United Kingdom Hydrographic Office Experience of Producing Electronic Navigational Charts

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When the United Kingdom Hydrographic Office (UKHO) decided to produce Electronic Navigational Charts (ENCs) it had to make a number of fundamental decisions. This paper describes those decisions and the UKHO's subsequent experience of producing and distributing ENCs.

ENCs are modern replacements for traditional paper navigational charts. By the definition of the IMO (Ref. A) an ENC is: 'The database, standardised as to content, structure and format, issued for use with ECDIS[1] on the authority of government authorised hydrographic offices. The 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.' An ECDIS is: 'A navigation information system which with adequate back-up arrangements can be accepted as complying with the up-to-date chart required by regulation V/20 of the 1974 SOLAS Convention, by displaying selected information from a System Electronic Navigational Chart (SENC) 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 main benefits of ECDIS are:

- Safer and easier navigation with automatic warnings of the risk of grounding and real-time display of own ship position
- Instantaneous and more accurate chart updating
- Reduced workloads for watch-keepers and the consequent availability of manpower for other duties
- More accurate navigation, leading to better passage planning and the use of less fuel
- The ability to receive chart information by telecommunications, thus minimising the number of charts which need to be carried while improving access to charts and their updates
- The ability to include information from navigational publications, again with an ability to very rapidly update this information
- The potential to integrate the navigation and collision avoidance functions by superimposing information from radar displays on ENCs
- The potential to incorporate temporal data such as information about tidal streams and sea ice
- The potential to incorporate third party data such as relayed VTS traffic information outside of own ship radar or visual range

[1] Electronic Chart Display and Information Systems

Composition of ENCs

The 'content, structure and format' of 'the database' referred to in the IMO's definition of an ENC is defined in the IHO Transfer Standard for Digital Hydrographic Data, S-57 (Ref. B). Appendix B.1 of the Standard contains the IHO approved Product Specification for ENC. The specification is comprehensive, but it is not totally prescriptive. In particular, hydrographic offices have to decide what data their ENCs will contain, how the data will be divided up into cells and how these cells will be allocated to 'navigational purposes' or 'usage bands'.

Content

Ref. A states that ENCs should contain 'all the chart information necessary for safe navigation'. Ref. C similarly states that ENCs should contain 'all information relevant to navigation at present depicted on paper charts'. The IHO Product Specification for ENC lists which object classes are not allowed in ENCs and which attributes are mandatory, but it does not contain a list of mandatory object classes. It is therefore left largely to the discretion of individual hydrographic offices to decide what information to include in their ENCs.
The UKHO decided to capture all of the chart detail shown on its paper charts for its first generation ENCs. It made this decision for two reasons. Firstly, because market research conducted at that time indicated that mariners believed that they required all of the information shown on paper charts. Secondly, because it was planned to use the data captured for ENC to populate one or more databases which would form the basis of a national database of hydrographic information.

The current aim of the UKHO is to build up extensive coverage of UK waters with these first generation ENCs. Coverage is also being built up in other areas for which the UKHO is the primary charting authority. At the time of writing this paper (June 2002), the UKHO had produced 245 of these ENCs.
In due course the UKHO expects to improve the quality of its ENCs based on the feedback it receives from users. It is envisaged that at an early stage the UKHO will introduce the use of the S-57 attributes CATZOC and SCAMIN. CATZOC is needed to indicate the quality of the data. SCAMIN is needed to minimise clutter and screen refresh times. These attributes have been omitted from the first generation ENCs because they could not be populated easily from the information shown on paper charts, and it was judged that it would take too long to populate the attributes by any other means.
Looking further ahead the UKHO is likely to include more depth contours in its ENCs, especially for those in the harbour and approach usage bands. The present content of ENCs may be simplified by removing all non-conspicuous topography and much of the hydrography within areas enclosed by danger and drying lines. Information from nautical publications will be added, either by including the information directly in the ENCs or by providing links to the information in digital versions of the publications. ENCs may similarly be linked to tidal stream models, and although it is not permitted in the present version of the IHO's Product Specification for ENC, in due course depths may be corrected for predictions or real-time observations of tides.

Cell Limits

The only guidance that the IHO Product Specification for ENC gives about cell limits is that they must be rectangular and the size of each cell must not exceed 5 megabytes. Most hydrographic offices have either based the limits of their ENCs on the limits of their paper charts or they have used a regular grid for their ENCs, similar to that which was specified for ENC in Version 2.0 of S-57.
The UKHO initially decided to adopt a completely fresh approach to the design of cell limits. These were based loosely on the limits of the UKHO's paper charts, but where more than one paper chart covered a port or the approaches to a port, these were merged into single cells. In the most extreme case, a single cell covering the approaches to Southampton was made up of data from five paper charts.
The UKHO abandoned this approach to cell design when it found that it was impossible to keep these 'super cells' up to date, such that new editions of these cells could be issued at the same time as new editions were

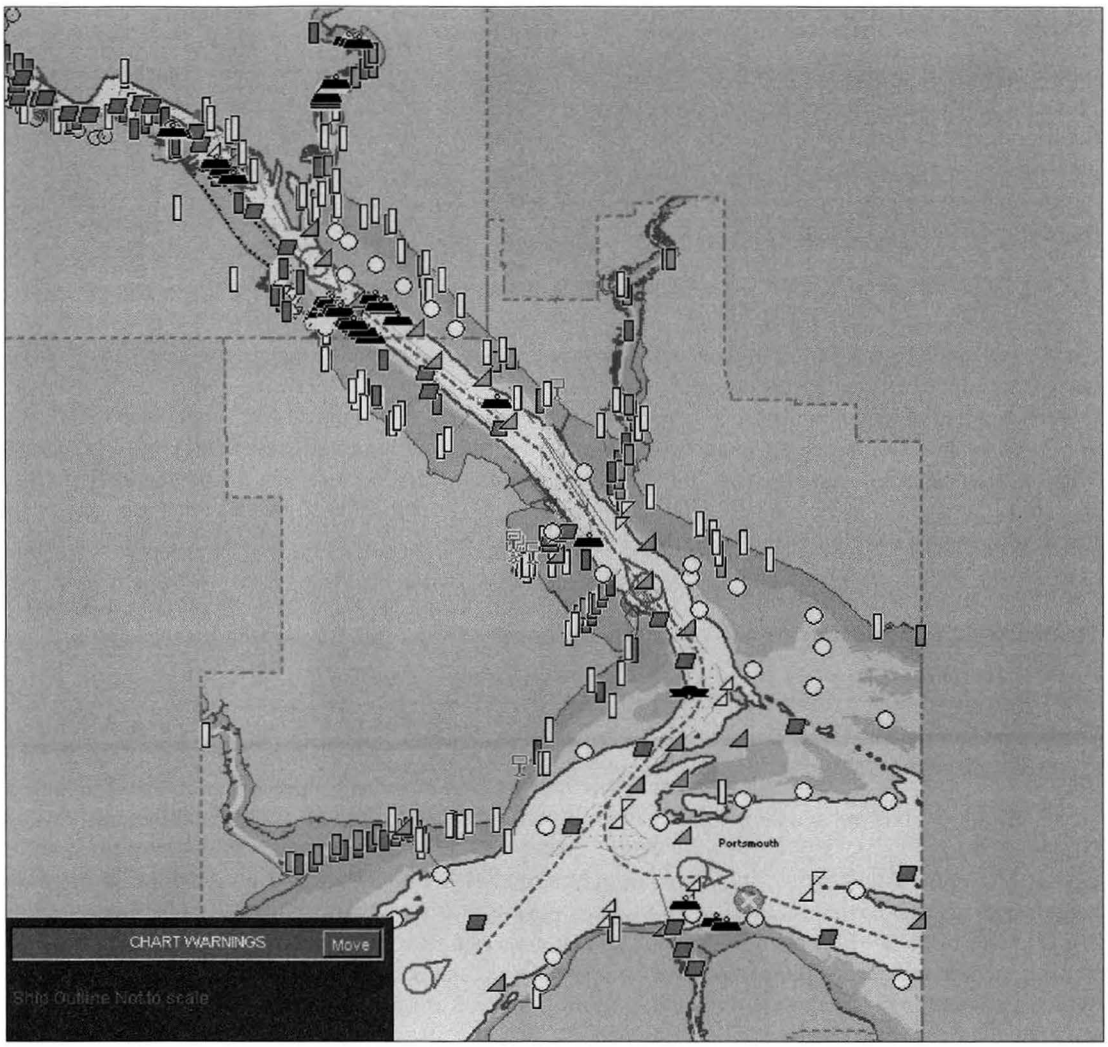

Figure 1: Standard ECDIS display of UKHO-produced ENCs of the approaches to Southampton

issued for the component paper charts. These cells have since been re-schemed and the limits of most of the UKHO's ENCs now coincide with or are similar to those of the paper charts from which they are derived.

Usage Bands

A third key area in which practices vary between hydrographic offices is in the allocation of cells to 'navigational purposes' or 'usage bands'. The IHO Product Specification for ENC lists six navigational purposes: overview, general, coastal, approach, harbour and berthing, but it does not specify the scale ranges that apply to each band. This is because the hierarchy of scales of charts covering ports in different parts of the world vary from country to country, if not from port to port.

The UKHO makes use of five of the six usage bands. It took the decision not to use the berthing band because it considered that none of its paper charts are sufficiently large scale to be used for berthing. As a general rule it allocates cells to usage bands on the basis of the following scale ranges: harbour - 1:5,000 to 1:25,000; approach - 1:20,000 to 1:40,000; coastal - 1:50,000 to 1:100,000; general - 1:150,000 to 1:200,000 and overview - 1:300,000 and smaller.

The Effects of Differences in the Composition of ENCs on ENC Services

Individually, most hydrographic offices ensure that all of their ENCs contain the same object classes, are part of a single cell schema and are allocated to usage bands on a consistent basis. However, because the standards do not define precisely what ENCs must contain, nor how they should be divided up into cells and allocated to usage bands, practices inevitably vary between hydrographic offices. This would not matter if each hydrographic office provided a complete ENC service independent of its neighbours. However, it can be a serious concern for organisations such as IC-ENC and PRIMAR Stavanger, that want to combine ENCs from several nations into a coherent and cohesive regional ENC service in accordance with the IHO's WEND principles[2]. It can also lead to confusion in the minds of mariners and arguably affect safety, if ENCs from different countries contain different information, have different limits and are allocated to different usage bands. The differences are most noticeable along international boundaries, especially where these coincide with major shipping routes.

It is therefore imperative that hydrographic offices work together to minimise the differences in their ENCs and in particular, to harmonise the production of ENCs that span international boundaries. IC-ENC and PRIMAR Stavanger are working to ensure that this happens in Europe, and France has recently proposed an extension to the WEND principles which defines how hydrographic offices should co-operate to produce ENCs that cover the waters of more than one country (Ref. E).

Methods of Production

Chart data in ENCs is stored digitally as collections of separate, geographically referenced objects with associated attributes. When the UKHO decided to produce ENCs it had the choice of either populating its ENCs with data digitised from the information shown on its paper charts or of compiling ENCs afresh from original source material. Early trials indicated that it would be prohibitively expensive and take too long to create ENCs from original source material. It was therefore decided to capture the data from paper charts. The production process for ENCs is very closely linked to the production processes for paper and ARCS charts (Admiralty raster charts), and is entirely driven by changes to the paper charts upon which they are based. Data for new base cells is digitised from raster images of the bases that are used in the production of paper charts, rather than from the paper charts themselves. The UKHO contracts out most of this work to a company in India. Stringent quality checks are applied to the data both in India and the UK. Third party software is used to check that the data is fully S-57 compliant. On-screen checks are made to ensure that all of the data has been captured with the correct attributes and that all objects have been digitised to within +/- 0.2mm of their positions on the raster images of the paper charts. ENCs are only produced if the accuracy of the transformation of the data from local horizontal datum to WGS 84 is known to an accuracy of +/- 0.3mm or better at chart scale. All of the production processes are ISO 9001 certified.

The UKHO keeps its ENCs up to date for changes by issuing updates and new editions for base cells that correspond exactly to the Notices to Mariners and new editions that are issued for the paper and ARCS charts. Updates and new editions for all three products are issued simultaneously. New editions of base cells are produced from raster and vector files produced during the paper chart production process. The raster files are used to identify all of the objects that must be deleted from ENCs and data from the vector files is used to insert the new work. Updates are produced by manually editing the base cells for the changes described in advance copies of the weekly bulletin of chart-correcting Notices to Mariners.

While this method of producing and keeping ENCs up to date is effective, it could be made more efficient. Although the production processes for paper charts, ARCS and ENC are linked, they are produced on what are in effect three separate production lines. This has several consequences. Costs are comparatively high because each product is produced and maintained separately, although they are essentially the same product in different formats. Secondly, because each product is produced in sequence, and ENC is at the end of the sequence, it has not always been possible to publish new editions of ENC and paper charts at the same

[2] The concept of a WEND, a worldwide Electronic Navigational Chart Database, and a global network of RENCs, Regional ENC Co-ordinating Centres, was formulated by the IHO in 1994 as a mechanism for providing mariners with a worldwide ENC service (Ref. D.)

time. In addition the positional accuracy of objects in ENC is not as accurate as it would be if all three products were produced directly from the same source material. This is because the information shown on most charts was originally compiled by hand and then digitised, once as part of the paper chart production process and then again for ENC. Each time the data is plotted by hand or digitised this introduces small positional errors, since it is impossible to perform either of these activities with absolute accuracy.

The UKHO has recently embarked on an ambitious project to establish a National Hydrographic Database for the UK. In future the UKHO will produce all of its ENCs from this database. Computerised product generation specifications will be used to extract all of the relevant data for ENCs from the database, and to display this data on workstations for operators to carry out whatever remaining tasks are necessary to turn the datasets into finished ENCs.

This method of production will have several advantages over the present method of digitising paper charts. It will be more efficient and cost less, because the same data will only be captured once for all three of the UKHO's main chart products, paper, ARCS and ENC. This data will be scanned or digitised, validated and stored in the National Hydrographic Database. As new source material is received this will be compared with the data already held in the database and the existing data will be updated accordingly. Periodically, these changes will be drawn off from the database to produce updated versions of the products that contain the data. This will include updates and new editions for ENCs. Not only will this method of working do away with the need to edit the same objects in all three chart products, it should also do away with the need to edit the same objects in each of the ENC usage bands.

Because the National Hydrographic Database will be the source for all up to date chart information, it will be possible to produce new paper and ARCS charts and ENCs, or new editions of these charts, simultaneously. As a result there will be more time to produce new editions of ENCs and it should always be possible to publish these new editions at the same time as the corresponding new editions for paper and ARCS charts. The quality of ENCs should also be improved. Data will not be repeatedly plotted and digitised by hand so the original positional accuracy of the data will be the same in the finished ENCs as it was in the original source material.

In the early days of using the National Hydrographic Database, base and update cells for ENCs will be produced semi-automatically, but the ultimate goal will be to fully automate the production of ENCs.

Methods of Distribution

Until it closed, the UKHO made its ENCs available through PRIMAR, the former European RENC. The UKHO now distributes its ENCs through IC-ENC, the International Centre for ENCs, based at Taunton in the UK. The primary purpose of IC-ENC is to act as a focal point for the distribution of ENCs produced by hydrographic offices in Europe, and in due course, other parts of the world.

Most importantly, IC-ENC provides hydrographic offices with a means of distributing their ENCs worldwide. This is especially important for those hydrographic offices that do not have access to an international network of chart agents. IC-ENC also validates all of the ENCs that it receives to ensure that they are fully compliant with S-57 and the IHO's ENC Product Specification. It checks that there are no gaps or overlaps in the coverage of ENCs along international boundaries and encourages hydrographic offices to work together to produce a homogeneous ENC service. It provides feedback on the practicalities of implementing the ENC and ECDIS standards, to the international bodies that are responsible for these standards. IC-ENC also provides feedback to the commercial companies that produce the ENC validation tools that it and hydrographic offices use to check that ENCs are compliant with S-57 and the IHO Product Specification for ENC.

For distributors, IC-ENC provides easy access to ENCs. Distributors only have to sign a single distributor agreement to gain access to all of the ENCs available from IC-ENC. They do not have to establish separate distribution agreements with each hydrographic office. IC-ENC supplies ENCs to its distributors in a secure manner, either electronically or on CD-ROM. These distributors in turn supply these ENCs to end users using their own, IC-ENC approved, secure methods. IC-ENC does not sell ENCs directly to end users.

As well as supplying its ENCs to IC-ENC, the UKHO has also participated in SHARED[3] and operated a pilot

[3] Singapore Hong Kong Admiralty Raster and ENC Demonstration

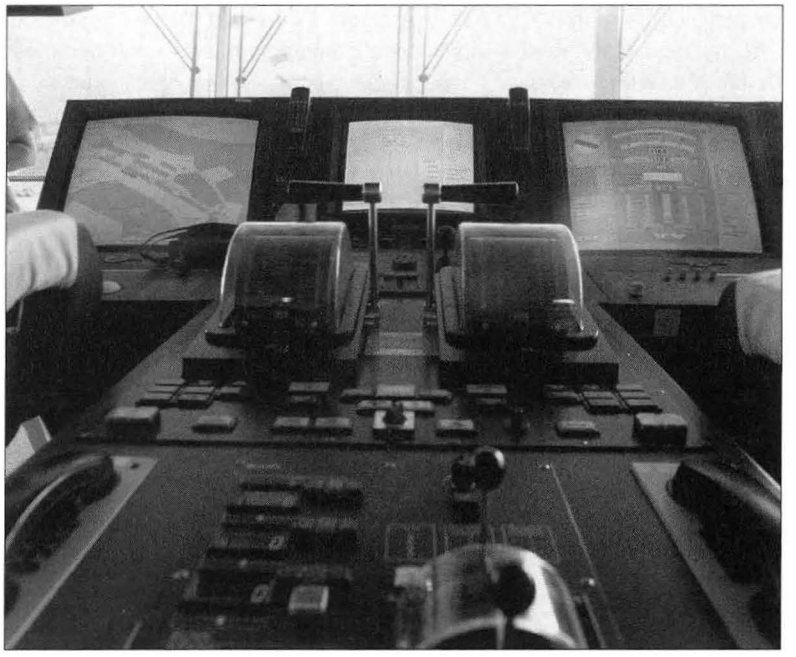

Figure 2: ECDIS display on the bridge of the P&O cruise ship AURORA

or trial ENC service. The purpose of SHARED and the trial was to test whether the UKHO's ENC production system has the capacity and is sufficiently robust to support a commercial ENC service and to obtain feedback on the operation of ECDIS in the normal and RCDS[4] modes. At its peak 26 vessels were involved in either SHARED or the trial. Users subscribed to the UKHO's ARCS service and were supplied with ENCs wherever these were available along a route from North West Europe to the Gulf and the Far East. In return, users were asked to provide the UKHO and the hydrographic authorities of Singapore and Hong Kong with feedback on the content and quality of their ENCs and details of any problems they experienced when navigating with a mixed folio of ENCs and ARCS charts.

Two features of ECDIS received universal acclaim from users. These were the ability to display own ship position automatically on ENCs, and the ability to update ENCs automatically for Notices to Mariners. These features were acclaimed for reducing the workload of watch-keepers, taking the drudgery out of the more mundane aspects of navigation and reducing the likelihood of ships' positions and Notices to Mariners being mis-plotted. Users also welcomed being able to select the chart detail that they displayed. Route planning was said to be easier and it was an advantage to be able to save details of these routes for future use. (Ref. F)

Users were less complimentary about certain other aspects of ENC and ECDIS. No-one disputed the value of ECDIS in providing automatic warnings and alarms if vessels are in danger of running aground or entering restricted areas, but many users complained of alarms of one type or another sounding almost continually. In some cases at least this was because too much information had been encoded as caution areas that trigger alarms. Some users were not content with the colours and symbols used in ECDIS for displaying ENCs. This may have been in part due to a lack of familiarity with the new symbols, but there was a general dislike of the colours, especially the dusk and night palettes and the insipid nature of the colours used for overlay information. Some users also found that ENCs became cluttered when zooming out. This was due both to the lack of SCAMIN values in the data and also, in some cases, to the ECDIS not 'jumping' to ENCs in the next usage band. Many users said that they would prefer ECDIS to have a standardised user interface. Users also reported that it was less easy to assimilate information about objects displayed in text boxes than it was to assimilate the same information from paper charts. There was also a tendency for these boxes to obscure large parts of the chart display.

Although relatively little use is made at present of on-line services for the delivery of ENCs, there is no doubt that this method of delivery will all but replace delivery on CD-ROM or other hard media in the long-

[4] Raster Chart Display System

term. This will come about when the data carrying capacity of satellite communication systems increases and the cost of transmission falls to the extent that it is economic for users to dial in and download data direct from databases of ENCs managed by RENCs or hydrographic offices. The ultimate goal will be for mariners to view these databases as part of their ECDIS systems and download data as it is required. When this happens it will revolutionise the way in which ENCs are managed. Producers will keep the databases up to date for changes as they occur, and users will have immediate access to these changes by downloading the latest versions of ENCs. Users will still need to maintain some form of back-up for ECDIS, but they will no longer need to apply updates to ENCs held on board ship. Producers will no longer have to create update cells and new editions of base cells. Users will no longer be restricted to receiving updates on a weekly basis and will no longer experience delays of several weeks while CDs containing updates reach vessels at sea.

Conclusion

After a long period of gestation ENCs and ECDIS are at last becoming more widely available. They satisfy all of the relevant standards of the IMO and IHO, they make ships' operations safer and more efficient and they have the potential to revolutionise the way vessels are navigated. As this paper has shown, there is the potential to enhance ENCs and ECDIS in various ways. Mariners would like all makes of ECDIS to have the same user interface. ECDIS displays could be modified to reduce clutter and to make it easier for mariners to assimilate certain types of information. Some classes of less used information could be deleted from ENCs in favour of including additional information from other sources. ENCs could be overlaid with temporal information about weather conditions, tides, sea states, ice cover, etc. The list of possibilities is almost endless. One thing is certain though, as the temptation to include more and more information in ENCs and ECDIS grows, the main challenge for hydrographic offices and ECDIS manufacturers alike will be to avoid overloading mariners with unnecessary or poorly presented information.

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Acknowledgement

The opinions expressed in this paper are those of the author. They are not necessarily those of either the UK Hydrographic Office or any other UK Government Department.

Biography

Peter Wright joined the UK Hydrographic Office (UKHO) in 1979, having obtained a degree in geography from the University of Wales and a doctorate in coastal geomorphology from the University of Southampton.

During his early years in the UKHO, he worked on the development of computer systems for processing hydrographic data and computer assisted techniques for reproducing nautical charts. He managed the Admiralty chart coverage of the South Coast of England and the North Coast of France, and he advised the UK Ministries of Defence and Transport on requirements for dredging and repeat surveys.

More recently, he has been involved with the development of the UKHO's ARCS and ENC services. As the Head of Electronic Charting, Peter is responsible for the production of ARCS and ENC and the maintenance of the Charts Databank that holds the masters of the UKHO's paper charts.

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