TOWARDS THE NEXT GENERATION OF ECDIS

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Abstract

In addition to its sophisticated navigational functionalities and high accuracy rendition of the geographic and environmental information, ECDIS offers full integration of data for a total situational awareness and should be considered as an expert system capable of providing solutions to navigational and safety problems, and of automatic initiation of safety or emergency procedures. All dynamic data from outside systems, such as radar or AIS as well as environmental data from various sources can be fully integrated with ECDIS, which can then assist in finding safe solutions to navigational problems, especially in emergencies. It will be able to calculate and to present an appropriate safe avoidance manoeuvre or an escape route, taking into consideration all the available data: bathymetry, environmental conditions, own and other vessel's handling characteristics, even the regulatory restriction that may be in place. Automatic output of the instructions to the ship steering and engine controls can be easily implemented. Various regulatory restrictions may need to be removed to enable some of the useful functionalities, e.g. the dynamic depth adjustment. Similar applications of the ECDIS technology are being developed for the port management usages.

ECDIS is already the most comprehensive safety and decision support device on a ship's bridge and it can become as important in a cockpit of a small boat thus improving the safety of small craft. AIS for small vessels is being encouraged, since this is often the only way for a such a vessel to be visible to a large ship. At the same time, the AIS data presented on the small boat ECDIS will give its skipper a much better situational awareness. Voice output at the steering position of a small boat (e.g. in an open cockpit) will be another important safety tool, especially in poor visibility and/or bad conditions.

ECDIS

Electronic Chart Display and Information System or simply ECDIS displays the vector format Electronic Navigational Charts (ENC) - an equivalent of the paper charts produced by, or on behalf of, the Hydrographic Offices of the world. It is more than a navigational and anti-grounding tool of a ship, its safety features are much more sophisticated and it should be regarded as the main safety tool onboard a vessel. Even the present generation of ECDIS is already more than a paper chart on the screen, it provides more information, faster and more accurately than any previous navigational system. It has several features unavailable on the paper charts which relieve the navigators of many time consuming tasks and let them concentrate on navigational and ship management decisions.

The other advantage of ECDIS is its capability to display temporal variability of its objects, especially that of the non-cartographic information which represents the dynamics of the real world. Practically all objects which make up an ENC, including coastlines and bathymetry, change with time at different speeds, with various frequencies and with varying levels of predictability. The cartographic objects may be considered as constant while time variable navigational objects represent the dynamic variability of the elements surrounding the ships. Marine Information Objects (MIO) are used to encode these time varying data in accordance with the S-57 standard, and their representation will be through switchable overlays to prevent the chart clutter. These objects include i.a. tides and currents, weather, oceanographic parameters and Universal Automatic Identification System (AIS). The next generation of ECDIS will be able to handle all the dynamic variables and to present them dynamically in real or near-real time.

AIS and ECDIS

The AIS carriage requirements are defined in SOLAS V (Regulation 19) which states that all ships covered by it and constructed on or after 1st July 2002 shall be fitted with AIS. According to a retrofitting calendar all the so-called SOLAS convention ships must be fitted with AIS by 1st July 2008. Other vessels will be encouraged to fit the AIS voluntarily. The 9.11 events in the USA have introduced extreme urgency to the matter.

The inclusion of the AIS information in ECDIS will make the latter an efficient anti-collision tool and provide redundancy for radar. AIS allows to base navigational real-time decisions on information derived automatically and directly from another ship's electronic environment.

The information about the vessels in the vicinity of own ship is usually obtained from radar. It provides approximate position and course and speed of other vessels. ECDIS is regarded as mainly an anti-grounding tool. However, with addition of the AIS information, it will become also an efficient anti-collision tool. The AIS transponders provide much more information than radar is capable of: in addition to precise speed, course and position obtained from the vessel's GPS, they also identify the vessel and supply her basic handling characteristics. All information is available to all users in real-time. Identification, position and movement of targets can be obtained quicker and with more accuracy with AIS than with radar. Calculated information from the received data and other navigational information is more accurate and obtained quicker than from the Automatic Radar Plotting Aid (ARPA). AIS information can be displayed on ECDIS in a graphical manner that allows direct spatial reference to ship's own, target ships and/or other hazards. It will enhance situational awareness of the traffic situation to all users, and optimize traffic flow without significant increase in workload.

AIS operates on two dedicated VHF channels and is based on a cellular principle. In practical terms, the capacity of the system is unlimited and allows for a great number of ships to be accommodated at the same time. Its propagation is slightly better than that of radar, due to the longer wavelength, so it's possible to "see" around bends and behind islands if the land masses are not too high. A typical value to be expected at sea is nominally 20 nautical miles. With the

help of repeater stations the range and coverage behind topographical obstructions for both ship and VTS stations can be considerably enlarged.

There are three main options for displaying the AIS data on the bridge: dedicated display, radar and ECDIS. A dedicated display offers only very limited capabilities of integrating the AIS data with the geographic and environmental information. It also means an additional screen on the bridge which may not be easy to install and, more importantly, would be not as efficient as integrating AIS data with radar or ECDIS since the watch officer would need to divide his/her attention between more rather than less screens.

Radar will be able to support position monitoring of other vessels using AIS information, but its rendition of geographic and environmental information is limited and it may not have sufficient range to show all vessels of interest reporting via AIS. It has also limited capability to display additional information which is available through AIS. The only system which can at present support all the functionalities of AIS is ECDIS. In addition to AIS, it is fully capable of displaying radar/ARPA information, thus providing a double-check on any AIS carrying target with the same level of competence as radar. There are also other IMO requirements which radar cannot easily fulfill, but ECDIS can. ECDIS, being a vector system enables the user to query any displayed object for more information and is the only ready-made system which can provide this facility to AIS data. ECDIS can also export the route data for AIS transmission which neither radar nor dedicated AIS display can, since they do not have an in-built chart system.

It is planned that AIS transponders be fitted to fixed and floating aids to navigation to provide information to the mariner such as: position monitoring, functionality of aid, tidal and current data, weather and visibility conditions [1]. Once again, ECDIS is an ideal tool to display the information provided by the AIS attached to the aids to navigation. While radar can support position monitoring it is incapable of providing tidal and current data or weather and visibility conditions.

AIS ship-to-ship mode offers a large potential for collision avoidance. It provides the information necessary to evaluate a potential collision situation:

Where are the other vessels?	- position, bearing, distances, time
Which way are they heading?	- course, heading
How fast are they going?	- speed
Collision risk?	- CPA, TCPA,
Who are they?	- identification

In comparison with radar/ARPA, AIS offers improvement in the areas of target detection, tracking, evaluation and identification. It is not affected by clutter in bad weather and over very short distances. In general, AIS tracking is highly accurate, provided in near real – time, capable of instant presentation of target course alterations, not subject to target swap, not subject to target loss in clutter, not subject to target loss due to fast maneuvers and able to look around bends and behind islands. It also provides the users with identification information of the targets. In short, the navigator receives more information needed for collision avoidance quicker and with more accuracy.

ECDIS offers unification of displays for radar, charts, AIS, etc., with user choosing what and when he or she requires and combining the data as the need be. It can be considered as a total, integrated navigational system. It can already display charts and navigational information, radar/ARPA and AIS data. Additional data and information can be easily incorporated making ECDIS the most comprehensive safety device on a ship's bridge. It has been proposed that the multitude of screens on a ship's bridge be replaced by an Integrated Hazard & Collision Avoidance System (HACAS) unifying the displays for radar, charts, AIS, etc., and to giving the user an option to choose and display any combination of the data, as required. Only ECDIS can fulfill such requirements effectively.

Dynamic ENCs

ECDIS is capable of a dynamic display of various time varying objects which represent the real world around the ship. One of the most important variables is depth of water. At present, the depths shown in the ENC are digitised from the paper charts, rather than originated from the high density digital surveys. This reduces the accuracy of the bottom topography somewhat, but should not be the ground for prohibiting the introduction of dynamic depth display [2], [3], where bathymetry is combined with tidal and other data influencing the water level (e.g. storm surges). These additional data can be real-time or predicted. Some forward looking port authorities, like San Diego in California, have already installed the web-site and pilots' packages with a dynamic display of depths. This offers the port authorities the advantages not only in safety but also in traffic management. No other system can offer this functionality since none is designed to present bathymetric and environmental data.

It is expected that dynamic depth display will be soon allowed in ECDIS, especially in the areas where high density digital bathymetry is available. The demand is likely to come from the ship owners, once they realise that this capability will permit optimal loading of the vessels which can increase their profitability considerably.

Military uses

ECDIS technology is already being used for military applications, with more developments expected. Like the civilian thematic data layers, the Additional Military Layers (AML) will be overlaid on the chart as and when required by the navigator/tactician. Several AMLs are an extension of the civilian data and require no or few new objects or attributes, the others, purely military products are being developed from scratch. Some products may require the definition of both vector and model components.

Inland ECDIS

ECDIS is not restricted to the open sea navigation. The system has been already adapted to the requirements of inland navigation. Inland waterways are of prime economical importance on all

continents and ECDIS is vital to maintaining safety and efficiency of the navigation on the rivers, canals and lakes.

ECDIS developed by the SevenCs has an additional special capability of predicting ship's track and position over a selectable period of several minutes ahead. For the sea-going vessels this is of great help when manoeuvering in close confines, but for the inland shipping it offers an additional advantage of reducing the amount of steering input required during the voyage, with the concommitant increase in speed and reduction of fuel consumption. This particular capability has been turned into CEACT or Channel ECDIS and Course Trajectory System distributed in the North America by CEACT Information Systems, Inc. of Wayne, WV.

CEACT uses the charts in the official S-57 vector data format, produced by the USACE or NOAA. In addition to the standard features of the sea-going ECDIS, CEACT offers special features needed for inland navigation, such as true scale ship and barge towbuilding menus, channel text orientation to reduce clutter, rate of turn indication, etc. The real time course trajectory information is computed every second from shipboard heading, speed, rate of turn, course and positional data. Since all these variables are influenced by wind and channel current, the course prediction takes them into the account. Enabling the pilots to steer instead of sliding around the bends in the channel can improve propulsion efficiency, speed and control. The difference in fuel consumption between the pilots driving identical rigs over the same route can be as high as 7% [4]. With an annual fuel bill of say $50,000,000 for an inland shipping company, optimising the steering of all its vessels can save a considerable amount of money.

The course prediction also makes it possible to hold the vessel's position in bad visibility, e.g. at night or in fog. When not moving, the predicted position overlaps the ships outline, any movement is quickly detected and the pilot can compensate for it and maintain the position.

Several special objects and attributes had to be created to extend the system abilities for the inland navigation needs. In addition to the real time adjustable course predictor CEACT offers a seamless connection between the inland and coastal/offshore chart data, the engine of it is after all the same as that of an official ECDIS. An inland navigator will be able to use the CEACT when venturing into coastal areas, including the Intracoastal Waterway covered by NOAA. An offshore navigator on the other hand will be able to use the onboard ECDIS when sailing up the major rivers like Mississippi. What the US inland navigators now await is the release by the USACE of the official charts covering all the important inland routes. Further developments will follow in response to the users demand. It is expected that, with creation of the digital charts for the main rivers in Asia and Africa, the CEACT will become the tool of choice for the inland skippers of the world.

ECDIS and real-time data for Port and Coastal Zone Management

When used for navigation, ECDIS is restricted by the IMO/IHO regulations with regard to dynamic data presentation, but there are no regulatory restrictions on the port or coastal information systems and dynamic variables can be presented either real-time or as predictions.

These variables can include navigational, meteorological and oceanographic data as well as depth adjusted for tides and surges.

The web-based port management package developed for Port of San Diego by InterOcean Inc of San Diego together with SevenCs from Germany offers the harbour authorities new possibilities through real-time navigational and environmental data inputs and access to the land-based data bases for ECDIS presentation through the Internet. The data are presented on top of the ENC in form of thematic overlays using ECDIS technology. The real-time information transmitted from the environmental sensors includes weather, currents and tidal heights. As mentioned earlier in this paper, tidal data are used also to provide the real-time, dynamic under-keel clearance information in the ship manoeuvring areas. The data are supported by the web-camera images with zooming and panning capability and by the radar overlay and AIS information. Ship movement information is included together with static data showing relevant regulatory information, emergency response information, lists of facilities, fees, marine events, etc [5].

The information can be accessed from any computer equipped with a Web browser. The access is controlled by a multiple level password structure. The system offers the port authorities the advantages not only in traffic management, but also in pollution control, safety, and public information.

The PORTS and other CO-OPS initiatives of NOAA will provide the basis for similar, even more sophisticated systems for other ports. The Physical Oceanographic Real-Time System (PORTS) is a program of the National Ocean Service that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions. The Center for Operational Oceanographic Products and Services (CO-OPS) collects, analyzes and distributes historical and real-time observations of water levels, coastal currents and other meteorological and oceanographic data with an aim of providing the most accurate models and predictions for the mariners and other users.

ECDIS methodology of display of dynamic variables can be easily extended to coastal zone applications. Future uses can include e.g. presentation of coastal flooding predictions, disaster management, etc., and ECDIS-type software may become a new tool not only for scientists but also for coastal zone managers and insurance offices. Basing such systems on the web will provide the general public with access to important information.

ECDIS as an expert system

ECDIS offers sophisticated navigational functionalities and high accuracy rendition of the geographic and environmental information. It can also fully integrate the data from various sources togive the user a total situational awareness. It can be an expert system capable of providing solutions to navigational and safety problems, and of automatic initiation of safety or emergency procedures. The information from outside systems, such as radar or AIS as well as dynamic environmental data from various sources can be fully integrated within ECDIS, which can then assist in determining solutions to navigational problems, especially in emergencies. It can take into consideration all the available data: bathymetry, environmental conditions, own and

other vessel's handling and behavioural characteristics, even the regulatory restriction that may be in place, calculate the possible results on the fly, and present a solution, e.g. an appropriate safe avoidance manoeuvre or an escape route. Automatic output of the instructions to the ship steering and engine controls can be easily implemented. A more futuristic, but still realistic application of the ECDIS capabilities is the remote pilotage. ECDIS can export and import routes and, using for example the spare capacity of the AIS bandwidth, this information can be exchanged between the ship and a land based control centre (VTS, pilot centre). The preplanned route can be substituted then by the one modified by the local controllers allow for the latest traffic conditions. In extreme cases the actual pilotage could be done remotely, with ECDIS receiving the information and converting it into instructions for ship controls. This is not to advocate the replacement of pilots by the electronics, but to provide emergency override for ship controls if the navigators onboard are not capable to perform their tasks, due to e.g. accident, sickness, etc.

ECDIS is the most comprehensive safety and decision support device on a ship's bridge or in a cockpit of a small boat and is just as important for the pleasure and fishing craft as for the large vessels. The smaller boats frequently have no radar and usually no room for dedicated displays. However, ECDIS and similar systems are becoming prevalent on small vessels and are the best means to display all navigational information, thus improving the safety of small craft. The new functionality of voice output is a particularly important safety feature of ECDIS for the recreational sailors and fishermen. The IALA AIS recommendations for AIS equipment and its operation to IMO and other organisations cover not only the SOLAS class vessels but also Aids to Navigation and small boats AIS. The AIS transponders for these applications will be of simpler type that those for SOLAS vessels and the messages which they will be able to transmit will be tailored according to needs. Since many small vessels do not carry radar, this AIS application will improve considerably their safety. AIS for small vessels is being encouraged, since this is often the only way for a such vessels to be visible to a large ship. At the same time, the AIS data presented on the small boat ECDIS will give its skipper a much better situational awareness. Dynamic depth information is as important to the small vessels as to the large ones. Voice output at the steering position of a small boat (e.g. in an open cockpit) will be an important safety tool, especially in poor visibility and/or bad conditions when it may be impossible for a small boat skipper to check the boat's position visually on a the ECDIS screen hidden in the cabin. All these developments will result in a considerable improvement in safety for the small craft. They are either already available, or will become so in the near future. ECDIS in the small boats can become their *de facto* integrated navigational system.

Has ECDIS the future?

ECDIS as we know it today is not a thriving success and its future does not seem very rosy despite all its capabilities described above. In its form specified by IMO and IHO it increases costs and at the same time is still not fully operational, due to the continuing lack of official digital charts. It is also not a carriage requirement. Eventually, however, ECDIS will make its way to the bridges of all SOLAS vessels not "just" because it reduces the workload and prevents disasters. Without a carriage requirement in sight ECDIS will finally be successful when it is integrated with the current paper chart regime. It is expected that only then the non-type

approved Electronic Chart Systems will succumb to certified ECDIS, capable of e.g. printing the paper charts onboard on demand. The quality of such print on demand (POD) system is likely to be comparable with that of the POD charts produced by NOAA. There should be no problems accepting such charts as an official back-up for the ENCs originating from the same onboard data base. The inventory of paper and digital charts can be integrated to turn ECDIS from a luxury item into a widely accepted commodity. The old acronym will acquire a new meaning – Efficient Chart Data Inventory System [6].

Summary

We should try and remain optimistic about the future of ECDIS. It deserves to survive and to thrive. This is the best navigational system available and nothing better looms on the horizon. It can save or make money for the ship operators. It can also be expanded for other, non-navigational uses. And in combination with other forthcoming technologies it offers unbeatable value in providing safety to navigation and to environment.

AIS offers obvious advantages in safety of navigation, particularly in collision avoidance, where it provides redundancy for radar. Its full value cannot be realised however when the AIS information is displayed on a dedicated unit or on the radar screen. At present, only ECDIS can support the AIS to the full extent of its capabilities. AIS is now the carriage requirement and since the official chart coverage is finally increasing, it can be expected that the two systems – AIS and ECDIS - will become inseparable on most ship bridges in the future.

Presentation of other dynamic variables, especially of dynamic depth or underkeel clearance, is possible only on ECDIS. Interfaces with the necessary real-time or near real-time information sources are already a reality, and so is dynamic depth adjustment, as well as Internet chart and data access and presentation. Long term aims include provision of the high density digital bathymetric data and determining the methodology of supplying dynamic data by various scientific, government and commercial organisations. New data exchange formats, such as Marine XML [7], are being considered to improve interoperability of various data bases and other data sources with the users on ships.

New MIOs will enhance further the capabilities of ECDIS and increase the safety of navigation. The move from offshore or coastal waters to inland navigation will be seamless, with additional land description information and symbology coming automatically from a built-in environmental data base. ECDIS will become then a fully-fledged Marine GIS rather than a simple electronic chart. Dynamic variables will be supplied by the real-time transmitters, models, predictions or by any combination of these. New methods of display will be needed. The present two-dimensional display is likely to remain mandatory, but it restricts ECDIS to the methods used by the print technology. Many MIOs are three dimensional in their effect and it is not easy or efficient to represent this on an electronic copy of a paper chart. A prototype three-dimensional display has been already developed, with more sophisticated solutions, e.g. based on neural networks [8], being under way.

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