inform IMO that the system is operational and available for use by merchant shipping while keeping IMO informed in good time of any changes that could affect the performance of shipborne receiving equipment.

Updated performance standards for Decca Navigator and Loran-C and Chayka receivers and performance standards for shipborne global positioning system (GPS) receiver equipment were also adopted in 1995. By then, GPS was fully operational, while GLONASS became fully operational in 1996. The future for terrestrial-based radio-navigation systems - in view of the development of the satellite-based systems
- is unclear.

OMEGA was also phased out in 1997 while DECCA will be phased-out in many countries by the year 2000. The United States-controlled LORAN-C networks are under consideration for phasing out by the year 2000. However, the Russian Federation-controlled CHAYKA networks will not be considered for phasing out until at least the year 2010. Civil-controlled LORAN-C and LORAN-C/CHAYKA networks are being set up in the Far East, North-West Europe and other parts of the world with plans for extension in some areas.

Meanwhile, there are several initiatives to improve the accuracy and/or integrity of GPS and GLONASS by augmentation. The use of different differential correction signals for local augmentation of accuracy and integrity and RAIM (Receiver Autonomous Integrity Monitoring) are examples of such initiative. In addition integrated receivers are being developed, combining signals from GPS, GLONASS, LORAN-C and/or CHAYKA. Wide area augmentation systems are also being developed using differential correction signals from geostationary satellites, in particular Inmarsat III satellites, for instance by the United States and Europe.

However, the main concern is that while GPS and GLONASS are expected to be fully operational until at least the year 2010, their availability beyond that is not guaranteed.

As a result, IMO (and other users, such as civil aviation) has recognised the need for a future system to improve, replace or supplement GPS and GLONASS, which have shortcomings on integrity, availability, and control and system life expectancy. As a result, IMO in 1997 adopted resolution A.860(20) on *Maritime policy for a future global navigation satellite system (GNSS*).

OMEGA

A very low frequency (VLF) hyperbolic radionavigation system based on phase comparison techniques, which ceased operations in September 1997.

Omega evolved from a low frequency system known as Radux first proposed in 1947 and was further developed in the 1950s, was the first world-wide radio-navigation system offering global coverage. It operated from eight Omega stations in Norway, Liberia, Hawaii, North Dakota, La Reunion, Argentina, Australia and Japan. Differential Omega refers to the provision of increased accuracy in a local area, such as a harbour, through the use of local transmitters of the Omega signal.

CHAYKA

A radionavigation system, similar to LORAN-C, operated by the Russian Federation. Accuracy is 50 to 200 metres.

DECCA

A low frequency (LF) hyperbolic radionavigation system based on harmonically related continuous wave transmissions.

The basic principles of the Decca Navigator were invented in the United States in 1937 and the system was used for guiding the leading minesweepers and landing craft in the Allied invasion of Normandy during World War Two.

In 1945, the Decca Navigator Co, Ltd was formed and the first commercial chain of stations established in south-east England in 1946.

The system expanded and by 1989 had 42 fully operational chains around the world, including 42 master stations and 119 slave transmitters. Chains normally comprise one master station and three slave transmitters. Stations radiate four harmonically related frequencies in the band 70 kHz to 130kHz. Coastal accuracy is 50 metres by day and 200 metres by night.

LORAN-C

A low frequency (LF) hyperbolic radionavigation system based on measurements of the differences of times of arrival of signals using pulse and phase comparison techniques.

The Loran system was initially proposed by the United States in 1940 and the first full-scale trials, of Standard Loran, or Loran-A, took place in 1942. By 1943 coverage extended over much of western and northern Atlantic and by 1945 had extended to cover north and central Pacific, Bay of Bengal, and northern Australia. It was the standard Allied long-range navigation system for ships and aircraft. Coverage in the Japanese and East China Sea Areas was extended in the 1950s and in 1965 stations were established in Portugal and the Azores. Loran-C was a modified version of Loran-A, developed to provide longer range and greater accuracy. Loran-C first came into operation in 1957.

By 1989, there were 16 Loran-C chains comprising 67 stations, transmitting on 100 kHz.
Typical coastal accuracy is 50 to 200 metres.

Satellite Navigation Systems

Satellite navigation and positioning has, during the later years, gone from something most people had not even heard anything about to something used in a large number of applications. Primarily it is the American Global Positioning System (GPS) (see *Hoffman-Wellenhof et al.* [1994] and *Parkinson and Spilker (eds.)* [1996]) that is used but there also exists another system in the shadow of GPS, namely the Russian Global Navigation Satellite System or GLONASS. GLONASS has been around since the early eighties, however information about it has been very scarce in western countries until the last five years or so. The reason for this has probably much to do with the reluctance of the former Soviet Union to reveal any information about military resources and since GLONASS was developed as a military guidance and navigation system information has been very scarce.

The interest for GLONASS has increased due to larger flow of information about the system, which made it possible to manufacture receivers capable of not only tracking GPS satellites but also GLONASS satellites. This made it possible to start exploring the possibilities of applications relying on a larger number of satellites visible than provided by GPS only as well as the challenge of trying to tie measurements together stemming from two different reference systems.

The studies undertaken and presented in this thesis have been made in order to investigate the impact and usability of GLONASS, both in its own respect and in combined use together with GPS. Further, the experience that can be drawn from GLONASS usage today can be very useful in the future when more satellite navigation systems will be developed. Today Europe has plans for its own navigation system, Galileo, and in order to utilize this from the very beginning it is important to have gained experience earlier from combined use of different satellite navigation systems, a perfect role for GLONASS in conjunction with GPS.

Current Status of NAVSTAR GPS.

The launch of the 24th Block II 28 satellite in March 1994 completed the GPS constellation. The NAVSTAR system currently consists of 25 satellites, including one Block I satellite. Initial Operational Capability (IOC) was formally declared December 8, 1993, in a joint announcement by the DoD and the Department of Transportation (DoT). The IOC notification means that the NAVSTAR GPS is capable of sustaining the Standard Positioning Service (SPS), the 100-meter positioning accuracy available to civilian users of the system on a continuous, worldwide basis. Unlike IOC for other DoD systems, IOC for GPS has purely civil connotations.

In 1995, the U.S. Air Force Space Command formally declared that GPS met the requirements for Full Operational Capability (FOC),32 meaning that the constellation of 24 operational (Block II/IIA) satellites now in orbit has successfully completed testing for military functionality. While the FOC declaration is significant to DoD because it defines a system as being able to provide full and supportable military capability, it does not have any significant impact on civil users.

An additional 21 satellites called Block IIRs are being developed by Martin Marietta (formerly General Electric Astro Space division) as replacements for the current GPS satellites. The Block IIR satellites will provide enhanced performance over the previous generation of GPS satellites, including the capability to autonomously navigate (AUTONAV) themselves and generate their own navigation message data.

This means that if the control segment cannot contact the Block IIR satellites, the AUTONAV capabilities will enable these satellites to maintain full system accuracy for at least 180 days. The Block IIR satellites will be available for launch as necessary beginning in late 1996.

A follow-on set of replenishment satellites, known as Block IIFs, is planned to replace the Block IIR satellites at the end of their useful life. The Air Force in-tends to buy 33 Block IIF satellites to sustain the quality of the GPS signal as a worldwide utility for the foreseeable future. These satellites will have to meet even higher levels of performance than previous generations of GPS satellites, including a longer life cycle of 6.5 to 10 years. The IIF satellite will be launched on an Evolved Expendable Launch Vehicle (EELV). The Air Force issued a draft request for proposals (RFP) on June 20, 1995, and plans to award a con-tract for the development and procurement of the Block IIF satellites in spring 1996.

Satellite positioning

The technique used in satellite positioning today, be it in GPS, GLONASS or any other system to obtain a position solution is based on a concept called time of arrival ranging. The idea behind time of arrival ranging is to have precise atomic clocks onboard the satellites, transmitting a precise timestamp signal. This signal gets another timestamp when it arrives in the receiver and the two timestamps are compared to get an estimated travel time for the signal. If the transmitting and receiving timestamps are synchronized it is possible to measure the signal's travelling time and use that for calculating a distance, or range measurement, to the satellite.

From this it is easy to see that high-accuracy timing is crucial for the success of this method or the range measurements would not be accurate and positioning would be more or less impossible to do. In order to be as accurate as possible and to avoid clock biases to as large extent as possible, the system is driven by precise atomic clocks aboard the satellites. A ground-based control network and a Master Control Station monitor these onboard clocks.

Furthermore each satellite broadcasts a navigation message which, among other things, contains almanac information - information about where the satellites are at any given time epoch. This is a necessity, otherwise the user would only know the distance between the receiver and an unknown point, giving no information about the user's position.

GPS

Background

In 1978, the first prototype satellite for use in the come-to-be global navigational satellite system GPS was launched. Since then GPS has developed to the well-known and highly utilized system of today. However, for ordinary civilian users the accuracy is intentionally degraded down to 100 m by means of Selective Availability (SA), which consists of a degradation in the accuracy of the broadcast orbit information a dithering of the signal and. This dithering will affect both the carrier phase and the code data.

Status

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations.

GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter!

In a sense it's like giving every square meter on the planet a unique address.

GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible to virtually everyone.

These days GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, even laptop computers.

Soon GPS will become almost as basic as the telephone. Indeed, at Trimble, we think it just may become a universal utility.

The latest GPS replenishment launch took place in 1997 and the current number of orbiting operational satellites is 27, an increase from the originally planned constellation using 24 satellites divided in six different, equally distributed, orbital planes.

How it Works

The operation of the GPS and GLONASS systems is basically the same and can be resumed in five steps.

1. The basis of GPS is "triangulation" from satellites.
2. To "triangulate," a GPS receiver measures distance using the travel time of radio signals
3. To measure travel time, GPS needs very accurate timing which it achieves with some tricks.
4. Along with distance, you need to know exactly where the satellites are

in space. High orbits and careful monitoring are the secret.

5. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Problems at the satellite

Even though the satellites are very sophisticated they do account for some tiny errors in the system.

The atomic clocks they use are very, very precise but they're not perfect. Minute discrepancies can occur, and these translate into travel time measurement errors.

And even though the satellites positions are constantly monitored, they can't be watched every second. So slight position or "ephemeris" errors can sneak in between monitoring times.

Basic geometry itself can magnify these other errors with a principle called "Geometric Dilution of Precision" or GDOP.

It sounds complicated but the principle is quite simple.

There are usually more satellites available than a receiver needs to fix a position, so the receiver picks a few and ignores the rest.

If it picks satellites that are close together in the sky the intersecting circles that define a position will cross at very shallow angles. That increases the gray area or error margin around a position.

If it picks satellites that are widely separated the circles intersect at almost right angles and that minimizes the error region.

Good receivers determine which satellites will give the lowest GDOP.

In this section you will see how a simple concept can increase the accuracy of GPS to almost unbelievable limits.

And you will see:

- Why we need Differential GPS
- How Differential GPS works
- Where to get Differential Corrections
- Other ways to work with Differential GPS
- Advanced Concepts

Basic GPS is the most accurate radio-based navigation system ever developed. And for many applications it's plenty accurate. But it's human nature to want MORE!

So some crafty engineers came up with "Differential GPS," a way to correct the various inaccuracies in the GPS system, pushing its accuracy even farther.

Differential GPS or "DGPS" can yield measurements good to a couple of meters in moving applications and even better in stationary situations.

That improved accuracy has a profound effect on the importance of GPS as a resource. With it, GPS becomes more than just a system for navigating boats and planes around the world. It becomes a universal measurement system capable of positioning things on a very precise scale.

Differential GPS involves the cooperation of two receivers, one that's stationary and another that's roving around making position measurements.

The stationary receiver is the key. It ties all the satellite measurements into a solid local reference.

Here's how it works:

The problem

Remember that GPS receivers use timing signals from at least four satellites to establish a position. Each of those timing signals is going to have some error or delay depending on what sort of perils have befallen it on its trip down to us.

(For a complete discussion of all the errors review the "Correcting Errors" section of the tutorial.)

Since each of the timing signals that go into a position calculation has some error, that calculation is going to be a compounding of those errors.

Where to get differtential signals

In the early days of GPS, reference stations were established by private companies who had big projects demanding high accuracy - groups like surveyors or oil drilling operations. And that is still a very common approach. You buy a reference receiver and set up a communication link with your roving receivers.

But now there are enough public agencies transmitting corrections that you might be able to get them for free!

The United States Coast Guard and other international agencies are establishing reference stations all over the place, especially around popular harbors and waterways.

These stations often transmit on the radio beacons that are already in place for radio direction finding (usually in the 300kHz range).

Anyone in the area can receive these corrections and radically improve the accuracy of their GPS measurements. Most ships already have radios capable of tuning the direction finding beacons, so adding DGPS will be quite easy.

Many new GPS receivers are being designed to accept corrections, and some are even equipped with built-in radio receivers.

Future global navigation satellite system

Maritime policy for a future global navigation satellite system (GNSS) sets out IMO policy in terms of the maritime requirements for a future civil and internationally- controlled Global Navigation Satellite System (GNSS), to provide ships with navigational position-fixing throughout the world for general navigation, including navigation in harbour entrances and approaches and other waters in which navigation is restricted.

The resolution notes that development of a future GNSS is presently only in a design stage and these requirements have been limited only to basic user requirements, without specifying the organizational structure, system architecture or parameters. These maritime requirements, as well as the Organization's recognition procedures, may need to be revised as a result of any subsequent developments.

The resolution sets out the general, operational and institutional requirements for a future GNSS in terms of maritime users and envisages a review of the requirements in 1999 (21st Assembly); consideration of the proposed future GNSS in 2001 (22nd Assembly) and completion of the implementation of the proposed GNSS in 2008.

ELECTRONIC CHART SYSTEMS

Every day thousands of vessels arrive at or depart from harbours all over the world. Most of them manage without any problems, but despite all the modern techniques available vessels still run aground.

An aid to reducing the large number of grounding accidents is the digital chart coupled to an accurate positioning system such as GPS/DPGS (Global Positioning

System/Differential GPS). Many claim that Electronic Chart Display and Information System (ECDIS) is the greatest improvement to safety at sea since radar was introduced after WWII.

ECDIS will simplify chart maintenance which until now has been a time consuming manual process. In the future updating will be carried out automatically by ECDIS.

The Digital Chart

For over 200 years all local geographical information has been supplied to the end user in the form of printed paper charts. Digital techniques have made it possible to increase the amount of information considerably, and open up new fields of opportunity.

It is important to understand the digital chart system in order to use the new techniques correctly and safely.

Fundamental Concepts

Local information of the landscape is known as geographic data. The main component of geographical data is geometric data, i.e. description of position, size and shape of objects in the land-scape (lights, buildings, perches, buoys, etc). Geometric data can be digitised by two methods, either as raster data or as vector data. To understand the difference between different types of digital charts it is important to know that:

- **ENC**
  An ENC is a digital chart produced by National Hydrographic Offices which complies with the IOH's (International Hydrographic Organisation's) S-57 Edition 3 product specification. The ENC contains all necessary naviagational information not be shown on paper charts e.g. characteristics of objects such as lighthouses, lights, bouys..etc. Official ENC's fulfil the IHO S-57/3.1 product specification and have the most recent updated data from originating National Hydrographic Offices. When used in an ECDIS, ENC data facilitates unique functionality that improves the safety of navigation at sea.

  - **RasterData**
    Raster data is a surface coverage described by a limited area which can be divided into regular squares. The individual squares are called picture points, pixels or picture elements. Each element gives information on colours, but gives no details of which object (e.g. a lighthouse) is contained in the picture element.

  - **Vector Data**
    Vector data consists of fixed coordinate points and links between them,

organised so that they describe geometric figures in the form of points, lines and areas. Each object is charted and given a specific code which can be linked to other information, for example, to pictures and text from books.

The difference between raster and vector data is that with vector data there is the possibility of having a more "intelligent" system than with raster data. Raster data is one digital picture of the chart, while vector data puts together a number of objects which can be shown in different ways as required by the user. Raster data cannot therefore be used to display different themes on the chart.

Vector data can be seen as a number of transparent "layers" on which one has coastline, another has light buoys, a third has five metre depth contours, and a fourth has ten metre depth contours etc. The whole chart can be presented with all these "layers" on a screen. Information which the user does not wish to be shown can be removed by dispensing with one or more "layers".
For example, a mariner with a boat which requires five metres may wish to eliminate depth contours greater than ten metres. An ECDIS operator will also define his own "safety depth contour". Such central safety functions connected to objects cannot be directly supported by raster systems. It is also possible to remove lights and light sectors (during day-light use), or it may be desirable to omit names. This can be achieved by removing the "layer" containing the unwanted information. By this means the clearest display of the chart is available. The information can be easily replaced. The raster chart does not have this function as it usually consists of only one "layer".

- **Raster Chart**
  Raster Charts, essentially digital scans of printed paper charts. They look identical to paper charts, they cannot be updated like vector charts, and they cannot be zoomed in to very high magnifications without losing sharpness; their data is limited to that which is on the paper charts. Raster navigational chart (RNC) data, itself, will not trigger automatic alarms (e.g. anti-grounding).

- **Vector Chart**
  Vector Charts are, in essence, a point by point hand rendering of a chart. They bear little resemblance to regular paper charts, but have some real advantages, they allow you to zoom in to large magnifications, and they can be edited to include updates from Notices to Mariners.

- **ECDIS**
  In practical terms, an ECDIS shows the mariner where his ship is in real-time using digital versions of paper charts.

  ECDIS is the acronym of Electronic Chart Display and Information System. It has been defined by the International Maritime and Hydrographic

Organizations (IMO/IHO) as a navigation system displaying selected information from an Electronic Navigational Chart (ENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring.

- **RCDS**
  The RCDS (Raster Chart Display System) is similar to the ECDIS; however, it is limited to the presentation of Raster Charts. It not necessarily has to be a dedicated equipment and it does not meet the SOLAS requirement for Electronic Chart Display Systems; it has to be backed up by an up-to-date paper chart portfolio.

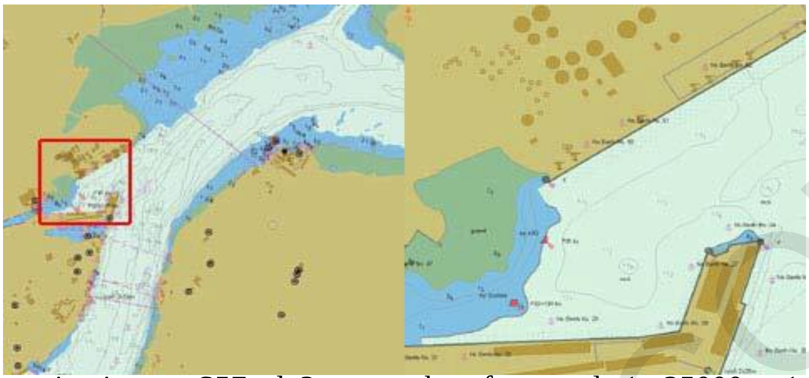
- **ECS**
  Although generally defined as a system that display real-time vessel position and relevant electronic chart data, it is not intended to comply with up-to date chart requirements of V/20 of SOLAS.

Differences between Vector Charts & Raster Charts

Electronic Navigational Charts (ENC) are basically available in two different formats that are not interchangeable: raster and vector. Only the vector format is deemed compliant with the ECDIS performance standards. Here is why: The raster format is just a plain image of the paper chart. The navigation system can not differentiate between the various objects composing the chart (i.e. it doesn't know if a certain object is a buoy or a depth area).

Zooming in on a ARCS raster chart from scale 1 : 25000 to 1 : 5000

The vector format is one where all the objects composing the chart are well defined. All the points, lines and areas are known by the navigation system. This brings "intelligence" to the ENC and hence to the navigation system.



Zooming in on a S57 ed. 3 vector chart from scale 1 : 25000 to 1 : 5000

Most chart plotters (like those from Magellan, Garmin, some Northstar models, and others) use vector charts, which bear little resemblance to regular paper charts, but have some real advantages.

Raster Chart data is a digitized "picture" of printed paper charts and they look identical to paper charts. All data is in one layer and one format. They cannot be zoomed in to very high magnifications without losing sharpness; their data is limited to that which is on the paper charts. The video display simply reproduces the picture from its digitized data file. With raster data, it is difficult to change individual elements of the chart since they are not separated in the data file. Raster data files tend to be large, since a data point must be entered for every picture element (pixel) on the chart. Further, they require the considerable computing power of a notebook computer to display the charts and drive the navigation software. All in all, raster charting systems are a heavier investment in technology than vector charting systems.

Vector Chart In essence, VECTOR charts are a point by point hand rendering of a chart. Chart data is organized into many separate files. They allow you to zoom in to large magnifications, and they can be edited to include updates from Notices to Mariners. It contains graphics programs to produce certain symbols, lines, area colors, and other chart elements. The programmer can change individual elements in the file and tag elements with additional data. Vector files are smaller and more versatile than raster files of the same area. The navigator can selectively display vector data, adjusting the display according to his needs. Current IMO/IHO standards for ECDIS recognize only the vector format as adequate. As a rule, the hardware that uses this technology are all in one units that include a screen, a GPS, and a programmable interface. All you add are the chart cartridges. Vector chart plotters generally cost between $500 and $2,000. Vector chart cartridges (of which Navionics and C-MAP NT cartridges are examples) cost more than similar coverage on raster charts.

Whether a digital chart system uses a raster or vector data base, any change to that data base must come only from the hydrographic office (HO) that produced the ENC.

Corrections from other sources affecting the data base should be applied only as an overlay to the official data base. This protects the integrity of the official data base.

Performance Standards for Electronic Charts

Performance standards for electronic charts were adopted in 1995, by resolution A.817(19)), which was amended in 1996 by resolution MSC.64 (67) to reflect back-up arrangements in case of ECDIS failure.

Additional amendments were made in 1998 by resolution MSC 86 (70) to permit operation of ECDIS in RCDS (Raster chart) mode.

IMO's Maritime Safety Committee (MSC), at its 73rd session from 27 November to 6 December 2000 adopted a revised Chapter V (Safety of Navigation) of SOLAS which enters into force on 1 July 2002.

Regulation 19 of the new Chapter V - Carriage requirements for shipborne 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. But the ship must also carry back up arrangements if electronic charts are used either fully or partially.

Performance standards for electronic charts were adopted in 1995, by resolution A.817(19)), which was amended in 1996 by resolution MSC.64 (67) to reflect back-up arrangements in case of ECDIS failure. Additional amendments were made in 1998 by resolution MSC 86 (70) to permit operation of ECDIS in RCDS mode.

Raster chart performance standards

The MSC, during its 70th session from 7-11 December, 1998, adopted performance standards for Raster Chart Display Systems, through amendments to the performance standards for electronic chart display and information systems (ECDIS), to allow the systems to be used with raster charts where vector electronic chart systems are not available.

- A raster chart is basically just a visual scan of a paper chart. It is a computer- based system which uses charts issued by, or under the authority of, a national hydrographic office, together with automatic continuous electronic positioning, to provide an integrated navigational tool.

- A vector chart is more complex. Each point on the chart is digitally mapped, allowing the information to be used in a more sophisticated way, such as clicking on a feature (for example, a lighthouse) to get all the details of that feature displayed.

The international standard for vector charts has been finalised by the International Hydrographic Organization (S-57, Version 3), and IMO adopted performance standards for ECDIS, using vector charts, in 1995 by Assembly Resolution A.817(19).

The amendments to Resolution A.817(19) state that some ECDIS equipment may operate in Raster Chart Display System (RCDS) mode when the relevant chart information is not available in vector mode.

The amendments to the ECDIS performance standards indicate which performance standards for vector charts apply equally to raster charts, and add specific specifications for raster charts, covering such aspects as display requirements, alarms and indicators, provision and updating of chart information and route planning. The amendments state that when used in RCDS mode, ECDIS equipment should be used together with an appropriate folio of up-to-date paper charts.

The MSC during its 70th sessionalso agreed a Safety of Navigation Circular on Differences between Raster Chart Display systems (RCDS) and Electronic Chart Display and Information Systems (ECDIS).

Hydrographic data and charts

All ships are required to carry "adequate and up-to-date charts" under SOLAS Chapter V (Regulation 20) to assist in navigation.

At present, the International Convention for the Safety of Life at Sea (SOLAS) does not specify Governmental responsibility for producing charts, but in 1983, IMO adopted a Resolution referring to the importance of the provision of accurate and up-to-date hydrographic information to safety of navigation and to the fact that many areas had not been surveyed to modern standards.

The Resolution invited Governments to conduct hydrographic surveys and co-operate with other Governments where necessary. This was followed in 1985 by a Resolution urging IMO Member Governments to establish regional hydrographic commissions or charting groups and to support groups already set up by the International Hydrographic Organization (IHO) to prepare accurate charts.

The Resolution was adopted after representation from the IHO, which had informed IMO of the inadequacy of nautical charts of many sea areas as a result of dependence on old hydrographic surveys and noted that, in order to develop up to date charts for these areas, substantial technical co-operation would be required between developed and developing coastal states on a regional basis.

In the revised chapter V of SOLAS, entry into force 2002, Regulation 9 Hydrographic services states:

1. Contracting Governments undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and keeping up to date of all nautical information necessary for safe navigation.
2. In particular, Contracting Governments undertake to co-operate in carrying out, as far as possible, the following nautical and hydrographic services, in the manner most suitable for the purpose of aiding navigation: .1 to ensure that hydrographic surveying is carried out, as far as possible, adequate to the requirements of safe navigation; .2 to prepare and issue nautical charts, sailing directions, lists of lights, tide tables and other nautical publications, where applicable, satisfying the needs of safe navigation; .3 to promulgate notices to mariners in order that nautical charts and publications are kept, as far as possible, up to date; and .4 to provide data management arrangements to support these services.
3. Contracting Governments undertake to ensure the greatest possible uniformity in charts and nautical publications and to take into account, whenever possible, relevant international resolutions and recommendations. (Refers to the appropriate resolutions and recommendations adopted by the International Hydrographic Organization.

   Contracting Governments undertake to co-ordinate their activities to the greatest possible degree in order to ensure that hydrographic and nautical information is made available on a world-wide scale as timely, reliably, and unambiguously as possible.

Correcting the Digital Nautical Chart

There are currently three proposed methods for correcting the DNC data base: Interactive Entry, Semi-Automatic Entry, and Fully Automatic Entry.

Interactive Entry: This method requires the interactive application of the textual Notice to Mariners. The operator determines the corrections from the Notice. Then, using a toolkit, he selects the symbol appropriate to the correction required, identifies the location of the symbol, and adds the appropriate textual information identifying the nature of the correction. This method of It also clutters the screen display because it can be applied only as an overlay to the ENC data.

Semi-Automatic Entry: This method requires the operator to enter the correction data furnished in correct digital format by the originating hydrographic office into the system via electronic medium (a modem or floppy disc, for example). The ECDIS then processes these corrections automatically and displays an updated chart with the changed data indistinguishable from the remaining original data base.

Fully Automatic Entry: The fully automatic method of correction entry allows for a direct telecommunications link to receive the official digital update and input it into the ECDIS. This process is completely independent of any operator interface. Internal ECDIS processing is the same as that for semi-automatic updating of the data base.

DIFFERENCES BETWEEN RCDS AND ECDIS

1. The Maritime Safety Committee, at its seventieth session (7 to 11 December 1998), adopted amendments to the performance standards for Electronic Chart Display and Information Systems (ECDIS) to include the use of Raster Chart Display Systems (RCDS).
2. These amendments permit ECDIS equipment to operate in two modes: .1 the ECDIS mode when ENC data is used; and .2 the RCDS mode when ENC data is not available. However, the RCDS mode does not have the full functionality of ECDIS, and can only be used together with an appropriate portfolio of up- to-date paper charts.
3. The mariners' attention is therefore drawn to the following limitations of the RCDS mode:

.1 unlike ECDIS where there are no chart boundaries, RCDS is a chart-based system similar to a portfolio of paper charts;

.2 Raster navigational chart (RNC) data, itself, will not trigger automatic alarms anti-grounding). However, some alarms can be generated by the RCDS from user-inserted information. These can include:

- clearing lines
- ship safety contour lines
- isolated dangers
- danger areas

.3 Horizontal datums and chart projections may differ between RNCs. Mariners should understand how the chart horizontal datum relates to the datum of the position fixing system. In some instances, this may appear as a shift in position. This difference may be most noticeable at grid intersections and during route monitoring;

.4 Chart features cannot be simplified or removed to suit a particular navigational circumstance or task at hand. This could affect the superimposition of radar/ARPA;

.5 Without selecting different scale charts, the look-ahead capability may be somewhat limited. This may lead to some inconvenience when determining range and bearing or the identity of distant objects;

.6 orientation of the RCDS display to other than chart-up, may affect the readability of chart text and symbols (e.g., course-up, route-up);

.7 it may not be possible to interrogate RNC features to gain additional information about charted objects;

.8 it is not possible to display a ship's safety contour or safety depth and highlight it on the display, unless these features are manually entered during route planning;
.9 Depending on the source of the RNC, different colors may be used to show similar chart information. There may also be differences in colors used during day and nighttime;

.10 An RNC should be displayed at the scale of the paper chart. Excessive zooming in or zooming out can seriously degrade RCDS capability, for example, by degrading the legibility of the chart image; and

.11 Mariners should be aware that in confined waters, the accuracy of chart data (i.e., paper charts, ENC or RNC data) may be less than that of the position-fixing system in use. This may be the case when using differential GNSS. ECDIS provides an indication in the ENC which allows a determination of the quality of the data.

.12 Member Governments are requested to bring this information to the attention of the relevant authorities and all seafarers for guidance and action, as appropriate

ECDIS

In practical terms, an ECDIS shows the mariner where his ship is in real-time using a digitized version of the paper chart.

ECDIS is the acronym of Electronic Chart Display and Information System. It has been defined by the International Maritime and Hydrographic Organizations (IMO/IHO) as a navigation system displaying selected information from an Electronic Navigational Chart (ENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring.

The two major IMO/IHO documents governing the design requirements for ECDIS are S52 and S57.

1. S57 defines the data structure for all the information contained in the ENC.
2. S52 defines the colors and symbols to be used by the ECDIS to display the various objects contained in the ENC.

IMO Performance Standards

Performance Standards for ECDIS were formally adopted by the International Maritime Organization (IMO) on 23 November 1995 and issued as IMO Resolution A19/Res.817. These Performance Standards are the same as those first approved in draft form by the Maritime Safety Committee of IMO in May 1994, and originally issued by IMO as MSC Circ./637. Back-up arrangements for ECDIS were adopted by IMO in November 1996 (MSC/67/22-ADD.1) and will become Appendix 6 to the Performance Standard. The IMO Performance Standards permit National Maritime Safety Administrations to consider ECDIS as the legal equivalent to the charts required by regulation V/20 of the 1974 SOLAS Convention. IMO has specifically requested that Member Governments have their National Hydrographic Offices produce electronic navigational charts (ENCs) and the associated updating service as soon as possible, and to ensure that manufacturers conform to the performance standards when designing and producing ECDIS.

IHO Standard, Format and Specifications

In conjunction with the development of IMO Performance Standards for ECDIS, the International Hydrographic Organization (IHO) has developed technical standards and specifications related to the digital data format, and specifications for the ECDIS content and display. IHO Special Publication 52 (IHO S-52) is the IHO Specification for Chart Content and Display of ECDIS. It includes appendices describing the means/process for updating, colour and symbol specifications, and a glossary of ECDIS-related terms. The 4th edition of IHO S-52 was issued in December 1996. IHO Special Publication 57 (IHO S-57) is the IHO Transfer Standard for Digital Hydrographic Data that was formally adopted as the official IHO standards by the XIV International Hydrographic Conference, Monaco, 4-15 May 1992. It includes an object catalog, DX-90 format, an ENC Product Specification, and ENC updating profile. The current edition (Edition 3.0) was released in November 1996, and will be “frozen" for three years. Both IHO S-57 and S-52 are specified in the IMO Performance Standards for ECDIS.

ECDIS is much more than simply images of a chart on a computer screen. It provides a powerful decision making tool on the bridge of a ship by combining satellite and other position fixing with ship's sensors and a sophisticated electronic database containing charting and other navigation information.

The chart information in ECDIS is continuously analysed and compared with a ship's position, intended course and its manoeuvring characteristics to give warning of approaching dangers. ECDIS also provides alerts and prompts for planned course alterations. Additional material, such as photographs and views, as well as navigational notices and cautions can be accessed instantly and displayed as required on high resolution full colour screens. In addition, ECDIS provides many other sophisticated navigation and safety features, including continuous data recording for later analysis.

In the near future, ECDIS will also incorporate and display information contained in other nautical publications such as Tide Tables and Sailing Directions and incorporate additional maritime information such as radar information, weather, ice conditions and automatic vessel identification.

The chart database used in ECDIS is known as an Electronic Navigational Chart (ENC). ENCs and their updates are only published by or under the authority of governments. As such, they carry full official status and the backing of the issuing government.

The chart information in an ENC is not held as a single image or "picture" of a chart, but as individual items (vectors) in a database. Each chart feature and its associated information is recorded separately in the database. This allows all the chart data to be analysed and re-assessed continuously by ECDIS in relation to a ship's current and intended position. Dangers or hazards which will affect a ship can then be identified automatically and warnings and alarms raised.

ECDIS supports a comprehensive update mechanism to ensure ENCs can be kept up to date, with things such as Notices to Mariners. Chart maintenance is achieved in effect automatically via disk update, e-mail message or satellite data transfer.

The versatility of the ENC vector chart database and the comprehensive ECDIS display and performance standards allow the mariner to select and display navigational information most relevant to the requirements and the situation at the time. For example, ECDIS will display and respond to the safety depth contour based on a vessel's actual draft. The level of chart detail that is shown can also be adjusted according to the circumstances and alternative colour schemes can be selected for use by day or by night.

ECDIS and ENCs must conform to rigorous standards regarding how they operate and what information is displayed. The standards govern such things as chart data structure, minimum display requirements and minimum equipment specifications as well as many other aspects. The International Hydrographic Organization (IHO) and the International Maritime Organization (IMO) set the ECDIS and ENC standards.

ECDIS Warnings and Alarms

Since the ECDIS is a "smart" system which combines several different functions into one computerized system, it is possible to program it to sound alarms or display warnings when certain parameters are met or exceeded. This helps the navigator to monitor close navigation hazards. IMO standards require that certain alarms be available on the ECDIS. Among these are:

1. Deviating from a planned route.

2. Chart on a different geodetic datum from the positioning system.

3. Approach to waypoints and other critical points.

4. Exceeding cross-track limits.

5. Chart data displayed overscale (larger scale than originally digitized).

6. Larger scale chart available.

7. Failure of the positioning system.

8. Vessel crossing safety contour.

9. System malfunction or failure.

Alarms consist of audible and visible warnings. The navigator may determine some setpoints. For example, he may designate a safety depth contour or set a maximum allowed cross-track error. Operational details vary from one system to another, but all ECDIS will have the basic alarm capabilities noted. The navigator is responsible for becoming familiar with the system aboard his own ship and using it effectively.

ECDIS Units

The following units of measure will appear on the EC-DIS chart display:

• **Position:** Latitude and Longitude will be shown in degrees, minutes, and decimal minutes, normally based on WGS-84 datum.

• **Depth:** Depth will be indicated in meters and deci-meters. Fathoms and feet may be used as an interim measure only:

- when existing chart udata is held in those units only,
- when there is an urgent need for an ENC of the applicable area, and
- Time does not allow for an immediate conversion of the English units to

their metric equivalents.

• **Height:** Meters (preferred) or feet.

• **Distance:** Nautical miles and decimal miles, or meters.

• **Speed:** Knots and decimal knots.

ECDIS Priority Layers

ECDIS requires data layers to establish a priority of data displayed. The minimum number of information categories required and their relative priority from the highest to lowest priority, are listed below:

• ECDIS Warnings and Messages.

• Hydrographic Office Data.

• Notice to Mariners Information.

• Hydrographic Office Cautions

• Hydrographic Office Color-Fill Area Data.

• Hydrographic Office on Demand Data.

• Radar Information.

• User's Data.

• Manufacturer's Data.

• User's Color-Fill Area Data.

• Manufacturer's Color-Fill Area Data.

IMO standards for ECDIS will require that the operator be able to deselect the radar picture from the chart with min-mum operator action for fast "uncluttering" of the chart presentation.

ECDIS Calculation Requirements
As a minimum, an ECDIS system must be able to perform the following calculations:

• Geographical coordinates to display coordinates, and display coordinates to geographical coordinates.
• Transformation from local datum to WGS-84.
• True distance and azimuth between two geographical

• Geographic position from a known position given distance and azimuth.

ECDIS - Additional information Advantages over the paper chart

- On a single ECDIS display, the following data can be shown:
  - Nautical chart
  - Parts of the Sailing Directions, German List of Radio Signals, List of Lights
  - Radar overlay, ARPA targets
  - Lubber's line and present position of own ship
  - Alphanumerical position and navigation data (planned routes, current navigation data, recorded track information)
  - AIS symbols (Automatic Identification System)

- Time-consuming manual correction is no longer necessary. The updates are read into the system and automatically correct the ECDIS database.

The position of one's own vessel is determined by navigation systems like (D) GPS or LORAN-C which are linked to ECDIS. The vessel positions is continuously shown on the chart display and stored at regular intervals. The chart section displayed moves along with the ship's position, and at any moment at last 25 % of the chart display shows the area ahead of the vessel.

Manual chart exchange is no longer required. The elements of route planning in ECDIS are waypoints and leglines ensuring safe track keeping.

- The ECDIS display can be superimposed with radar images and with the radar targets of ARPA (Automated Radar Plotting Aid). In this way, also the movements of other vessels can be continually monitored.
- ECDIS "knows" whether a vessel can pass safely through an area, on the basis of the vessel's draugh data, and may sound an alarm if she approaches, e.g., the 10-meter contour. ECDIS "knows" the properties of all objects, and thus helps to avoid dangerous close quarter's situations.

This wide functional range is only provided by electronic charts which are supported by object-oriented data. Raster charts do not have a comparable "intelligence" because they are just digital copies of paper charts and do not provide access to any additional, digitally stored information layers. Therefore, an ECDIS system supplied with raster data only has a limited range of functions.

The Risks of Over Reliance

An ECDIS is only a navigational tool. It aids the navigator by providing automatic positioning and consolidating all information. One of the biggest risks of using an ECDIS is over reliance in the information provided. Below are some things to consider:

1. Automatic positioning is usually accomplished by GPS. GPS is accurate to 100m (SPS) 95% of the time. That means 5% of the time, its accuracy is less than 100m. There is no way of knowing when your accuracy is degraded. The only means of determining system accuracy, with military receivers, is with a Figure of Merit (FOM). This, however, is only an estimation of the accuracy of GPS.

2. DGPS improves the accuracy of GPS. The use and/or lack of use may cause large discrepancies in the positioning of the ship.

3. Approaching a hostile shore, GPS may be jammed. An understanding of traditional navigation techniques as well as the introduction of emerging inertial navigation technology are necessary to enable military operations.

4. Like any other piece of equipment, ECDIS may malfunction. To be certified, any ECDIS system must have adequate back up. A means to check the operation of ECDIS must be in place (including positioning info).

Electronic charts may have embedded errors. Most Hydrographic services are compiling the first generation of electronic charts from current charts. Raster and vector pictures of nautical charts retain the inaccuracies and incongruities of the source from which they are derived. These charts may be based on old survey data, i.e. not a true “digital chart” (from original sounding and source data). Surveys are expensive and time consuming. Some estimations say it would take over 50 years with the current technology to update the world’s charts with original data. This limitation is unavoidable until some affordable, broad area means of surveying comes to the technical forefront. It is still an important limitation to understand.
Additionally, numerous commercial companies are producing their own electronic charts, which lack official (legal) certification.

5. Finally, as with any system, there must be trained human operators. Human error, primarily a lack of understanding of the system, can have serious consequences.

The electronic chart display systems require the navigator to use every means of determining the ship’s position. The US Navy, with NAVSSI and its embedded COMDAC software, allows the navigator to do just this. On the display, radar data can be projected on the electronic chart. This immediately gives the watchstander an understanding of the accuracy of the system. Visual bearings, radar ranges and celestial observations can also be used to check the positional accuracy of the system. Without knowing the particular constraints of an ECDIS system, the safe navigation of the ship may be endangered.

Training is necessary

In January 1999, the IMO Committee on Standards for Training and Watch-keeping (STW) approved a standardized IMO Model Training Course on the Operational Use of ECDIS (IMO Model Course 1.27) [1]. Initially developed by the Institute of Ship Operation, Sea Transport and Simulation (ISSUS) in Hamburg, Germany, the primary objective of the Model Course is to ensure proper use and operation of ECDIS in terms of a thorough understanding and appreciation of its capabilities and limitations [2]. The one-week model course syllabus (40 hours of instruction) includes classroom lecture, hands-on training, and exercise scenarios.

CONCLUSION

The emergence of extremely accurate electronic positioning systems coupled with the technology to produce an electronic chart is effecting a revolution in navigation. When fully mature, this technology will replace the paper charts and plotting instruments used by navigators since the beginning of sea exploration. There are several hurdles to overcome in the process of full replacement of paper charts, some legal, some bureaucratic, and some technical. Until those hurdles are overcome, electronic charting will be in a transitional state, useful as a backup to traditional techniques, but insufficient to replace them.

INTEGRATED BRIDGE SYSTEMS

INTRODUCTION

Operating Concept

Bridge watch officers have three main duties:

Navigation

• Watch officers process navigation information from several different sources. They take fix positions from satellite and hyperbolic receivers. They measure bearing lines and radar ranges to suitable NAVAIDS. They then plot this information on a paper chart.

• After plotting the information on a chart, watch officers evaluate the navigation picture. They determine if the ship’s present position is a safe one. They project the ship’s position ahead and plan for future contingencies. The evaluation step is the most important step in the navigation process. Properly executing this step is a function of the watch officer’s skill and how well the ship’s actual navigation situation is represented on the chart. That representation, in turn, is a function of both plotter and sensor accuracy.

Collision Avoidance

• Watch officers evaluate the contact situation and calculate the closest points of approach (CPA’s) for various contacts.

• Watch officers maneuver in accordance with the Rules of the Road to avoid close CPA’s and collisions.

Ship Management

• Watch officers conduct evolutions that are part of an individual ship's routine.
The integrated bridge is designed to reduce the time spent on navigation by eliminating manual data processing and providing the navigator with a display which aids him in quickly evaluating the navigation picture. Preliminary studies seem to indicate that time spent on navigation as a percentage of total watch officer duties drops significantly when using the integrated bridge. This does not necessarily lower the overall watch officer work-load, but it does increase the percentage of time he can devote to ship management and collision avoidance.

THE INTEGRATED BRIDGE

System Components

The term "integrated bridge" encompasses several possible combinations of equipment and software designed specifically for each individual vessel's needs. Therefore, each integrated bridge system is different. This section introduces, in general terms, the major equipment likely to be found in an integrated bridge system.

• **Computer Processor and Network:** This subsystem controls the processing of information from the ship's navigation sensors and the flow of information between various system components. It takes inputs from the vessel's navigation sensors. Electronic positioning information, contact information from radar, and gyro compass outputs, for ex-ample, can be integrated with the electronic chart to present the complete navigation and tactical picture to the conning officer. The system's computer network processes the positioning information and controls the integrated bridge system's display and control functions.

• **Chart Data Base:** At the heart of any integrated bridge system lies an electronic chart. An electronic chart system meeting International Maritime Organization (IMO) specifications for complying with chart carrying requirements is an **Electronic Chart Display and Information System (EC-DIS**). All other electronic charts are known as **Electronic Chart Systems (ECS**). Following sections discuss the differences between these two types of electronic charts.

An integrated bridge system may receive electronic chart data from the system manufacturer or from the appropriate government agency. The mariner can also digitize an existing paper chart if the system manufacturer provides a digitizer. Electronic charts can differentiate between and display different types of data far better than conventional charts. Paper charts are usually limited to four colors, and they display all their data continuously. An electronic chart can display several colors, and it can display only the data the user needs. If the electronic chart is part of an ECDIS, however, it must always display the minimum data required by IMO/IHO. The database for a typical civilian electronic chart contains layers consisting of hydrography, aids to navigation, obstructions, port facilities, shoreline, regulatory boundaries and certain topographic features. Other layers such as communication networks, power grids, detailed bathymetry, and radar reflectivity can also be made available. This allows the user to customize his chart according to his particular needs, something a paper chart cannot do.

• **System Display:** This unit displays the ship's position on an electronic chart and provides information on sensor status and ship's control systems. It displays heading data and ship's speed. It provides a station where the operator can in-put warning parameters such as minimum depth under the keel or maximum cross track error. It plots the ship's position and its position in relation to a predetermined track.
There are two possible modes of display, **relative** and **tru**e. In the relative mode the ship remains fixed in the center of the screen and the chart moves past it. This requires a lot of computer power, as all the screen data must be updated and re-drawn at each fix. In true mode, the chart remains fixed and the ship moves across it. The operator always has the choice of the north-up display. On some equipment, the operator can select the course-up display as well. Each time the ship approaches the edge of the display, the screen will re-draw with the ship centered or at the opposite edge.

A separate monitor, or a window in the navigation monitor, can be used for display of alpha-numeric data such as course, speed, and cross-track error. It can also be used to display small scale charts of the area being navigated, or to look at other areas while the main display shows the ship's current situation.

• **Planning Station:** The navigator does his voyage planning at this station. He calculates great circle courses, planned tracks, and waypoints. The navigator digitizes his charts, if required, at this planning station.

• **Control System:** Some integrated bridges provide a system that automatically adjusts course and speed to follow a planned track. If the system is equipped with this feature, the navigation process is reduced to monitoring system response and providing operator action when required by either a changing tactical situation or a system casualty.

• **Radar:** Radar for navigation and collision avoidance is included in the integrated bridge. Since both the chart and the radar process their data digitally, data transfer between the two is possible. The "picture" from either one can be imposed on top of the picture of the other. This allows the navigator to see an integrated navigation and tactical display and to avoid both navigation hazards and interfering contacts.

BRIDGE PROCEDURES & PASSAGE PLANNING

Safe navigation is the most fundamental attribute of good seamanship. An increasingly sophisticated range of navigational aids can today complement the basic skills of navigating officers, which have accumulated over the centuries.

But sophistication brings its own dangers and a need for precautionary measures against undue reliance on technology. Experience shows that properly formulated bridge procedures and the development of bridge teamwork are critical to maintaining a safe navigational watch.

Finally, an essential part of bridge organisation is the procedures, which should set out in clear language the operational requirements and methods that should be adopted when navigating. In this section, we have attempted to codify the main practices and provide a framework upon which masters, officers and pilots can work together to achieve consistent and reliable performance.

Seafaring will never be without its dangers but the maintenance of a safe navigational watch at all times and the careful preparation of passage plans are at the heart of good operating practice. If this Guide can help in that direction it will have served its purpose.

Safe navigation is of utmost importance to. Safe navigation means that the ship is not exposed to undue danger and that at ah times the ship can be controlled within acceptable margins.

To navigate safely at all times requires effective command, control, communication and management. It demands that the situation, the level of bridge manning, the operational status of navigational systems and the ships' engines and auxiliaries are ah taken into account.

It is people that control ships, and it is therefore people, management and teamwork which are the key to reliable performance. People entrusted with the control of ships must be competent to carry out their duties.

People also make mistakes and so it is necessary to ensure that monitoring and checking prevent chains of error from developing. Mistakes cannot be predicted, and once a mistake has been detected, it is human nature to seek to fit circumstances to the original premise, thus compounding a simple error of judgement.

Passage planning is conducted to assess the safest and most economical sea route between ports. Detailed plans, particularly in coastal waters, port approaches and pilotage areas, are needed to ensure margins of safety. Once completed, the passage plan becomes the basis for navigation. Equipment can fail and the unexpected can happen, so contingency planning is also necessary.

Ergonomics and good design are essential elements of good bridge working practices. Watchkeepers at sea need to be able to keep a look-out, as well as monitor the chart and observe the radar. They should also be able to communicate using the VHF without losing situational awareness. When boarding or disembarking pilots, handling tugs or berthing, it should be possible to monitor instrumentation, particularly helm and engine indicators, from the bridge wings. Bridge notes should be provided to explain limitations of any equipment that has been badly sited, pointing out the appropriate remedies that need to be taken.

The guiding principles behind good management practices are:

- Clarity of purpose
- Delegation of authority;
- Effective organization
- Motivation

Clarity of purpose

lf more than one person is involved in navigating it is essential to agree the passage plan and to communicate the way the voyage objectives are to be achieved consistently and without ambiguity. The process starts with company instructions to the ship, as encompassed by a safety management system supported by master's standing orders and reinforced by discussion and bridge orders. Existing local pilotage legislation should also be ascertained to enable the master to be guided accordingly.

Before approaching coastal and pilotage waters, a ship's passage plan should ensure that dangers are noted and safe-water limits identified. Within the broad plan, pilotage should be carried out in the knowledge that the ship can be controlled within the established safe limits and the actions of the pilot can be monitored.

In this respect early exchange of information will enable a clearer and more positive working relationship to be established in good time before the pilot boards. Where this is not practicable the ship's plan should be sufficient to enable the pilot to be embarked and a safe commencement of pilotage made without causing undue delay.

Delegation of authority

The master has the ultimate responsibility for the safety of the ship. Delegation of authority to the officer of the watch (OOW) should be undertaken in accordance with agreed procedures and reflect the ability and experience of the watchkeeper.

Similarly, when a pilot boards the master may delegate the conduct of the ship to the pilot, bearing in mind that pilotage legislation vanes from country to country and from region to region. Pilotage can range from optional voluntary pilotage that is advisory in nature, to compulsory pilotage where the responsibility for the conduct of the navigation of the ship is placed upon the pilot.

The master cannot abrogate responsibility for the safety of the ship and he remains in command at ah times.

lf the master delegates the conduct of the ship to the pilot, it will be because he is satisfied that the pilot has specialist knowledge, shiphandling skills and communications links with the port. In doing so the master must be satisfied that the pilot's intentions are safe and reasonable. The OOW supports the pilot by monitoring the progress of the ship and checking that the pilot's instructions are correctly carried out. Where problems occur which may adversely affect the safety of the ship, the master must be advised immediately.

The process of delegation can be the cause of misunderstanding and so it is recommended that a clear and positive statement of intention be made whenever handing over and receiving conduct of the ship.

When navigating with the master on the bridge it is considered good practice, when it is ascertained that it is safe to do so, to encourage the OOW to carry out the navigation, with the master maintaining a monitoring role.

The watch system provides a continuity of rested watchkeepers, but the watch changeover can give rise to errors. Consequently routines and procedures to monitor the ship's position and to avoid the possibility of mistakes must be built into the organisation of the navigational watch.

The risks associated with navigation demand positive reporting at all times, self verification, verification at handover and regular checks of instrumentation and bridge procedures. The course that the ship is following and compass errors must be displayed and checked, together with the traffic situation, at regular intervals and at every course change and watch handover.

Effective organisation

Preparing a passage plan and carrying out the voyage necessitates that bridge resources are appropriately allocated according to the demands of the different phases of the voyage.

Depending upon the level of activity likely to be experienced, equipment availability, and the time it will take should the ship deviate from her track before entering shallow water, the master may need to ensure the availability of an adequately rested officer as back-up for the navigational watch.

Where equipment is concerned, errors can occur for a variety of reasons and poor equipment calibration may be significant. In the case of integrated systems, it is possible that the failure of one component could have unpredictable consequences for the system as a whole.

It is therefore essential that navigational information is always cross checked, and where there is doubt concerning the ship's position, it is always prudent to assume a position that is closest to danger and proceed accordingly.

Motivation

Motivation comes from within and cannot be imposed. It is however the responsibility of the master to create the conditions in which motivation is encouraged.

A valuable asset in any organisation is teamwork and this is enhanced by recognising the strengths, limitations and competence of the people within a team, and organising the work of the bridge team to take best advantage of the attributes of each team member.

Working in isolation when carrying out critical operations carries the risk of an error going undetected. Working together and sharing information in a professional way enhances the bridge team and the master/pilot relationship. Training in bridge resource management can further support this.

Bridge Organisation

Overview

General principles of safe manning should be used to establish the levels of manning that are appropriate to any ship.

At ah times, ships need to be navigated safely in compliance with the COLREGS and also to ensure that protection of the marine environment is not compromised.

An effective bridge organisation should efficiently manage ah the resources that are available to the bridge and promote good communication and teamwork.

The need to maintain a proper Iook-out should determine the basic composition of the navigational watch. There are, however, a number of circumstances and conditions that could influence at any time the actual watchkeeping arrangements and bridge manning levels.

Effective bridge resource and team management should eliminate the risk that an error on the part of one person could result in a dangerous situation.

The bridge organisation should be properly supported by a clear navigation policy incorporating shipboard operational procedures, in accordance with the ship's safety management system as required by the SM Code.

Bridge Resource management and the bridge team Composition of the navigational

watch under the STCW Code

In determining that the composition of the navigational watch is adequate to ensure that a proper Iook-out can be continuously maintained, the master should take into account ah relevant factors including the following:

- visibility, state of weather and sea;
- traffic density, and other activities occurring in the area in which the ship is navigating;
- the attention necessary when navigating in or near traffic separation schemes or other routing measures;
- the additional workload caused by the nature of the ship's functions, immediate operating requirements and anticipated maneuvers;
- the fitness for duty of any crew members on cali who are assigned as members of the watch;
- knowledge of and confidence in the professional competence of the ship's officers and crew;
- the experience of each OOW, and the familiarity of that OOW with the ship's equipment, procedures and manoeuvring capability;

activities taking place on board the ship at any particular time, including radiocommunication activities, and the availability of assistance to be summoned immediately to the bridge when necessary;

- the operational status of bridge instrumentation and controls, including alarm systems;
- rudder and propeller control and ship manoeuvring characteristics;
- the size of the ship and the field of vision available from the conning position;
- the configuration of the bridge, to the extent such configuration might inhibit a member of the watch from detecting by sight or hearing any external

development;
- any other relevant standard, procedure or guidance relating to watchkeeping arrangements and fitness for duty.

Watchkeeping arrangements under the STCW Code

When deciding the composition of the watch on the bridge, which may include appropriately qualified ratings, the following factors, inter alia, must be taken into account:
- the need to ensure that at no time should the bridge be left unattended;
- weather conditions, visibility and whether there is daylight or darkness;
- proximity of navigational hazards which may make it necessary for the OOW to carry out additional duties;
- use and operational condition of navigational aids such as radar or electronic position-indicating devices and any other equipment affecting the safe navigation of the ship;
- whether the ship is fitted with automatic steering;
- whether there are radio duties to be performed;
- unmanned machinery space (UMS) controls, alarms and indicators provided on the bridge, procedures for their use and limitations;
- any unusual demands on the navigational watch that may arise as a result of special operational circumstances.

Reassessing manning levels during the voyage

At any time on passage, it may become appropriate to review the manning levels of a navigational watch.
Changes to the operational status of the bridge equipment, the prevailing conditions, the nature of the waters in which the ship is navigating, fatigue levels and workload on the bridge are among the factors that should be taken into account.

A passage through restricted waters may, for example, necessitate a helmsman for manual steering, and calling the master or a back-up officer to support the bridge team.

Sole Look-out

Under the STCW Code, the OOW may be the sole look-out in daylight conditions.

lf sole look-out watchkeeping is to be practised an any ship, clear guidance should be given in the shipboard operational procedures manual, supported by master's standing orders as appropriate, and covering as a minimum:
- under what circumstances sole look-out watchkeeping can commence;
- how sole look-out watchkeeping should be supported;
- under what circumstances sole look-out watchkeeping must be suspended.

It is also recommended that before commencing sole look-out watchkeeping the master should be satisfied, an each occasion, that:

- the OOW has had sufficient rest prior to commencing watch;
- in the judgement of the OOW, the anticipated workload is well within his capacity to maintain a proper look-out and remain in full control of the prevailing circumstances;
- back-up assistance to the OOW has been clearly designated;
- the OOW knows who will provide that back-up assistance, in what circumstances back-up must be called, and how to call it quickly;
- designated back-up personnel are aware of response times, any imitations an their movements, and are able to hear alarm or communication calls from the bridge;
- all essential equipment and alarms an the bridge are fully functional.

The Bridge Team

AII ship's personnel who have bridge navigational watch duties will be part of the bridge team. The master and pilot(s), as necessary, will support the team, which will comprise the OOW, a helmsman and look-out(s) as required.

The OOW is in charge of the bridge and the bridge team far that watch, until relieved.

It is important that the bridge team works together closely, bath within and across watches, since decisions made on one watch may have an impact on another watch.

The bridge team also has an important role in maintaining communications with the engine room and other operating areas on the ship.

The bridge Team and the Master

It should be clearly established in the company's safety management system that the master has the overriding authority and responsibility to make decisions with respect to safety and pollution prevention. The master should not be constrained by a shipowner or charterer from taking any decision which in his professional judgement, is necessary for safe navigation, in particular in severe weather and in heavy seas.

The bridge team should have a clear understanding of the information that should be routinely reported to the master of the requirements to keep the master fully informed, and of the circumstances under which the master should be called (see bridge checklist 813).

When the master has arrived on the bridge, his decision to take over control of the bridge from the OOW must be clear and unambiguous.

Working within the Bridge

team Assignment of Duties

Duties should be clearly assigned, limited to those duties that can be performed effectively, and clearly prioritised.

Team members should be asked to confirm that they understand the tasks and duties assigned to them.

The positive reporting on events while undertaking tasks and duties is one way of monitoring the performance of bridge team members and detecting any deterioration in watchkeeping performance.

Co-ordination and communication

The ability of ship's personnel to co-ordinate activities and communicate effectively with each other is vital during emergency situations. During routine sea passages or port approaches the bridge team personnel must also work as an effective team.

A bridge team which has a plan that is understood and is well briefed, with all members supporting each other, will have good situation awareness. lts members will then be able to anticipate dangerous situations arising and recognise the development of a chain of errors, thus enabling them to take action to break the sequence.

AII non-essential activity on the bridge should be avoided.

New Personnel and familiarization

There is a general obligation under the ISM Code and the STCW Convention for ship's personnel new to a particular ship to receive ship specific familiarisation in safety matters.

For those personnel that have a direct involvement in ship operation such as watchkeeping, a reasonable period of time must be allocated to become acquainted with the equipment that they will be using and any associated ship procedures. This must be covered in written instruction that the company is required to provide to the master.

A knowledgeable crew member must be assigned to new personnel for one-to-one training in a common language, ideally supported by checklists (see checklist B1). Self-teaching manuals, videos or computer based training programmes, are examples of other methods that could be used on board

Prevention of fatigue

In order to prevent fatigue, the STCW Code stipulates that bridge team members must take mandatory rest periods. Rest periods of at least 10 hours in any 24-haur period are required. If the rest is taken in two separate periods, one of those periods must be at least 6 hours. However the minimum period of 1 0 hours may be reduced to not less than 6 consecutive hours provided that any such reduction does not extend beyond two days, and not less than 70 hours rest is provided during each seven-day period. Detailed guidance is available in the 1SF publication 'International Shipboard Work Hour Limits'.

The STCW Code also advises governments lo prescribe a maximum blood alcohol level of 0.08% for ship's personnel during watchkeeping and to prohibit alcohol consumption within 4 hours prior to commencing a watch. Port states, flag state administrations and companies may have more stringent policies.

Use of English

The STCW Code requires the OOW to have knowledge of written and spoken English that is adequate to understand charts, nautical publications, meteorological information and messages concerning the ship's safety and operations, and adequate to communicate with other ships and coast stations. A handbook on Standard Marine Navigational Vocabulary (SMNV) has been published, and Standard Marine Communication Phrases (SMCP) are being introduced by MO.

Communications within the bridge team need to be understood. Communications between multilingual team members, and in particular with ratings, should either be in a language that is common to all relevant bridge team members or in English.

When a pilot is on board, the same rule should apply. Further when a pilot is communicating to parties external lo the ship, such as tugs, the ship should request that the pilot always communicate in English or a language that can be understood on the bridge. Alternatively, the pilot should always be asked to explain his communications to the bridge team, so that the ship is aware of the pilot's intentions at all times.

The Bridge team and the Pilot

When the pilot is on board a ship, he will temporally join the bridge team and should be supported accordingly (see section 3.3.3).

Navigation policy and company procedures

Every management of shipowning company should have a safety management policy. It should provide practical guidance concerning safe navigation and include:

- a dear statement that safety of life and safety of the ship take precedence over all other considerations;
- allocation of bridge watchkeeping duties and responsibilities for navigational procedures;
- procedures for voyage planning and execution;

- chart and nautical publication correction procedures;
- procedures to ensure that ah essential navigation equipment and main and auxiliary machinery are available and fully operational;
- advice concerning emergency responses;
- ship position reporting procedures;
- accident and near miss reporting procedures;
- recording of voyage events;
- procedures for familiarisation training and handover at crew changes;
- a recognised system for identifying special training needs;
- company contacts, including the designated person under the ISM Code

Master's standing orders

Shipboard operational procedures manuals supported by standing instructions based upon the company's navigation policy should form the basis of command and control on board.

Master's standing orders should be written to reflect the master's own particular requirements and circumstances particular to the ship, her trade and the experience of the bridge team employed at that point in time.

Standing orders and instructions should operate without conflict within the ship's safety management system.

Standing orders should be read by ah officers before the commencement of the voyage and signed accordingly. A copy of the orders should be available on the bridge for reference.

Bridge order book

In addition to general standing orders, specific instructions may be needed for special circumstances.

At night the master should write in the bridge order book what is expected of OOW. These orders must be signed by each OOW when going on watch.

Passage planning

Overview

Passage planning is necessary to support the bridge team and ensure that the ship can be navigated safely between ports from berth to berth. The passage plan should cover ocean, coastal and pilotage waters.

The plan may need to be changed during the voyage; for example a destination port may not have been known or may alter, or it may be necessary to amend the plan following consultation with the pilot.

If the plan is changed during the voyage, the bridge team on each watch should be consulted and briefed to ensure that the revised plan is understood,

The passage plan should aim to establish the most favourable route while maintaining appropriate margins of safety and safe passing distances offshore. When deciding upon the route, the following factors are amongst those that should be taken into account:

- the marine environment;
- the adequacy and reliability of charted hydrographic data along the route;
- the availability and reliability of navigation aids, coastal marks, lights and radar conspicuous targets for fixing the ship along the route;
- any routeing constraints imposed by the ship e.g. draught, type of cargo;
- areas of high traffic density;
- weather forecasts and expected current, tidal, wind, swell and visibility conditions;
- areas where onshore set could occur;
- ship operations that may require additional searoom e.g. tank cleaning or pilot embarkation;
- regulations such as ships' routeing schemes and ship reporting systems;
- the reliability of the propulsion and steering systems on board.

The intended voyage should be planned prior to departure using appropriate and available corrected charts and publications. The master should check that the tracks ¡aid down are safe, and the chief engineer should verify that the ship has sufficient fuel, water and lubricants for the intended voyage.

In addition, the duty of the master to exercise professional judgement in the light of changing circumstances remains a basic requirement for safe navigation.

Responsibility for passage planning

In most it is customary for the master to delegate the initial responsibility for preparing the passage plan to the officer responsible for navigational equipment and publications.

In small ships the master may plan the voyage himself.

While responsibility for the plan in pilotage waters rests with the ship, the pilot on boarding, or before if practicable, should advise the master of any local circumstances so that the plan can be updated (see section 2.6).

Notes on passage planning

Plan appraisal
Before planning can commence, the charts, publications and other information appropriate for the voyage will need to be gathered together and studied. A passage appraisal checklist is included in this Guide as bridge checklist B5.

Charts and publications
Only official nautical charts and publications should be used for passage planning, and they should be fully corrected to the latest available notices to mariners and radio navigation warnings. Any missing charts and publications needed for the intended voyage should be identified from the chart catalogue and obtained before the ship sails (see sections 4.9.2 and 4.9.3).

For coastal and pilotage planning and for plotting each course alteration point (or waypoint) large scale charts should be used. For ocean passage planning and open water legs smaller scale charts should be used.

The route plan
The route plan should incorporate the following details:

- planned track showing the true course of each leg;
- leg distances;
- any speed changes required en route;
- wheel over positions for each course alteration, where appropriate;
- turn radius for each course alteration, where appropriate;
- maximum allowable off-track margins for each leg.

At any time during the voyage, the ship may need to leave the planned route temporarily at short notice. Marking on the chart relatively shallow waters and minimum clearing distances in critical sea areas is but one technique which will assist the OOW when having to decide quickly to what extent to deviate without jeopardising safety and the marine environment. However, in using this technique, care should be taken not to obscure chart features. On paper charts, only pencil should be used.

The route plan should also take into account the need to monitor the ship's position along the route, identify contingency actions at waypoints, and allow for collision avoidance in line with the COLREGS.

The main details of the route plan should be recorded using sketches, if appropriate, so that the plan can be readily referred to at the main conning position.

Passage planning and electronic navigation systems

Planning using electronic chart display systems

Passage planning can be undertaken either on paper charts or using an electronic chart display and information system (ECDIS) displaying electronic navigational charts (ENC), subject to the approval of the flag state administration. Raster chart display systems (RCDS) displaying raster navigational charts (RNC) can be used for passage planning in conjunction with paper charts (see section 4.9).

When passage planning using ECDIS, the navigating officer should be aware so that a safety contour can be established around the ship. The crossing of a safety contour, by attempting to enter water which is too shallow or attempting to cross the boundary of a prohibited or specially defined area such as a traffic separation zone, will be automatically indicated by the ECDIS while both being planned and executed.

When passage planning using a combination of electronic and paper charts, particular care needs to be taken at transition points between areas o electronic and paper chart coverage. The voyage involves distinct pilotage, coastal and ocean water phases. Planning within any one phase of the voyage should be undertaken using either all electronic or all paper charts rather than a mix of types.

Where a passage is planned using paper charts, care should be taken when transferring the details of the plan to an electronic chart display system. In particular, the navigating officer should ensure that:

- positions are transferred to, and are verified on, electronic charts of an equivalent scale to that of the paper chart on which the position was originally plotted;
- any known difference in chart datum between that used by the paper chart and that used by the electronic chart display system is applied to the transferred positions;
- the complete passage plan as displayed on the electronic chart display system is checked for accuracy and completeness before it is used.

Transferring route plans to other navigation aids

Care must be taken when transferring route plans to electronic navigation aids as GPS, since the ship’s position that is computed by the navaid is likely to be in WG384 datum. Route plans sent to the GPS for monitoring cross track error must therefore be of the same datum

Similarly in the case of radars, routes and maps displayed on the radar will be referenced to the position of the ship. Care must therefore be taken to ensure that maps and plans transferred to, or prepared on, the radar are created in the same datum as the navaid (typically a GPS) which is connected to, and transmitting positions to, the radar.

Notes on passage planning in ocean waters

In open waters, the route selected will be either a great circle, composite great circle or rhumb line route.

When planning ocean passages, the following should be consulted:

- small scale ocean planning and routeing charts providing information on ocean currents, winds, ice limits etc.;
- gnomonic projection ocean charts for plotting great circle routes;
- the load line zone chart to ensure that the Load Line (LL) Rules are complied with;
- charts showing any relevant ships' routeing schemes.

Anticipated meteorological conditions may have an impact on the ocean route that is selected. For example:

- favourable ocean currents may offer improved overall passage speeds offsetting any extra distance travelled;
- ice or poor visibility may limit northerly or southerly advance;
- the presence of seasonal tropical storm activity may call for certain waters to be avoided and an allowance made for searoom.

Details of weather routeing services for ships are contained in lists of radio signals and in Volume D of the World Meteorological Organization (WMO) Publication No. 9. Long-range weather warnings are broadcast on the SafetyNET Service along with NAVAREA navigational warnings as part of the World-Wide Navigational Warning Service (WWNWS).

Landfall targets need to be considered and identified as to their likely radar and visual ranges and, in respect of lights, their rising and dipping ranges and arcs/colours of sectored lights.

Notes on passage planning in coastal or restricted waters

By comparison with open waters, margins of safety in coastal or restricted waters can be critical, as the time available to take corrective action is likely to be limited.

The manoeuvring characteristics of the ship and any limitations or peculiarities that the ship may have, including reliability problems with its propulsion and steering systems, may influence the route selected through coastal waters. In shallow water, particularly if the ship is operated at speed, ship squat can reduce underkeel clearances.

Ships' routeing schemes and reporting systems along the route, as well as vessel traffic services, should be taken into account (see sections 2.7, 2.8 and 2.9).

Coastal weather bulletins, including gale warnings and coastal navigational warnings broadcast by coast radio stations and NAVTEX, may require changes to be made to the route plan.

Monitoring the route plan

It is important that when a route is planned through coastal or restricted waters, due consideration is given to ensuring that the progress of the ship can be effectively monitored.

Of particular importance is the need to monitor the position of the ship approaching the wheel over position at the end of a track, and checking that the ship is safely on the new track after the alteration of course.

Distinctive chart features should be used for monitoring the ship's position visually, by radar and by echo sounder, and therefore need to be an integral part of the route plan.

Visual monitoring techniques

Ahead, transits can provide a leading line along which a ship can safely steer. Abeam, transits provide a ready check for use when altering course. At anchor several transits can be used to monitor the ship's position.

Bearing lines can also be effectively used. A head mark, or a bearing line of a conspicuous object lying ahead on the track line, can be used to steer the s while clearing bearings can be used to check that a ship is remaining within a safe area.

Radar monitoring techniques

When radar conspicuous targets are available, effective use can be made radar clearing bearings and ranges.

Ships with good arthwartship track control can use clearing bearings to monitor the advance of a ship towards a wheel over position, while parallel indexing can be used to check that the ship is maintaining track and not drifting to port or starboard.

Passage planning and pilotage Pre arrival planning

A preliminary plan should be prepared covering pilotage waters and the roles of bridge team personnel.

A plan should still be prepared even if the master of the ship has a "Pilotage

Exemption Certificate" for the port.

Planning for anchoring off the port or aborting port entry in the event of problems arising should feature as part of the plan. The plan should also identify charted features that will assist monitoring progress and include measures in the event of primary equipment failure, poor visibility etc.

The Pilot Card should also be updated. The Card contains information on draught and ship's speed that is liable to change as the loading conditions of the ship changes, as well as a checklist of equipment available and working.

Pre-arrival information exchange with the pilot
Particularly where the master has limited local knowledge of the pilotage waters, it is recommended that a pre-arrival exchange of information take place with the pilot before boarding.

An information exchange initiated by the ship approximately 24 hours before the pilot's ETA will allow sufficient time far more detailed planning to take place both an the ship and ashore. The exchange will also allow communications between the ship and the pilot to be firmly established before embarkation.

These forms are intended only to provide a basis; the exact detail of the forms can vary from ship to ship, trade to trade, or indeed from port to port. It is nevertheless recommended to keep preliminary information exchange to a minimum, and limit the information to that which is strictly necessary to assist in planning the pilotage. If appropriate, the Shore to Ship Pilot/Master Exchange form can be supported by a graphical route plan.

In certain pilotage areas, the passage can last for several hours, in which time circumstances can alter significantly, necessitating changes to the plan. The preferred way of working within any pilotage area can also vary between pilots.

Detailed exchanges can take place when the pilot arrives on board, as indeed can discussions on berthing.

Pilot on board
The pilotage passage plan will need to be discussed with the pilot as soon as he comes on board. Any amendments to the plan should be agreed, and any consequential changes in individual bridge team responsibilities made, before pilotage commences.

Where pre-arrival exchange has not taken place extra time and sea room may need to be allowed before pilotage commences in order to discuss the plan fully.

The pilot should be handed the Pilot Card and shown the Wheelhouse Poster . The Wheelhouse Poster provides a summary of ship manoeuvring information. A manoeuvring booklet containing more detailed information may also be available on the bridge.

Preparing the outward bound pilotage plan

After berthing and before the pilot departs the ship, the opportunity should be taken to discuss the outward bound pilotage passage plan with the pilot, bearing in mind that the precise way of working within any pilotage area can vary between pilots.

Passage planning and ship's routeing

Ship's routeing measures have been introduced in a number of coastal waters to:

- reduce the risk of collision between ships in areas of high traffic densities;
- keep shipping away from environmentally sensitive sea areas;
- reduce the risk of grounding in shallow waters.

The use of ships' routeing measures should form part of the passage plan.

Ships' routeing measures can be adopted internationally by MO. Such schemes are recommended for use by, and may be made mandatory for all ships, certain categories of ships or ships carrying certain cargoes. Mandatory ships' routeing schemes should always be used unless the ship has compelling safety reasons for not allowing them.

IMO routeing schemes will be shown on charts with a note of any pertinent provisions as to their use. Fuller details may be described in Sailing Directions. The IMO publications Ships' Routeing and Amendments to Ships' Routeing contain full descriptions of each scheme and any rules applying, but this publication is produced primarily for the benefit of administrations. It is not kept up to date as regularly as nautical publications, which should always be consulted for the latest information. Elements used in routing systems include:

- traffic separation scheme - a routeing measure aimed at the separation of opposing streams of traffic by establishing traffic lanes;
- traffic lane - areas within defined limits in which one-way traffic flows are established;
- separation zone or line — a means to separate traffic lanes in which ships are proceeding in opposite or nearly opposite directions in order to separate traffic lanes from adjacent sea areas or to separate different traffic lanes;
- roundabout - a separation point or circular zone and a circular traffic lane within defined limits;

- inshore traffic zone - a designated sea area between the landward boundary of a traffic separation scheme and an adjacent coast;
- recommended route - a route of undefined width, for the convenience of ships in transit, which is often marked by centreline buoys;
- deep water route - a route which has been accurately surveyed for clearance of sea bottom and submerged articles;
- archipelagic sea lane - sea lanes designated for the continuous and expeditious passage of ships through archipelagic waters;
- precautionary area - an area where ships must navigate with particular caution and within which the direction of flow of traffic may be recommended;
- area to be avoided - an area in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by ah ships, or by certain classes of ships.

Passage planning and ship reporting systems
Ship reporting has been introduced by a number of coastal states so that they can keep track, via radio, radar or transponder, of ships passing through their coastal waters. Ship reporting systems are therefore used to gather or exchange information about ships, such as their position, course, speed and cargo. In addition to monitoring passing traffic, the information may be used for purposes of search and rescue and prevention of marine pollution.

The use of ship reporting systems should form a part of the passage plan.

Ship reporting systems can be adopted internationally by IMO. Such systems will be required to be used by all ships or certain categories of ships or ships carrying certain cargoes.

The master of a ship should comply with the requirements of ship reporting systems and report to the appropriate authority ah information that is required. A report may be required upon leaving as well as on entering the area of the system, and additional reports or information may be required to update earlier reports.

Ship reporting requirements may be referred to on charts and in sailing directions, but lists of radio signals provide full details. Details of ¡MO adopted systems are contained in Part G of the ¡MO publication Ships' Routeing updated by the 1 996 Amendments to Ships' Routeing.

Passage planning and vessel traffic services
Vessel traffic services (VTS) have been introduced, particularly in ports and their approaches, to monitor ship compliance with local regulations and to optimise traffic management. VTS may only be mandatory within the territorial seas of a coastal state.

VTS requirements on ships should form part of the passage plan. This should include references to the specific radio frequencies that must be monitored by the ship for navigational or other warnings, and advice on when to proceed in areas where traffic flow is regulated.

VTS reporting requirements may be marked on charts but fuller details will be found in sailing directions and lists of radio signals.