 Center for Coastal and Ocean Mapping

12-2001

Harmonising Chart and Navigation-related Information on ECDIS

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ECDIS is a real-time navigation system that integrates a variety of chart and navigation-related information. More than simply a replacement for a paper nautical chart, ECDIS is capable of continuously determining a vessel's position in relation to land, charted objects, aids-to-navigation, and unseen hazards. Increasingly, ECDIS is being used for both navigation and collision-avoidance tasks. There is growing concern about the display of ever-increasing amounts of both chart and navigation-related information. When it comes to using ECDIS, displaying more information is not necessarily better. Too much information (i.e., clutter) may only lead to confusion. In this regard, there is need to 'harmonize' the simultaneous display of both chart and navigation-related information.

Background

Roles of Various Organisations

A number of international organisations have been involved in the development of information display standards for ECDIS. The International Maritime Organisation (IMO) adopted Performance Standards that broadly specified the types of information and levels of display (e.g., Base and Standard Display). The International Hydrographic Organisation (IHO) developed the colours and symbols specifications for chart-related information. The International Electrotechnical Commission (IEC) and the International Organisation for Standardisation (ISO) developed navigation-related symbols such as own-ship, radar/ARPA, and Automated Identification System (AIS) targets. More recently, the International Association of Lighthouse Authorities (IALA) has initiated an effort to standardise the display of Vessel Traffic Services (VTS) information.

Display Standards and Specifications

As it pertains to the display of chart and navigation-related information on ECDIS, it is useful to review what is stated in the various performance standards and specifications.

In November 1995, the IMO adopted Performance Standards for ECDIS [1]. It specifies that for chart-related information, the Electronic Navigational Chart (ENC) contains:

"all the chart information necessary for safe navigation, and may contain supplementary information in addition to that contained in the paper chart (e.g., sailing directions) which may be considered necessary for safe navigation" (Section 2.2).

It is further stated in Section 4.1 that the chart database used in ECDIS conform to IHO S-57 standards [2]. IHO took this one step further when it specified an ENC Product Specification in Appendix B.1 of IHO S-57 Edition 3.0.

In terms of how the chart information is to be displayed, the IMO Performance Standards specify that: *"IHO recommended colours and symbols (S-52) should be used to represent System ENC (SENC) information."* (Section 8.1)
For this, IHO developed IHO S-52, Appendix 2, Colours and Symbols Specifications [3].

As it pertains to navigation-related information, the IMO Performance Standards specify that:
Radar information or other navigational information may be added to the ECDIS display. However, it should not degrade the SENC information, and should be clearly distinguishable from the SENC information (Section 6.1).
More over,
the colours and symbols other than those mentioned in 8.1 [i.e., SENC colours and symbols] should be used to describe the navigational elements and parameters listed in Appendix 3 and published by IEC Publication 61174 (Section 8.2) [4].

While the intent of all this seems relatively clear and straight-forward, it is now being realised that the simultaneous display of both chart and navigation related information can lead to problems – if not properly harmonised.

IHO-IEC Harmonisation Group on MIOs

In November 1999, a Workshop on the Development of Marine Information Objects (MIOs) for ECDIS was held in Burlington, Ontario, Canada [5]. MIOs include such information as tides/water levels, ice coverage, current flow, weather, oceanographic, marine mammals, critical habitats, etc. During the Workshop, there was considerable discussion on whether MIOs were primarily chart-related, navigation-related, – or both. It was also recognised that two primary organisations were involved in regard to the simultaneous display of ECDIS information: IHO for chart-related and IEC for navigation-related (see Figure 1). For this reason, at the 11th Meeting of the IHO Committee on Hydrographic Requirements for Information Systems (CHRIS), it was proposed that an IHO/IEC Harmonisation Group on MIOs (HGMIO) be formed.

Based on the Terms of Reference that were agreed in June 2001 between the IHO CHRIS and IEC Technical Committee No. 80 (IEC TC80), the primary focus of the HGMIO would be to develop specifica-

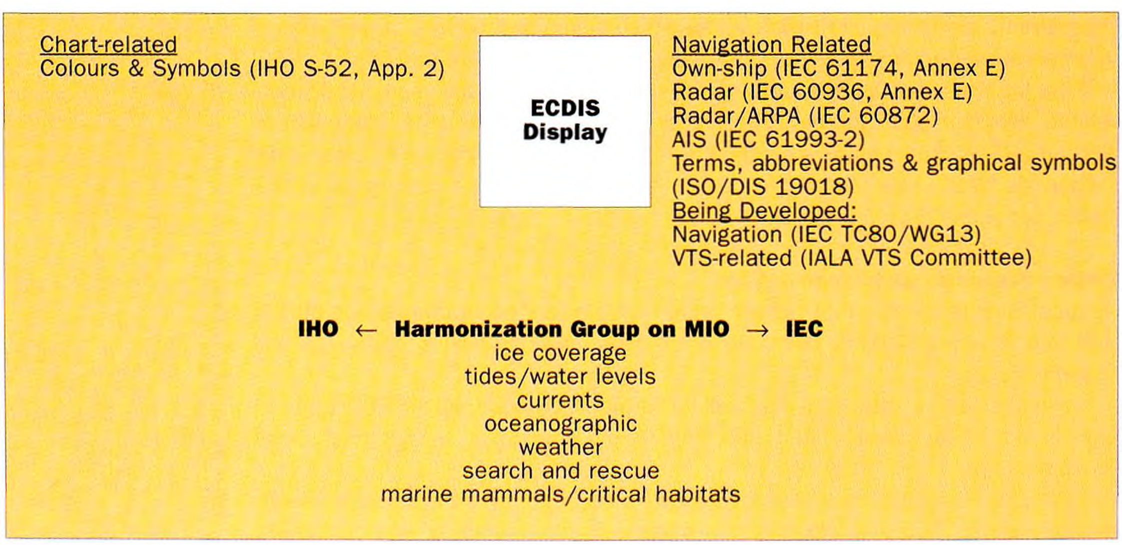

Figure 1: Current Standards for Chart and Navigation-related Information on ECDIS

tions for MIOs that would supplement the minimum chart- and navigation-related information required for safety of navigation. In doing so, the HGMIO would consider other ECDIS-related developments that involve the display of additional information on ECDIS such as VTS-related information proposed by IALA. It was also agreed that new standards for MIOs would not be finalised without first conducting comprehensive testing and evaluation, validation by ECDIS manufacturers and at sea-trials with mariners.
More recently, the IALA and IHO have established a Co-Operation Agreement that includes the development of standards of mutual interest to both organisations [6]. In particular, co-operation includes electronic charting, co-ordination of ENC, VTS and AIS symbology, and the development of symbology and displays for inland-waterway navigational charting.

Experience Gained – Lessons Learned

During the past 10 years, some experience has been gained regarding the combined display of chart and navigation-related information on ECDIS. These include:
- U.S. ECDIS Testbed Project [7]
- Canadian Electronic Chart Pilot Project [8]
- BAFEGIS Project [9]
- Great Lakes ECDIS Sea Trials [10]
- FGAN Ergonomics Study [11]
- Product Specifications for Marine Information Objects [12]

However, for some of these efforts, there was not rigorous testing based on defined criteria for evaluation, nor scientific testing/analysis. Nevertheless, work toward developing MIOs has proceeded.
Work on developing additional S-57 objects as well as symbols for the display of MIOs associated with ice information, water levels, currents, and weather is ongoing. In particular, there has been considerable effort in Canada related to the development of ECDIS Ice Objects [13]. There has also been work by SevenCs GmbH on proposed Object Classes and Attributes for Weather Information [14]. Additional project work is also being performed by SevenCs related to water levels and currents.
Some ECDIS manufacturers have implemented the ability to display MIO-related information. In particular, the Transas Marine NaviSailor 3000 can display information pertaining to wind speed and direction, tidal heights and periodicity, wave heights and direction, current flow and direction, and climatic data (weather) [15]. This information can be of particular use for route planning. However, there is a dilemma. While this capability could be made available on the Transas NaviSailor 2400 ECDIS, there is concern that this may affect the ECDIS type-approval certification. As such, Transas Marine offers this capability on more-advanced versions of their systems that have not yet been type-approved.

Future Trend

Regardless of how MIOs will be displayed on ECDIS, it will have to be in conjunction with other chart- and navigation-related information. This includes such information as radar, Automated Radar Piloting Aid (ARPA), Shipborne Automatic Identification System (AIS), and Vessel Traffic Services (VTS). Couple this information with the current display levels of chart-related information (e.g., base and standard display), and the ECDIS monitor soon becomes rather cluttered. The challenge is not to arbitrarily decide what each type of information should look like. Instead, the focus should be toward how any information should be displayed in conjunction with other chart and navigation-related information.

Some Problem Areas

The following discussion provides some examples of issues that warrant attention. My intent is to raise awareness rather than propose specific solutions.

Data vs. Information

While these terms are often used interchangeably, there are fundamental differences between data and information. The term '*information*' pertains to the knowledge or description of something. Once interpreted and understood, information can be used to make decisions. Books, and nautical charts are traditional examples of printed media that are used to transfer information. However, the information content is independent of the means of the media or means of transfer. When information is 'packaged' for transfer, the information becomes 'data' Obviously, there can be many types of data, depending on medium and on transfer technology (e.g., analog or digital). However, the data, as such, has no use or utility if it cannot be interpreted and understood. For instance, digital ENC data stored on a CD-ROM is useless unless you have a computer-based system (e.g., ECDIS) that converts it into a meaningful display of information.

In the case of ECDIS, it is the ENC (i.e., a database) that contains all the chart-related data that a Hydrographic Office considers is necessary for safe navigation. This data is packaged and distributed in digital format (e.g., on a CD-ROM). However, the data must first be converted into a System ENC (SENC) by the ECDIS, before it is displayed. What level of information is displayed is up to the user to decide (e.g., base display, standard display, or 'other information'). To say that an ENC is 'equivalent to a paper chart' is not correct. As defined in the IMO ECDIS Performance Standards: [1]

the SENC... that is actually accessed by ECDIS for the display generation and other navigational functions, and is the equivalent to the up-to-date paper chart. The SENC may also contain information from other sources. (Section 2.3)

The information from other sources can be either chart- or navigation-related.

Standard vs. Base Display

In the ECDIS Performance Standards, both a Standard Display and Base Display of SENC information are defined. [1] Aside from the inconsistent use of an adjectives and nouns in the wording of the ECDIS Performance Standards (i.e., using correct English grammar, it should be 'standard display' and 'base display' - not display base), the following definitions apply.

Standard Display *means the SENC information that should be shown when a chart is first displayed on ECDIS. The level of information it provides for route planning and route monitoring may be modified by the mariner according to the mariner's needs. (Sec. 2.4).*

Display Base *[sic] means the level of SENC information which cannot be removed from the display, consisting of information which is required at all times in all geographical areas and all circumstances. It is not intended for safe navigation. (Sec. 2.5).*

Some believe that these two different displays ought to contain a level of information content similar to that of a paper chart. Alternatively, some believe that mariners are not capable of deciding what is important chart information for the task at hand.

One example is the mandatory inclusion of fixed and floating aids to navigation in the Base Display. Although Section 2.3 of Appendix 2 of the IMO Performance Standards for ECDIS specifies that fixed and floating aids-to-navigation be part of the Standard Display, the IHO Colours and Symbols Presentation Library includes fixed and floating aids as part of the Base Display. The justification given for this decision was that the wording contained in Section 1.4 of Appendix 2 indicates that buoys and beacons should be considered 'isolated dangers which lie within the safe water.' While many mariners would consider this to be an illogical argument (i.e., in concept and in practice, aids-to-navigation are aids - not hazards), this implementation means that aids-to-navigation are always shown - regardless whether the mariner wishes to see them. At a small-scale display often used for route planning, this can lead to a very cluttered display where the buoy symbols may obscure a channel. Likewise, when operating with radar/ARPA in confined waters, there are often times during route monitoring when it is critical for the mariner to be able to decide quickly which targets are (and are not) the aids-to-navigation. The fact that the colours used for radar information and some buoys are both green, can lead to further problems of misinterpretation. There can be circumstances where green coloured buoys cannot be distinguished from the green radar overlay.

SCAMIN and Soundings

Scale Minimum (SCAMIN) is an attribute contained in the IHO S-57 specifications for ENC data. However, this attribute has significant implications in terms of display issues. As defined in IHO S57, Appendix B.1, Annex A - 'Use of the Object Catalogue for ENC': [2]

The SCAMIN of an object determines the display scale below which the object must no longer be displayed, in order to reduce clutter. In setting this level, the producer should consider both clutter and the scale which the object is no longer likely to be necessary for navigation.

The most widespread use of SCAMIN involves decisions by ENC data producers on what should be the density level for individual spot soundings. Under the SCAMIN concept, the density of soundings being displayed should change with the scale of the display (i.e., when zooming in or zooming out). Some (not all) electronic chart data producers try to base a SCAMIN factor on 'navigational purpose' [16]. Navigational purpose pertains to the general scale that the ENC was compiled and intended for use in ECDIS (e.g., overview, general, coastal, approach harbour, and berthing). However, this somewhat subjective decision mixes data and display (information) issues. For instance, the number of soundings contained in the ENC database could be very high. Depending on the desired scale, the density of displayed soundings could be relatively high at a small scale, or low at a large scale. Using SCAMIN to try to achieve a uniform density of sounding per display area (e.g., 100 soundings per a 10cm x 10cm display area on the ECDIS monitor) may give an impression that the spot sounding information is uniform throughout the entire ENC database. This can be misleading since sounding data is often based on the type/amount of survey data collected and/or the data compilation scale. Even within a single ENC cell, the sounding data is not always spaced uniformly – particularly if it is shoal-biased.

To further complicate the issue, regardless of how SCAMIN deals with soundings, there is a belief by some ENC data producers that mariners always want to see spot soundings displayed – regardless of the situation. This occurs even when there are contour layers showing a ship's 'safety contour' or colour-defined depth areas. The fundamental flaw in this logic is that it is the mariner – not the ENC producer -- who decides what needs to be displayed for safe navigation. Likewise, depending on the task at hand (e.g., route planning or route monitoring), different levels of display are required for the same geographic area depending on the situation.

Perhaps the best way to deal with SCAMIN is to consider Murphy's Laws of Science and Non-illogical Experimental Design:

"When you find yourself performing transfinite amount of work trying to decide what to do, the answer can usually be found by simple inspection." [17]

As mariners gain experience using ECDIS, they soon appreciate that they can turn on/off different content levels of display. In other words, modify the display and show only what is needed. The information that is not displayed (on purpose) is not lost or missing. When needed, it can easily be recalled from the SENC database. This is one of the fundamental benefits of using ECDIS compared to paper and raster charts. However, this concept of temporary and permanent information is new to many traditional chart makers.

Temporary vs. Permanent

The issue of what should be permanent and what can be temporary is a complicated and subjective matter. For many chart makers, the basic premise for what is contained on a paper chart is "what you see is what we think you need to know." In practice, this decision is based on many years of experience and knowing what chart information is/is not important for safety of navigation. While this approach makes sense in terms of what should be contained in the ENC database, it is not the same for the display. ECDIS provides a dynamic, real-time display of both chart and navigation-related information.

What type of information and/or content level is necessary for the current situation is up to the user to decide. For instance, many times a day a person may check their wristwatch to see what time it is. This can usually be done in just a few seconds, and does not require that the watch be held in front of a person's face all the time. The same applies to certain types of chart and navigation related information on ECDIS. Displaying individual depth soundings of a particular area can be important when a vessel is proceeding to anchorage. However, it is not necessary to clutter the display with sounding information at all

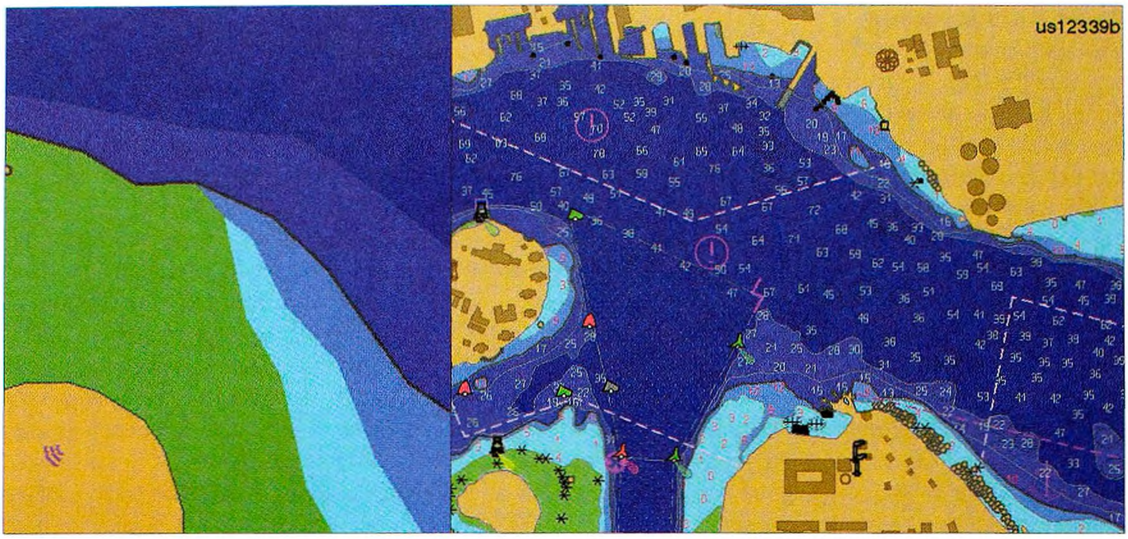

Figure 2: A possible bathymetric colour scheme for ECDIS display

times. What is important is that the mariner knows that this data is contained in the ENC (a database!) and how to display this *information* (i.e., turn on/off) when needed.

24-hour Colour Scheme

The IHO Colours and Symbols Specifications for ECDIS [3], lists five different background colour schemes:

1) Bright sun
2) Day-white background
3) Day-black background
4) Dusk
5) Night

The intended purpose of doing this is that depending on the time of day and lighting conditions on the bridge of a ship, displaying a white background during the day may be appropriate, but at night it would adversely impact the mariner's night vision. Some believe that this is an example of 'over-specification' on the part of IHO. Others feel that some of these colour schemes are ineffective, or counter-intuitive. In some cases, mariners do not use the IHO colours at all, and prefer those developed by ECDIS manufacturers [10].

At the 1999 meeting of the IHO Colours and Symbols Maintenance Working Group in Burlington, Ontario, it was agreed that a new 'Day Blue' (i.e., bathymetric) colour scheme should be investigated (Figure 3). Ideally, it could be used 24 hours a day rather than having to switch from day-bright (white background) to some other colour palette during dusk or night. The primary benefit is that day or night, the colours and symbols remain the same. At night, all the user would need to do is adjust the brightness or intensity of the display.

Clearly, a fair amount of simulator and at-sea test and evaluation is needed before this is decided upon as a standard. However, it may eventually be realised that a single, bathymetric colour scheme may be the preferred minimum standard for ECDIS - particularly when it is used with radar, ARPA, AIS, VTS information, and other types of marine information objects (MIOs). Having 3-5 colour tables for chart information will mean that IEC and IALA will have to develop 3-5 different colour schemes for navigation symbols. In addition to being a preferred display by Marine Pilots (inside a VTS Centre or Port Authority, it also has major implications for use onboard Navy vessels that may wish to have the same colour ECDIS display in the Operations Centre as on the Bridge. Finally, as more and more ECDIS installations include flat-panel displays, a predominately blue background may be the preferred colour scheme to use since a 'true' black background is difficult to achieve.

The Way Forward

The previous examples are intended to demonstrate some of the challenges associated with the simultaneous display of chart- and navigation-related information. During the original development of ECDIS colours and symbols, it was recognised early on that each colour, symbol, display draw priority, etc. had to be compatible with one another. A concerted effort was made to achieve a balance for both chart and navigation information. However, the situation has changed. There is now a trend to display increasing amounts of navigation and MIO-related information. But, simply adding more information to the existing display would be counter-productive. Too much information can clutter the display or cause some critical information to be obscured.

In terms of harmonising the type and amount of chart-information that should be shown on ECDIS, I suggest that a three-fold approach be followed:

1) Reduce and simplify
2) Adhere to guiding principles
3) Use a scientific approach for testing

Reduce and Simplify

Similar to the Laws of Natural Selection first identified by Charles Darwin, organisms (and human-developed systems) need to evolve and adapt to changing conditions. Like what occurred with whales and dolphins, appendages that no longer served any useful function were eliminated or evolved into fins. Also, whales and dolphins developed new capabilities that their land predecessors never had (e.g., sonar location, acoustic imaging, ultra-low frequency communication). For a variety of reasons, we need to make a concerted effort to reduce and simplify some of the chart-related specifications that were originally developed for ECDIS. First, we need to re-confirm (or re-establish) that IHO specifications – like the IMO Performance Standards that they serve – are 'minimum' specifications. They should not be regarded as the only way in which something can be accomplished. Over-specification stifles innovation and developing new/better ways of doing things. Since adding additional information is not only 'allowed' but also called for in the IMO Performance Standards for ECDIS, we need to look at more elegant means of displaying essential chart information. Also, alternative displays should be regarded as 'in addition to' rather than 'instead of' what is called for in the minimum specifications.

In this regard, there are some ongoing efforts by the IHO Colours and Symbols Maintenance Working Group to reduce and simplify some of the colours and symbols currently specified in IHO S-52, Appendix 2. The current 'dotted wallpaper' pattern used to denote a 'dredged area' will be changed to a small depth symbol within a narrow-lined border. Also, the 'hashed lines' (derisively called 'prison bars') currently used to indicate an over-scale display, will be reduced to a small box denoting a scale change. These changes are helpful, and more are being considered.

Guiding Principles

As described in the Introduction of IHO S-52 Appendix 2, the Colours and Symbols Standards were intended to ensure that the ECDIS display is clear and unambiguous [3]. Also, that there is no uncertainty about the meaning of the colours and symbols used, and to establish a familiar presentation pattern that would be easily recognised. IHO S-52, Appendix 2 also included some design considerations pertaining to colour contrast, luminance, background colours, and the need for day and night display. These considerations are useful, but when it comes to the display of both chart and navigation-related information, there are additional guiding principles that could be followed.

The following criteria are being used by IEC in the development of Shipborne Automated Identification System (AIS) symbology [17].

1) **Simple symbols** should be used to display basic information (KISS approach).
2) **Uniform and consistent** symbology
3) **Uniqueness** – only one possible meaning
4) **Non-ambiguous** – ability to determine differences (i.e., distinct)
5) **Intuitively obvious** – differentiate between own-ship symbol vs. ARPA or AIS targets
6) **Availability** - critical information is readily available

7) **Uncluttered display** – only show necessary information for the task at hand

Other criteria can be used as well such as the key 'interactive attributes of symbols' identified in a German study on Ergonomic Design for Presentation of AIS Information on Ships [10]:

- Detectability
- Legibility
- Interpretability
- Recognisability
- Preference

Scientific Approach

Before any determination is made on what is/is not suitable, a comprehensive test and evaluation effort should be conducted. As shown in the following test matrix (Figure 3), both chart-related and navigation related-symbols should be evaluated in conjunction with one another in order to determine the suitability and effectiveness of the various chart-related displays (i.e., SENC level of information) with different types and combinations of navigation-related information (e.g., own-ship, radar/ARPA, AIS, and VTS). Ideally, this type of testing will be performed both in a ship simulator facility and onboard vessels at sea.

	Navigation-related Information			
Chart-related (SENC Display)	own-ship	radar/ARPA	AIS	VTS
Less than base display				
Base display				
Standard display				
"other " (determined by mariner or VTS Centre)				

Figure 3: Test matrix approach to evaluating chart and navigation-related information

Looking Ahead

ECDIS as a Decision Support System

In the coming years, ECDIS will evolve from primarily a 'display' of chart and navigation information, to a decision-support system. For the 'Next Generation ECDIS', the chart information will become the background on which to display increasing levels of navigation-related information including:

- Own-ship (past track, current position, planned route)
- Radar overlay and ARPA targets
- AIS targets
- VTS (vessel traffic service)
- MIOs (ice, water level, currents, wave heights, etc.)
- Additional Military Layers (AMLs)

ECDIS will no longer be primarily a two-dimensional system (X and Y). In the future, mariners will increasingly expect ECDIS to include Z and time dimensions. Currently, we have the ability to conduct high-density hydrographic surveys capable of producing electronic chart databases that can display decimeter contour intervals or depth areas. This capability coupled with both forecast and real-time water levels will enable mariners to more precisely determine planned and actual under-keel clearance. Unfortunately, there exists some confusion about water levels in terms of data and display considerations.

In The Netherlands, a project has been conducted that demonstrated the utility of displaying changing contour levels and soundings based on a 12-hour tidal regime. This information can be highly useful in terms of forecasting the time and depth under-keel for heavily laden vessels entering a port. However, it is not clear if IHO S-57 Edition 3 'allows' the ability to display varying depths [2]. Nor is it clear if S-57 standards (e.g., objects) are the best way forward. Alternatively, some would argue that a dynamic water level is not a database but a display issue.

Implications for Mariner Training/Certification

There is a common-sense adage: 'A system is only as good as who is using it and what it is being used for.' Regardless of the capability of the system (e.g., type-approved ECDIS equipment), or the source and content of the ENC (e.g., HO-issued ENC data), or the accuracy of the positioning system (e.g., DGPS), it is the human factor that will ultimately determine how the system is used – and how well it performs. Similar to the employment of computers in the workplace, the proper use of ECDIS will require increasing levels of training for users. While many are becoming more knowledgeable about ECDIS, Training Certificates in the Operational Use of ECDIS will require a demonstrated level of proficiency [18].

Final Thoughts

In the final analysis, the three key aspects related to the proper use of (and dependence on) ECDIS will be:

1) Relying on data that is accurate and up-to-date (both chart- and navigation-related)
2) Understanding the capability and limitations of the entire system (hardware, software, data, sensor inputs, display, and human interface)
3) Knowing what information needs to be displayed - and when

Capt. Jean-Luc Bedard (Harbour Master for the Port of Montreal) said it best when he remarked during a Mariner's Workshop: 'When it comes to ECDIS, I don't want more information, I want better (information).' Better information is that which is required for the task at hand. No more than a person driving a car should be faced with a constant barrage of unnecessary visual or auditory information, a mariner needs relevant, accurate and up-to-date information clearly presented to meet his/her current needs. In the final analysis, hydrographers should determine the type and amount of chart data to be contained in the ENC. However, deciding what type and how much information should be displayed on ECDIS, is best left up to those who are actually using it – the mariners.

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This paper is a revised/updated version of a paper originally presented a the U.S. Hydrographic Conference, Norfolk, Virginia, 21-24 May 2001.

Acknowledgement

Brent Beale (Canadian Hydrographic Service) offered useful comments on a previous version of this paper. He also supplied the prototype 'day-blue display' for chart background. Robert Ward (Australian Hydrographic Service) and an anonymous reviewer provided critical appraisal and useful suggestions for this more recent version.

Biography

Dr. Lee Alexander is an Associate Research Professor at the Center for Coastal and Ocean Mapping at the University of New Hampshire, and an Adjunct Professor of Marine Science at the University of Southern Mississippi. Previously a Research Scientist at the U.S. Coast Guard Research and Development Center, he was a Visiting Scientist on Electronic Charts with the Canadian Hydrographic Service. His area of expertise is applied research, development, test and evaluation on electronic chart data and display, Marine Information Objects (MIOs) and the use of electronic charts for navigation safety and naval warfare. He chairs or serves on a number of international committees dealing with electronic charting, including IMO, IHO, IEC and NATO. He has published over 75 papers and reports on electronic chart-related technologies, and is a co-author of a textbook on Electronic Charting to be published in the fall of 2001. Alexander received his M.S. from the University of New Hampshire, and Ph.D. from Yale University. He is also a Captain (now retired) in the U.S. Navy Reserve.