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THE PRICE OF ECDIS - IS IT WORTH PAYING?

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Abstract

The idea of an Electronic Chart Display and Information System (ECDIS) was conceived a number of years ago and recent events, particularly the introduction of Differential GPS, have reduced the value of its original concept. It can now be argued that there are other means of applying a computer to the problems of marine navigation that will yield the mariner greater benefit than ECDIS. However, ECDIS has acquired a powerful momentum, with studies and investigations being conducted all over the world; this momentum may soon become unstoppable - so the time is ripe for a second look.

The principal point at issue is 'legal equivalency'; whether a computer system can ever replace the paper chart in all its functions and still be easy to use by a young ship's officer who does not speak English - or by a senior and experienced Master of any nationality who has had no exposure to computers. It is suggested that a more practical approach is to retain the paper chart in its present form (accepting that it will be increasingly produced by computerized methods) and to use the shipboard computer instead as a navigational tool that supplements the chart, the pilot, Notices to Mariners and all the present proven navigational support structure. The paper compares the two approaches in different situations and assesses their relative value.

INTRODUCTION

Fifteen years ago the concept of combining positions from Loran-C or Decca with the image from the radar, on a single computer screen whose background duplicated the published paper chart, excited many imaginations. The possibility that this computer based chart could be corrected by inserting a floppy disk,

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eliminating tedious manual chart correction, made it even more attractive. It follows however that if navigation is to be based solely on the computer display then the computer based chart must replace the paper chart in all its aspects; this has always been the premise of ECDIS.

The International Hydrographic Organization (IHO) and the International Maritime Organization (IMO) have set up numerous committees to consider different aspects of ECDIS; these have resulted in Reference 1 - the Third Draft of Specifications for ECDIS - and Reference 2, on Updating the Electronic Chart. A comparative trial of six different systems has been held in Norwegian waters and an ongoing trial has been conducted aboard a Norwegian ferry. All of these experiments have confirmed the value of a computer based navigation display.

An event has recently occurred however that will affect all forms of navigation; the Global Positioning System (GPS) is now available for marine use 24 hours a day and is providing 100 metre accuracy anywhere in the world. When used in differential mode (DGPS) the accuracy is increased to about 5 metres, and differential corrections are already available in NW Europe and the Gulf of Mexico from one of the Inmarsat satellites. By the time GPS is officially released for navigational use it is probable that differential corrections will be available worldwide, first by satellite and eventually over the existing network of radio beacons. The impact upon ECDIS is that DGPS positions will not benefit from supplementary inputs, either of radar or conventional radio navigation. There is always the need for redundancy, to protect against hardware failures, but radar or Loran-C and the paper chart provides better protection than any wholly electronic combination.

There is a disadvantage to a computer system based on the paper chart, in that the scale of the display is necessarily limited to that of the chart. A case has been made for an Electronic Navigation System (ENS) (Ref. 3), in which the ships track is entered numerically, without reference to the chart. Used in conjunction with DGPS, it can provide a Blind Navigation Aid, capable of guiding a vessel up an entrance channel and into its berth. This paper compares an ENS with ECDIS in order to show that a computer system that is designed to be used in conjunction with a paper chart has advantages over an ECDIS system used on its own. It is not however claimed that ENS is the only such alternative; it is to be expected that many different approaches will be developed over the course of time, to meet the requirements of different classes of vessel. Each however will retain the paper chart as the primary shipboard source of navigation data.

It is not claimed either that this suggestion is original; the following quotation is taken from a paper presented by a Director of the IHO who has long been a proponent of ECDIS. '... In retrospect, one may wonder if the procedure of developing Provisional Performance Standards as attempting to satisfy the 'equivalent' criteria of the SOLAS Convention was the best way to go. It is becoming increasingly clear that ECDIS will serve its greatest purpose, not as an equivalent to the paper chart, but as a completely new kind of navigational instrument that has the potential for integrating a selection of the chart information with navigational information and radar data. As such it provides the navigator with a system that is complementary to the paper chart rather than equivalent to it' (Ref. 4). Such a system however is not an ECDIS.

THE ELECTRONIC NAVIGATION SYSTEM

The term Electronic Navigation System is not yet in general use but for this paper it is defined as a shipboard computer system in which the vessel's desired track is entered into the computer, either in plane co-ordinates on the local survey grid or in latitude and longitude, and an outline of the vessel is displayed to scale, relative to this track. Whatever the form of input, the display is on the Mercator projection on WGS 84. The only positioning input is Differential GPS (DGPS), with heading input from gyro or fluxgate compass and speed input from the log. It would be possible for such a system to guide a vessel from dockside to dockside, in any visibility conditions - yet there is no data taken from the chart, so there is no limitation on the scale of display. In practice it may be desirable to show some charted information but if the position of this data is taken from the chart the user will be warned that it should not be used for navigation - to avoid imposing a scale restriction. In those cases where graphical data is inserted from surveyed co-ordinates, such as the edges of docks, it would be clearly differentiated from data taken off the chart so that the mariner would know that he could trust it at any scale. Note that no depths would normally be shown, the safety of the selected track having already been determined.

An ENS that would guide a vessel from seabuoy to seabuoy could be very simple and would not require the heading input. However the full utility of such a system will not be realized unless it can also guide the vessel up the entrance channel and alongside the dock in reduced visibility - a capability that requires access to data not normally available to the mariner; data that must be obtained by the ENS supplier and delivered as part of the system. This data will come from one of two sources, depending on whether or not the channel was dredged. Within the U.S. (and it is presumed in most other countries) a dredged channel is always defined on the local survey grid, normally by the co-ordinates of the centreline and the distance to each toe; these values are used by the dredging contractor to dredge the channel and again by the Corps of Engineers, or its survey contractor, to certify payment. If similar data is stored in the ENS computer then vessels transiting the channel can be guided along it just as a hopper dredge is guided along it. In the other situation, where the port has a deep water entry, it is only necessary that all vessels entering in low visibility should follow the same route and that all vessels leaving should follow a similar, preferably different, route. This would of course require that the Coast Guard should define such routes and publish them. In either case vessels approaching would be able to advise each other of their distance on one or other side of their common trackline.

For brevity throughout this paper the terms 'Coast Guard' and 'Corps of Engineers' are used. Outside the U.S. the first term should be read as the agency responsible for the regulation of marine affairs and the second as the port authority or other body responsible for dredging and maintaining waterways. It should be noted that just as an ENS does not replace the paper chart, it does not replace the pilot, whose local knowledge is still essential to advise where recent shoaling exists, for example.

A full ENS would compute the strength and direction of the tidal stream and current continuously; if interruption of the differential signal, shortage of satellites or hardware failure rendered the GPS output unreliable, the ENS would go into dead reckoning mode automatically, using the most recent current values to compute an estimated position and allowing positions computed from other sensors to be entered through the keyboard.

The user would have the ability to print the ship's position, both on demand and at specified intervals, and a continuous record of position, heading and speed through the water would be maintained automatically at whatever interval and for whatever period is called for by future regulations. For brevity this system will be described as ENS, but whenever this term is used hereafter it should be taken to refer to the use of an ENS in conjunction with the current published paper chart of the appropriate scale.

ECDIS

It is more difficult to define an ECDIS since it is a more complex system for which final specifications have yet to be determined. (Reference 1 contains the current draft). For this paper the ultimate version will be assumed, one that has the ability to display every chart that the vessel will need, readily available, and that has the same capabilities as the ENS in terms of: route entry, display of offtrack distance and distance to go, position printout, and automatic record. It is also assumed that, since this version has met the legal equivalency standard, no paper charts will be on board the ship.

ROUTE PLANNING

Any voyage is preceded by a planning stage in which the Master examines the charts and selects the route that he wishes to follow. At first sight ECDIS appears to have the advantage; there is no need to look through a chart index to identify the required chart and then to search the drawers to find it - just press a few buttons and the chart is on the screen. However only a part of the chart can be seen at one time. A typical large computer screen provides an area of 34.3 cm (13.5") x 27.4 cm (10.8") - considerably smaller than the average chart. Even with instantaneous switching from one part of the chart to another few users are likely to find this as convenient as the ability to see the whole chart at one time.

So far the score is about even, but in the next step ECDIS is a clear winner. Having chosen a waypoint, the Master can move a cursor over it and press a button; with ENS he must write down the position and enter it into the computer in a subsequent operation. In either case it is presumed that he would have the choice of selecting a Great Circle or Rhumb line track and of entering a radius of turn, when different from the default value for his vessel, so that the wheelover point may be calculated. There is also a further necessary step with ENS. The Master should consider the possibility of diversions, caused by fishing fleets or converging ships, and enter appropriate navaids, shoal areas or other points of interest, in effect building up his own electronic chart. In areas of congestion, traffic separation zones may already be on file, but where not, he might choose to enter danger lines on each side to define the area within which the ship could safely manoeuvre. This is however a one time operation since both the route and the data files can be recorded for later re-use.

ON PASSAGE

On a routine passage, with the ENS files correctly prepared in advance, there should be little difference between the two systems. The prudent ENS user would transfer periodic fixes to the paper chart but the ECDIS user would not have this option. In the event of GPS failure, ECDIS would take its input automatically from Loran-C or Decca, while ENS would go into dead reckoning mode. In this mode the user would have the ability to enter latitude and longitude through the keyboard, with conversion to WGS 84 performed by the computer. This position would not of course be restricted to radio positioning but could also be taken from astro fixes or compass bearings.

If the computer system fails however, ENS has the advantage, since there can be an immediate transfer to conventional navigation. The operator of an ECDIS fitted ship is faced with a difficult decision at the time of purchase; he must either install a redundant ECDIS system, with an independent source of power, or he must continue to purchase and maintain paper charts, thereby negating a major benefit of ECDIS.

PORT ENTRY IN LOW VISIBILITY

It is here that an ENS provides its greatest benefit, since if all vessels under way are ENS fitted, good communications and a minimum of shore control will permit them to enter and leave port safely, even to the point of going alongside their berths in zero visibility. The distinction between the two systems is that an ENS has no scale restriction - if the pilot or Master likes the image of the ship to fill the screen while docking, it can safely do so. An ECDIS on the other hand is restricted to the scale of the chart on which it is based, by any prudent hydrographic or navigational standard. It is true that Reference 1 appears to allow enlargement of the chart scale, by suggesting a warning if the display is 'overscale'. It is doubtful however that any hydrographic office would take responsibility for data which was used at a larger scale than that at which it had been surveyed or compiled; in that case responsibility could devolve upon the manufacturer of the system that allowed the user to select such a scale. Since the penalty for a marine disaster could bankrupt most commercial companies it is likely that system suppliers will take steps to prevent such use.

This is not to say that an ENS could not be improperly used; the Master of a cruise ship who wanted to give his passengers a thrill could still scale off a position half way between two islands a tenth of an inch apart on the published chart, and attempt to take his ship through. That however would be his responsibility. If, on the other hand, the files for a port had been supplied to the Master by the ENS supplier, he would know that they had been approved by the Coast Guard.

EASE OF MAINTENANCE

At first sight, ECDIS is the uncontested winner, it being far easier to insert a floppy disk once a week than it is to correct an outfit of charts by hand - and easier still if corrections are input automatically from Inmarsat. This is however an over-simplification. The database (termed the HO-ECDB)[1] will be supplied by Hydrographic Offices in a standardized format which is yet to be agreed. It is recognized that a format that is suitable for interchange will not be the most efficient means of storing the data within the ECDIS and each manufacturer will be free to develop his own database(Reference 1, 6.2), which is called the Ships-ECDB. Each manufacturer's Ships-ECDB will be different but each is subject to weekly correction by Notice to Mariners, which will necessarily be in HO-ECDB format and therefore incompatible. It is difficult to visualize a software package that could accept the corrections and convert them to Ships-ECDB format aboard ship automatically, given the considerable range of topics that Notices to Mariners can include. A feasible solution would be for the manufacturers' cartographers to convert the data to the different Ships-ECDB formats and send correction disks to each ship - but this would double the delay and make automatic update via Inmarsat impossible.

So far only one nation's HO-ECDB has been considered, but a Norwegian vessel might carry Norwegian charts of the Baltic, British Admiralty charts of the English Channel and North Atlantic, and Canadian charts of the St. Lawrence. Each nation would produce its HO-ECDB in identical format so the Ships-ECDB could be updated from each - but to insert Notices to Mariners the procedure must be repeated three times each week. This however will not be the end of the problem; Norwegian and British coverage of the North Sea overlaps as does British and Canadian coverage of the North Atlantic. The original databases may very well agree, but Notices to Mariners are produced by each country independently in a process in which time is of the essence - the same information may be given different treatment by each office.

Suppose a sector light was established in a Danish port for which Norway published a harbour plan but the Admiralty did not. The Norwegian correction would show the full characteristics while the B.A. Notice, since it was only correcting a small scale chart, would insert the light but might only indicate that it was flashing. If the Ships-ECDB was updated in the sequence Norway, Britain, Canada, the correction would be applied in full on the first pass but then abbreviated on the second one, particularly if the British Notice had a later date.

[1] the terminology is that of Reference 1.

It was presumably to avoid situations like this that caused the Working Group on Updating the Electronic Chart to recommend the establishment of Regional Centres and Regional Updating Coordinators (Reference 2, 8.2.3). Such centres are unlikely to be established in the early days of ECDIS use and in any event it is not clear that co-ordination alone will prevent errors of this type from occurring. It is not suggested that this problem is insurmountable but it is typical of the type of problem that will have to be solved before ECDIS is a viable system.

It is apparent therefore that entering the weekly corrections, at least in the early days, will not be a trivial undertaking. If the corrections are received by satellite they could be recorded in a file automatically, but it is unlikely that the file's subsequent incorporation into the Ship's-ECDB could be accomplished without operator intervention. This raises a further point. Today's operating system of choice for a computer system of the complexity of ECDIS is UNIX, which is rapidly becoming the standard for applications of all types. Every UNIX system however requires a System Administrator, an experienced UNIX user, to look after it - and this is not an easy task. The author has had 20 years experience in programming desktop computers of different types and has recently acquired a single-user UNIX system; he undertakes the occasional system administration tasks with considerable trepidation. In a shore office, if an experienced UNIX programmer is not available, a local consultant can be called in to sort out the problems - this option is not available at sea. A particular concern with ECDIS is that the System Administrator logs on as Super-user and as such has access to every file on the system. He could by accident remove every one of the previous year's Notices, or, 'by accident', remove all record of the vessel's track prior to a collision or grounding.

LEGAL EQUIVALENCY

It is fundamental to the ECDIS concept that the system should be considered the legal equivalent of the paper chart. The legal authority for such use is the requirement in SOLAS (Regulation 20 of Chapter V, quoted in Reference 4) that every ship should carry 'adequate and up-to-date charts...' and Regulation 5 of Chapter I (ibid.) which authorizes an Administration to allow '(equivalent equipment) to be fitted or carried...if it is satisfied by trial...(that the equipment) is at least as effective as that required by present regulations'. This concept however has yet to be tested in court. Suppose a marine disaster occurs to an ECDIS fitted ship and the court finds either that:

a) it is unable to determine from the evidence whether the fault lay with the ships' personnel, the manufacturer of the ECDIS, or with one of several hydrographic agencies that had supplied HO-ECDBs and corrections to them, or

b) that the ship's officer was at fault but that the complexity of the system was such that it was unreasonable to expect him to have used it correctly in the conditions prevailing at the time. In this connection Reference 2, Section 6.11, 'strongly recommends that in the "International ECDB", as opposed to the INT chart, the exchange language shall be English' - but not all mariners speak English.

Is it not possible that the Court might find that such a system did not meet the equivalency test and thereby make all ECDIS systems illegal? If such an event is ever to occur it is to be hoped that it will occur quickly, before too many resources have been wasted.

THE COST AND TIME OF IMPLEMENTATION OF ENS

These factors are considered together because in the case of ENS they both depend on the results of trials which have yet to be carried out. If the mariner can be satisfied with a minimal version, showing only the dredged channels or specified routes, data files could be provided for each port about as quickly as the respective agencies can make the data available. If on the other hand he insists on the inclusion of navaids, riverbanks and other charted data - all of which is possible - the cost will be higher, it will take longer to extend the system from port to port, and there will be need for a regular update procedure. From the developer's point of view the preferred middle ground would be to supplement the channels and routes only with permanent features, carrying out additional survey work where necessary to avoid the scale problem - for a harbour entrance, a turning basin or the edges of docks. This could be extended to submerged obstructions if accurate survey data was available. All of these are, like dredged channels, items that rarely change, so the maintenance requirement would be low. The exception to this would be rivermouths where the best route over the bar varies with the season, an exception that would be best handled by the pilot, entering the data through the keyboard when he arrives on board.

ENS systems have not yet reached the stage of development where firm prices can be quoted but in discussions of one such system a 'not to exceed' price of $50,000 has been quoted, a figure which would include the GPS receiver, the differential communications and basic data files. It would not seem unreasonable to expect that all major ports and many minor ones could be covered within a five year period -and that the price would fall as more vessels were fitted.

THE COST AND TIME OF IMPLEMENTATION OF ECDIS

ECDIS is more difficult to quantify. Both the shipboard hardware and software will be more complex than an ENS, and therefore more expensive. To this must be added the cost of the HO-ECDBs that must be purchased from the appropriate national hydrographic agency. The preparation of these files will be in addition to each agency's present responsibilities, since the production of paper charts cannot be abandoned till every ship has an ECDIS - and many would say, not even then. Thus additional staff must be hired and the additional costs will have to be paid for by the user of the data. For argument's sake let the total cost to the purchaser be put at $100,000 - even though this may be unrealistically low.

The time to completion is even more difficult to estimate. The IHO has published Provisional Performance Standards for ECDIS and formed six working groups to investigate different technical aspects, while several countries, including the U.S., are conducting testbed investigations. The target date for the publication of agreed Standards is 1993; once this has been done the development of ECDIS systems and HO-ECDBs can be started.

The introductory period will be difficult for the user. Returning to our vessel trading between Oslo and Montreal, the Norwegian and Canadian HO-ECDBs can be expected to be complete relatively quickly, since each country has been a leader in ECDIS development and since the areas traversed would probably be high on their respective priority lists. The British Admiralty however provides world coverage and can provide a precedent for the time that hydrographic change can take. In 1968 additional staff were taken on in order to convert all Admiralty charts from fathoms and feet to metres, a task that was estimated at the time to take 15 years; 20 years later the task was 53% complete. The additional staff were approved however because there was a national policy of metrication. One must question how many national Treasuries will approve additional expenditures on ECDIS when the willingness of shipowners to purchase datasets is an unknown factor - and one that will not be known until the greater part of the job is complete. Note that the promise of ECDIS will not be achieved until every chart on a vessel's route is contained in the database - in the interim there will be the inconvenience of a dual system.

THE SHIPOWNER'S CHOICE

It must not be forgotten that a ship's equipment is not bought by the Master -though he may well be consulted - but by the shipowner, who will expect to see a return on his investment, either in increased earnings or in reduced costs. An increase in safety does not unfortunately appear in this calculation (oil and chemical tankers possibly excluded) unless it results in lower insurance premiums. Given a choice between spending $50,000, to obtain a system that offers the possibility of reducing ship downtime, or of spending $100,000, to obtain a system that is unlikely to affect either earnings or costs, it is not difficult to guess what his choice will be.

CONCLUSIONS AND RECOMMENDATIONS

ECDIS was conceived at a time when a shipboard computer could provide a valuable service by combining data from multiple radio positioning systems with that from the ship's radar. This requirement has been eliminated by the 24 hour availability of GPS for worldwide positioning, while the equally wide availability of Differential GPS, that is likely to occur within the near future, makes it possible for a shipboard computer to provide an additional capability that could never have been considered earlier and that ECDIS cannot provide - the ability to navigate restricted waters safely in low visibility.

The requirement that ECDIS should replace the paper chart for all purposes imposes significant penalties in ease of use, overall cost and in the length of time necessary for complete implementation.

It is recommended that:

1) the paper chart should continue to be the primary product of Hydrographic Offices.

2) that any databases that Hydrographic Offices develop, for their own purposes and/or for exchange of data with other agencies, should be available for purchase by commercial organizations that wish to develop electronic charts for use as a supplement to the paper chart.

3) that hydrographic R & D sections should investigate ways in which modern technology, such as plain paper Fax and a shipboard PC, could ease the burden of chart correction for the mariner.

References

[1] 'Draft Specification (Third) for Electronic Chart Display and Information Systems (ECDIS)', International Hydrographic Bureau, Monaco, S.P. No. 52, October, 1988.

[2] 'Updating the Electronic Chart', International Hydrographic Bureau, Appendix to S.P. No. 52, November 1988.

[3] 'ECS or ECDIS - or ENS', Colin G. Weeks, *Hydrographic Journal*, July, 1991.

[4] KERR, A.J.: 'Status Report on Activities of IMO and IHO concerning the Electronic Chart', presented at Oceanology International 90, Brighton, UK, 6-9 March 1990. Reprinted in the *International Hydrographic Review*, Vol. LXVII(2), July 1990.