New role of GNSS
in the safety of maritime navigation

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BIOGRAPHY

Commander Rosario LA PIRA is an Officer of the Italian Navy currently employed as Professor of navigation at the Italian Naval Academy in Livorno, primarily involved in radionavigation, Electronic Chart and ship manoeuvring. He is a member of the full Marine casualty or incident safety investigation board of Direzione Marittima Livorno - Italian Coastguard.

He holds a Deck Officer High School Diploma from Pozzallo Nautical School, a 2nd degree in Maritime and Naval science from Pisa University, a 2nd University Master degree in Maritime Geomatics from Genova University and a Category A FIG/IHO Hydrographer recognition from the Italian Hydrographic Office.

In a career of over 25 years, he served for 13 years on board of various Italian Navy Ships, as Navigation Officer, Hydrographic surveyor, Executive Officer and Commanding Officer. From 1996 to 2002 Cdr. La Pira served as Head of the Electronic Chart Department of the Italian Hydrographic Office and was actively involved in various Committees and Working Groups of International Maritime Organization (IMO), International Hydrographic Organization (IHO), European Commission (EC) and Radio Technical Commission for Maritime Services (RTCM) dealing with the standardisation of maritime electronic chart such as carriage requirements, performance, data production/exchange and services. He drafted the requirements for the Electronic Chart Display an Information System (ECDIS) of the Italian Navy and the national performance standards for the Electronic Chart System (ECS) of the Italian pleasure and fishing boats.

MARITIME SAFETY BACKGROUND

IMO introduces the issue of maritime safety as follows: Shipping is perhaps the most international of all the world's great industries - and one of the most dangerous. Ship casualties and incidents can result in serious loss of life and pollution of the marine environment as modern ship can carry over 5,000 people and over 500,000 tons of petroleum.

Maritime safety is of paramount importance in the new role of GNSS. Increased safety at sea should be considered while taking into account the most critical issue of supplying the master of a vessel and those responsible for the safety of shipping ashore with modern, proven tools to make marine navigation and communications more reliable thereby reducing errors, especially those with the potential to cause equipment damage, pollution harm to the marine environment, injury and loss of life.

Maritime safety in this case means to address the particular needs of enhancing the prevention of collisions and groundings. According to statistics, the number of ship collisions and groundings has not appreciably changed over the last ten years despite the growing technology. Furthermore, it should be considered that there are serious concerns about the secondary disasters resulting from collisions and groundings, for example, loss of human life and oil spills.

The EMSA statistics show that 762 vessels were involved in 715 accidents (sinkings, collisions, groundings, fires/explosions and other significant accidents) in and around EU waters during 2007.

The majority of vessels in the 2007 EMSA survey were involved in collisions and contacts (around 40%) and groundings (around 26%), while sinkings accounted for around 7% of the total and fires and explosions for around 12% (other 15%).

It is acknowledged that there is evidence to show that the great majority of accidents have a human error component, and also that seafarers often make mistakes under difficult circumstances (eg bad weather, geographical/infrastructure restrictions, fatigue, task overload, training shortcomings, etc.).

There are numerous examples of collisions and groundings that might have been avoided had there been suitable input into the navigation decision-making process.

1 INTRODUCTION

In recent years, the enhanced Global Positioning System has dramatically changed the way mariners, surveyors and other professional engineers measure positional coordinates.

For the scope of navigation, this development should not be considered independently, but should be viewed from a broader perspective of enhanced navigation as a result of the simultaneous improvements of existing and new navigational tools, in particular electronic tools.

Today, mariners as well as those ashore can use enhanced information derived from GNSS in a reliably and efficient way through the extensive electronic navigational and communication technologies and services available or in development, such as Electronic Chart Display and Information Systems (ECDIS), Automatic Identification System (AIS), Automatic Radar Plotting Aids (ARPA), Integrated Bridge Systems/Integrated Navigation Systems (IBS/INS), Vessel Traffic Services (VTS), Long Range Identification and Tracking (LRIT) systems, Global Maritime Distress and Safety System (GMDSS) and the Marine Electronic Highway (MEH).

All these technologies and equipment/System needs to be connected with an Electronic Position Fixing System (EPFS) such as GNSS to perform the concerning navigational tasks they are used for. Fundamental Navigational tasks necessary to support the mariner to conduct navigation safely such as “Route monitoring”, “Collision avoidance”, “Navigation control data”, “Navigation status and data display” and “Alert management”.

This paper will discuss the enhanced GNSS technology in the realm of maritime navigation from the user’s perspective through the integration of the other navigation systems used in the decision-making process and taking into account the latest changes in international regulations and standards already in force and those under consideration.

2 GNSS MARITIME REQUIREMENTS

Since the earliest days of navigation, seafarers have sought to keep track of their direction and position.

Since the beginning an important part of IMO regulations have dialled with ship positioning and the related equipments.

The first step of IMO in radionavigation positioning occurred with the International Convention for the Safety of Life at Sea (SOLAS), 1948 which required all ship over 1600 tons gross tonnage engaged on international voyages, to carry Radio Direction Finder apparatus. In 1968 the amendments to the 1960 SOLAS Convention, added requirements to carry radar. While in 1988 IMO adopted an amendment which allowed ships the possibility to carry a radionavigation equipment instead of the Radio Direction Finder. On 1 September 1984, new requirements for shipborne navigational equipment came into force, requiring large ships, especially tankers, to be fitted with Automatic Radar Plotting Aids (ARPAs).

In July 2002, new requirements for the carriage of navigation equipment come into effect following a revision of Chapter V of the SOLAS 1974 Convention (current situation). After 1 July 2002, the radio direction-finding apparatus is not more required. Whit the carriage requirements currently in force all ships constructed on or after 1 July 2002 shall be fitted with a receiver for a global navigation satellite system or a terrestrial radio navigation system, or other means, suitable for use at all times throughout the intended voyage to establish and update the ship's position by automatic means. It is the first time GNSS receiver come out in SOLAS convention.

2.1 GNSS Minimum Requirements

It is in IMO resolutions A.953(23) and A.915(22) where are specified the maritime navigation user requirements for GNSS. The first of these resolutions is interpreted as specifying operational requirements relevant to GNSS-1 (the first generation GNSS), whereas the second resolution is interpreted as being a living document specifying top-level requirements more appropriate to a future GNSS-2 (the second generation GNSS). The IMO resolutions contain the internationally adopted maritime requirements for general navigation. These requirements are applicable to all radionavigation systems. The maritime use of radionavigation systems pass through the IMO recognition. The recognition by IMO of a radionavigation system would mean that the Organization recognizes that the system is capable of providing adequate position information within its coverage area and that the carriage of receiving equipment for use with the system satisfies the relevant requirements of the 1974 SOLAS Convention.

Area	Absolute horizontal Accuracy (95%)	Signal Availability	Continuity	Warning (non-availability)	Update Rate
Ocean	$\leq$ 100 m	> 99.8% over 30 days	N/A	ASAP by Maritime Safety Information (MSI) System	< 10 s < 2 s*
harbour entrances-approaches and coastal waters with a low volume of traffic and/or less significant degree of risk	$\leq$ 10 m	> 99.5% over 2 years	$\geq$ 99.85% over 3 hours	< 10 s	< 10 s < 2 s*
harbour entrances-approaches and coastal waters with a high volume of traffic and/or significant degree of risk	$\leq$ 10 m	> 99.8% over 2 years	$\geq$ 99.97% over 3 hours	< 10 s	< 10 s < 2 s*

* If the computed position data is used for AIS, graphical display or for direct control of the ship

Table 1: Operational requirements for a world-wide radionavigation system (GNSS-1)

	System level parameters				Service level parameters			
	Absolute Accuracy	Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	Fix interval* (sec)
	Horizontal (m)	Alert limit (m)	Time to alarm* (sec)	Integrity risk (per 3 hours)				
Ocean	10	25	10	10^{-5}	99.8	N/A**	Global	1
Coastal	10	25	10	10^{-5}	99.8	N/A**	Global	1
Port approach and restricted waters	10	25	10	10^{-5}	99.8	99.97	Regional	1
Port	1	2.5	10	10^{-5}	99.8	99.97	Local	1
Inland waterways	10	25	10	10^{-5}	99.8	99.97	Regional	1

* More stringent requirements may be necessary for ships operating above 30 knots.
** Continuity is not relevant to ocean and coastal navigation.

Table 2: Future GNSS minimum maritime user requirements for general navigation (GNSS-2)

Current first generation GNSS (GNSS-1) such as GPS and GLONASS systems have been recognized as a component of the World Wide Radionavigation System (WWRNS) for navigational use in waters other than harbour entrances and approaches and restricted waters.
Future GNSS(s) are expected to improve, replace or supplement the current systems, which have shortcomings in regard to integrity, availability, control and system life expectancy. Early identification of maritime user requirements has been developed to ensure that these requirements are considered in the development of future GNSS(s). These IMO requirements should be incorporated in GNSS plans to be accepted for maritime use. The second generation GNSSs will meet the maritime user's operational requirements for general navigation, including navigation in harbour entrances and approaches and restricted waters. Furthermore the shipborne GNSS equipment should meet performance standards adopted by IMO.
The developing European Galileo have already considered these second generation GNSS requirements in order to make possible for the mariners broader and enhanced safety critical applications. Actual assessment of the Galileo navigation service requirements, as laid down in the most recent issues of the GALILEO reference documents, indicates that the IMO requirements for Oceanic, Coastal, Port approach and restricted waters operations as stated in resolution A.915(22), can be met by the GALILEO stand-alone system using the Safety Of Life service.

3 GNSS AND THE NAVIGATION SYSTEM

The navigation system includes the GNSS and the Chart System. In order to specify the overall navigation system requirements and performance of a vessel it is necessary to consider all possible contributions to the errors in navigation.

In the navigation system context of GNSS used in the maritime environment, the sources of error affecting overall navigation performance include the GNSS signal, the user receiver, the charts and the equipment and crew (e.g., human factors) controlling the navigation of the vessel. Therefore in determining the requirements of a GNSS used in the maritime environment, it is necessary to understand these contributing factors.

Obviously, the most important new equipment that needs input of GNSS data is the Electronic Chart Display and Information System (ECDIS).

ECDIS, as defined by IMO, is the navigation information system which with adequate back-up arrangements can be accepted as complying with the up-to-date chart required by the 1974 IMO SOLAS Convention (regulations V/19 and V/27), by displaying selected chart information derived from electronic navigational charts (ENCs) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and if required display additional navigation-related information. The electronic chart navigation with ECDIS and real-time GNSS positioning with improved performance (accuracy, integrity, availability, continuity, coverage and fix interval) is a relatively new technology that is considered to be the most important advancement in maritime navigation since the advent of radar almost 60 years ago. IMO adopted, on 23 November 1995, the first performance standards for ECDIS, by resolution A.817(19), recently amended on 05 December 2006, with resolution MSC232(82). However, the introduction of new real-time electronic navigation has not been an easy process since the first type approved ECDIS occurred in 1999. It is not just an electronic representation of a paper nautical chart on a colour display with own ship's position plotted on it, but it represents a new, more powerful navigation aid that significantly improves safety.

ECDIS reduces the navigational workload compared to using the paper chart. It is capable of continuously plotting the ship's position to enable the mariner to execute in a convenient and timely manner all route planning, route monitoring and positioning currently performed on paper charts.

The most important improvement is surely the real time positioning. With ECDIS plus GNSS the mariner knows for the first time where he is and not where he was a few minutes before. This represents a notable change because it allows some most effective and immediate evaluations on the route monitoring activities. At the same time it reduces the officer of the watch (OOW) workload to determine and to plot the ship's position on the paper chart, leaving him increasing lookout capability and more time to other evaluations and activity related to the safety of the ship.

It is also of great benefit the new possibility to monitor in real time the effective movement of the ship (Cog and SOG) on the chart feature and in comparison to the true course steered (Heading) and the speed Log. It makes possible the continuous evaluation of the angular difference between GOC and Heading (sum of leeway and drift angle). Very important feature during route monitoring in narrow channel with bad whether.

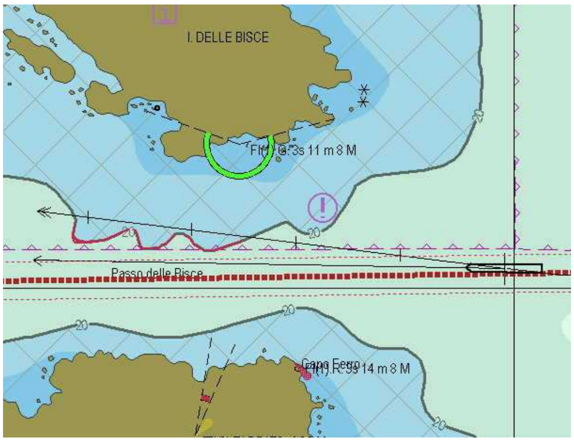

Figure 1: COG and SOG real-time monitoring

Moreover the GNSS integration on ECDIS makes possible the automatic generation of an alarm if, within a specified time set by the mariner, the own ship crosses the safety contour or the boundary of a prohibited area or of a geographical area for which special conditions exist.

It is in this context that mariners have the possibility to analyze in an efficient way their own ship's position related to the chart information for a safer decision-making process and where the best accuracy of the position data can be properly managed. This means that navigational risks could be reduced when using ECDIS compared to traditional paper charts.

It is for this reason that IMO has recently approved an amendment to SOLAS regulation V/19, introducing for the first time a mandatory carriage requirement for ECDIS with a view to adoption at the 86th session of the Maritime Safety Committee (MSC) in May 2009. No more only a mariner optional alternative to the adequate and up-to-date folio of paper nautical charts requirement.

The new ECDIS carriage mandatory requirement next to be adopted will have a phased implementation period from 2012 to 2018 depending on class of ship and tonnage.

Ship class	Gross Tonnage (KGT*)	New Construction on or after	Existing ship not later first survey on or after
Passenger	KGT≥0.5	1 July 2012	1 July 2014
Tanker	KGT≥3	1 July 2012	1 July 2015
Cargo	KGT≥10	1 July 2013	
	3≤KGT≤10	1 July 2014	
	KGT≥50		1 July 2016
	20≤KGT≤50		1 July 2017
	10≤KGT≤20		1 July 2018

* expressed in Kilo Gross Tonnage

Table 3 : ECDIS mandatory carriage requirement

Furthermore IMO has already agreed a carriage requirement for ECDIS on board all High-Speed Craft (HSC) from July 1, 2008 with a two years transition period for HSC constructed before (full mandate from July 1, 2010).

ECDIS are widely expected to improve safety at sea and make life easier for the navigator. Hardware, software and standards capable of supporting ECDIS have been available for some time, but to be of use they need chart and positional information.

Both these two kinds of information are the fundamental elements that make ECDIS a safe and reliable tool. They are the fuel and tyres that make the F1 cars win. Furthermore ECDIS performances are strongly dependent on their availability, reliability and quality. These make the real difference for the mariners to use ECDIS compared to paper chart for route monitoring activities and make ECDIS together with new enhanced GNSS a more powerful navigation aid that significantly improves safety.

3.1 ECDIS Chart Information

The chart information to be used in ECDIS are the latest edition electronic navigational chart (ENC), as corrected by official updates, of that issued by or on the authority of a Government, government-authorized Hydrographic Office or other relevant government institution, and conform to IHO standards (now S-57 and in future S-100).

The provision of chart information is a responsibility and obligation of the coastal State, so it is an issue that clearly the international rules put at the maximum level of importance.

This is an IMO obligation under regulation 9 of the revised chapter V of the International Convention for the Safety of Life at Sea (SOLAS), 1974, which entered into force on 1 July 2002. Regulation related to the provision on Hydrographic services under which is clearly stated that Contracting Governments undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and updating of all nautical information necessary for safe navigation.

Obligation that recall a previous United Nations General Assembly resolution (A/RES/53/32 -1988), that invites States to provide hydrographic services needed for safety at sea and the protection of the marine environment.

3.2 ECDIS Positional information

Noting that the collection and dissemination of accurate and up-to-date chart information is vital to safe navigation it is also evident that this accuracy will became useless if the positional information are not of the same reliability. This is more true for ECDIS compared to paper chart.

The last revision of SOLAS chapter V has introduced for the first time a mandatory carriage requirement of GNSS receivers from I July 2002.

The positioning requirements for ECDIS are clearly identified on the IMO Performance Standard for ECDIS (Resolution MSC232(82)). The ECDIS requirements related to positioning clearly identify the operational need to carry out the route monitoring activities in a simple and reliable manner. ECDIS is connected to the ship's position fixing system, to the gyro compass and to the speed and distance measuring device. The ship's position required is to be derived from a continuous positioning system of an accuracy consistent with the requirements of safe navigation. Whenever possible it is also required that a second independent positioning source, preferably of a different type, should be provided. In such cases ECDIS is able to identify and display discrepancies between the two sources.

Because of the fundamental importance of the position data input ECDIS has the requirement to provide to the user an alarm when the input from position sources is lost. Furthermore it also has to repeat, as an indication, any alarm or indication passed to it from position sources.

The collection and use of positioning data is a responsibility of the mariner. It is the mariners that asses which is the safety distance from dangerous chart features and the safety under-keel clearance through a quantitative estimation of the overall related accuracy.

If ECDIS relies on only GPS input, as it is a single position fixing system without integrity information, the exclusive use of this violates the golden rule of navigation: never rely on a single source of position fixing and try always to evaluate a quality indicator through LOP redundancy. A GPS ship's position as displayed on an ECDIS or plotted on paper chart can and should be cross-referenced using a separate independent positioning system, such as radar, Loran, visual, depth sounder etc. This is nowadays much more needed for GPS because of the absence of integrity information.

What are the requirements for position fixing for route monitoring?

The standard method of position fixing during route monitoring close to hazard such as coastal, restricted water and harbour approach navigation has always been by visual compass bearing while maintaining an appropriate Dead Reckoning (DR) and Estimated Position (EP) outlook. Furthermore it should be also available a backup method of fixing (usually Radar and radionavigation), independent from the primary, which makes possible for the mariner to cross-check and monitor the standard method. Currently, most often the primary position fixing method is GNSS with visual and Radar ranges as secondary. This is particularly true in restricted visibility conditions. The mariner should always have an indicator of the reliability of the ship's position that give trust of the route made good. This old rule still works nowadays and it is its violation that most often is the cause of grounding marine casualties.

The new challenge for the future will be to provide the mariner "assured positioning data" to fuel all the mandatory shipborne equipments and Systems as it happens for chart information. The key to success on navigation safety is first of all the quality of all the concern data throughout skilled and well trained mariners. This has been true for the past and will be true for the future beside the bridge navigation aids that make it possible for the mariners to use it better.

4 THE ISSUE OF QUALITY OF DATA

Hydrography from the beginning until nowadays was protected from the management of data quality issues by two natural barriers.

The first was the much better positioning accuracy available for hydrographic surveys compared to the one available to mariners. The second reason was on the means the surveyed data final product reaches the mariner end users, that was a printed paper chart with a scale of reduction. The power to control and to choose the scale of the printed chart, with its implicit limitation, makes it possible for Hydrographic Offices to include all the position errors in the graphic uncertainty (0.2 mm). The scale of the paper chart limits also the accuracy to which the mariner could plot geographic position on the chart (a plottable difference is considered to be 0.3 mm). In a common costal purpose chart with a scale of 1:100.000 it means that the graphic uncertainty produces a positional uncertainty of 20 m and a mariner plotable difference of 30 m.

4.1 The positioning barrier

The first barrier has been removed in the last years with the advent of GNSS and DGNSS and the consequent availability to the mariners of the same order of position accuracy of the hydrographic surveyors. This situation will be much more real in the near future with the enhancement of GNSS performances that will be delivered to the maritime navigation users. Nevertheless, the speed up of positioning accuracy has created a gap with some old surveys that need some years before updating.

In many parts of the world, even the most recent data available may have been gathered when survey methods were less sophisticated than they are now and the achievement of accuracy currently available with GPS was not possible. In these areas, GPS positions available to the navigator may be more accurate than the charted detail.

This deficiency may not be limited to sparsely surveyed waters of developing nations, but may also apply to the coastal waters of major industrial states. Fortunately, new survey technologies have improved the precision to which modern hydrographic surveys can be conducted.

Furthermore, in some areas of the world there are charts that are based on old surveys for which there is no determined geodetic datum or the datum is imprecise. Therefore in such areas, paper charts (and thus raster navigational charts - RNC) are not compatible with GNSS navigation, and it will take some time to resolve this problem. This makes it extremely difficult to accurately plot the ship's position obtained by the GNSS in relation to surrounding shoals and other dangers on such charts. The difference in the plotted position can often be significant and could lead to a casualty or unnecessary risk in restricted waters.

This has led to a specific IMO recommendation to the mariners to cross-check position using relative references such as visual or radar fixing or ECDIS radar overlay to provide for the immediate detection of datum inconsistencies in electronic charts, and immediately alert on potential positional shifts required for particular charts.

4.2 The chart scale barrier

The barrier of the paper chart scale was removed with the advent of the Electronic Chart era.

With ECDIS the mariner can change the scale of the video representation of the Electronic Navigational

Chart (ENC) without any limitation choosing to zoom-in and zoom-out as he wishes.

One of the most innovative aspects of digital cartography is represented by the fact, that for vector database (ENC) it would seem overcome the concept of representation scale ratio, since the hydrographic data are stored in absolute coordinates and therefore always in real scale 1:1. The protection of the carefully Hydrographic Office selected paper chart scale has been removed and subsequently also the user plottable limited difference.

It would seem therefore improper to speak of scale of an Electronic Navigational Chart. Nevertheless this reference cannot be removed because it is not more connected to the printed ratio of reduction but to the related content and accuracy it has been produced for. The concept of scale is still working as ENC compilation scale that refer to the scale at which the ENC was designed to be displayed and is related to the concerning navigational purpose.

It is important for the mariner to know that if he overzooms an ENC of a data compilation scale he will not get more data detail and better positional accuracy. This risk to overrate is increased in term of accuracy due to the fact that most ENCs have been produced by digitizing paper charts which were themselves designed to be used individually rather than as part of a database. Figure 1 and 2 put in evidence this risk – looking at the rocks close to P.ta delle Formiche in overscale the mariner performing route monitoring with DGPS could wrongly evaluate to pass between two of them; evaluation that for sure he will not realize in 1:1 scale display. The grater scale of representation gives expectation of grater detail and accuracy that instead should be experienced with a grater ENC compilation scale if available inside ECDIS storage.

Figure 2:
display scale = compilation scale (1:90,000)

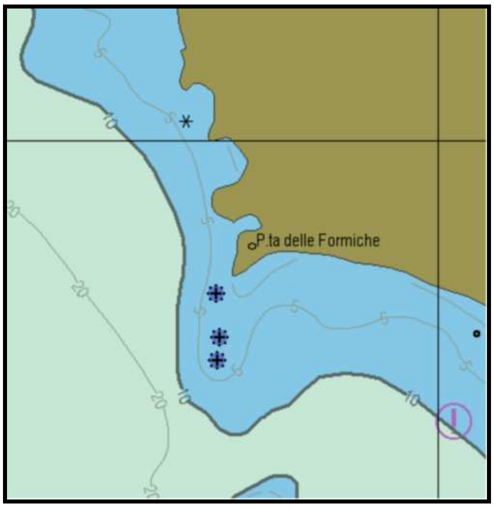

Figure 3:
display scale (1:20,000) > compilation scale (1:90,000)

As required by IMO Performance Standards, ECDIS should warn the mariner with an overscale indication whenever he selects a display scale that is larger than the ENC compilation scale. This is a new conceptual skill required to mariner ECDIS plus GNSS user.

4.3 Chart data quality indicator

ECDIS combines chart and navigational information in a powerful way that, by removing these two important barriers, gives the mariner a new aid with more accuracy expectation that is not always true.

As a result, there is evidence that enhanced navigation systems (e.g. GNSS and DGNSS) may offer comparable or more accurate positioning than the one provided by the ENC data. For this reason the IHO introduced a mandatory data quality indicator in the ENC, which allows a quantitative estimate of the accuracy of important chart features, to be used in combination with estimates of position accuracy from satellite navigation in assessing safe distance from hazards, in order that the mariner may be informed of the quality of the information he uses. This is another important new safety skill requirement for mariner user of future navigation system integration of GNSS and ECDIS.

A chart data quality indicator by zones of confidence (M_QUAL CATZOC) will cover the entire ENC (although not all data will be assessed initially). ZOC provide a simple and logical mean of displaying to the mariner the confidence that the national charting authority places on any particular selection of bathymetric data. It seeks to classify areas for navigation by identifying the various levels of confidence that can be placed in the underlying data using a combination of the following criteria:

- position accuracy,
- depth accuracy, and
- sea floor coverage (certainty of significant feature detection).

Under this concept there are six possible ZOCs value. ZOCs A1, A2, and B are generated from modern and future surveys with, critically, ZOCs A1 and A2 requiring a full area search. ZOCs C and D reflect low accuracy and poor quality data whilst ZOC U represents data which is un-assessed. ZOCs are designed to be depicted on the ECDIS electronic displays as a ready available symbol. The depth and position accuracy specified for each ZOC refer to the errors of the final depicted soundings and include not only survey errors but also any other errors introduced in the chart production process

5 ECDIS AND GNSS FUNCIONAL STATUS

ENC data for ECDIS are compiled for a variety of navigational purposes such as overview, general, coastal, approach, harbour and berthing (defined in the IHO ENC Product Specification, S-57 Appendix B.1). It is the responsibility of the coastal Hydrographic Offices to optimize and produce the ENC data that is most appropriate to the requirements of safe navigation in the area.

The future second generation GNSS receiver equipment should indicate to the user whether its performance is outside the bounds of requirements for general navigation in the ocean, coastal, port approach and restricted waters, and inland waterway phases of the voyage as specified in IMO resolutions.

As outlined above ECDIS and GNSS involved in the navigation system require some new important mariner skills related to the correct evaluation of quality of data. This evaluation is not an easy process and is of fundamental importance in electronic chart real-time positioning.

There is the need for a similar navigational purpose guaranty both for the Electronic Navigational Chart (ENC) and for the GNSS data. ECDIS should provide a functional status green, yellow or red light to warn the mariner performing the route monitoring of the overall navigation system situation related to the current type of navigation (coastal, approach, harbour, etc.).

FUNCIONAL STATUS	ENC	Positioning	
		GNSS	Other requirement
GREEN	Appropriate navigational purpose/scale for navigation available and up-to-date	Performance met the requirement for the navigational purpose	None
YELLOW	As above	Only accuracy performance met the requirement for the navigational purpose	Alternative appropriate positioning method required as integrity monitoring. Ship's position should be cross-referenced using a separate independent positioning system, such as visual, Radar, Loran, depth sounder etc
	As above	Performance not met for the navigational purpose	Appropriate positioning method required other than GNSS
RED	Appropriate navigational purpose/scale for navigation not available or not up-to date	Not applicable for ECDIS – refer to up-to-date paper nautical chart.	

Table 4: ECDIS +GNSS functional status

6 THE E-NAVIGATION STRATEGY

The rapid improvement of these new technologies and the consequent impact on maritime navigation resulted in the International Maritime Organization (IMO) considering in 2005 the need to develop a broad strategic vision. A new vision for incorporating the use of new technologies in a structured way and ensuring that their use is compliant with the various navigational communication technologies and services that are already available, with the aim of developing an overarching accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes.

This need has been summarized by a new concept of "e-navigation", where "e" stands for electronic and it is better to say "electronic-enhanced-navigation" since the electronic navigation has already been used in the maritime navigation for some years. What is new is the proper reliable and efficient integration of these electronic system and the related profit use of the related information technology. In December 2008, the IMO Maritime Safety Committee approved the strategy for the development and implementation of e-navigation along with a time frame and the framework for its implementation process. IMO also requested the participation of other international organizations (IHO, IALA, etc.) in the implementation of e-navigation.

This new concept has been well summarized in the definition: e-navigation is the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.

It is in this context that the new perspective and advantage of the GNSS information should be analyzed in light of the new requirements related to safety of navigation. Some of the most important requirements are:

- Information shall be automatically checked for validity and plausibility.
- Data failing these checks will trigger an alarm and should not be used by the system.
- The integrity of information should be monitored and verified automatically before being used.
- E-Navigation systems must have sufficient integrity and/or redundancy commensurate with the safety, security and environmental protection requirements.
- All navigation related information should be made available to the user in an effective manner via an integrated system.

7 CONCLUSION

ECDIS and GNSS are giving the mariner a powerful tool to increase operational performance and safety of the route monitoring activities. Furthermore it enables to conduct safely transits in confined and crowded waters that were previously not always possible. To make this integration reliable and successful the user has to know very well the capabilities and all kind of limitations related to the information provided such as ENC and GNSS data first and other sensor data supplied (AIS, ARPA, Radar, etc.). To obtain the maximum advantage and benefit from real-time navigation with ECDIS and GNSS positioning, a different approach by the mariner is required and a specific training program that provides comprehensive instruction on safe equipment operation as well as capabilities and limitations must be developed. This training program should use available modern, innovative instruction methodologies, including the use of simulators with integrated bridge systems, such as ECDIS, GNSS, ARPA and AIS system. The accuracy of GNSS position and the advantages of electronic charts will be worthless without this mutual system integration. This integration must occur in order to meet the user needs, in terms of coverage, accuracy and reliability for electronic charts and accuracy, integrity, reliability and system redundancy for position fixing systems.

It is important to be aware that in some areas chart accuracy is lower than that available from GNSS. Operationally, this discrepancy in accuracy requires the mariner to be alert to the danger of placing overconfidence in his position in relation to objects critical to navigation, which are likely to be located on charts to an accuracy inconsistent with that of the GNSS. In the future prospective of legal recognized real-time positioning in restricted water with enhanced GNSS and ECDIS, there is an urgent need, in some areas of the world, to revise charts to an accuracy consistent with GNSS and to a common datum. International bodies such as IMO and IHO are therefore giving high priority to this issue.

REFERENCES

EMSA, Annual Maritime Accidents Review 2007

IMO, SOLAS 1974, “International Convention for the Safety of Life at Sea”

IMO, Resolution A.915(22) “Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)”, 29 November 2001

IMO, Resolution A.953(23) “World Wide Radionavigation System”, 5 December 2003

IMO, Resolution MSC.232(82) “Revised performance standards for electronic chart display and information systems (ECDIS)”, 05 December 2006

IMO, 85th session of the Maritime Safety Committee (MSC), December 2008

IHO, S-52, Specification for Chart Content and Display aspect of ECDIS, 5th edition, 1996

IHO, S-57, IHO transfer Standard for digital Hydrographic data, edition 3.1, 2000

R. La Pira e D Francini, ASITA. 2001. La qualità nella cartografia nautica elettronica nel formato IHO/S57. 5^ Conferenza nazionale ASITA, ottobre 2001, Rimini.