International Hydrographic Review, Monaco, LXVII(2), July 1990

LEARNING FROM AN ELECTRONIC CHART TESTBED

by R.M. EATON (*), H. ASTLE (**), S.J. GLAVIN (**), S.T. GRANT (*), S.E. MASRY (**) and B.W. SHAW (**)

Abstract

Over the past five years, the Canadian Hydrographic Service's Electronic Chart Testbed has provided insights into the way an electronic chart (EC) will handle chart data — and from this the appropriate form for the Hydrographic Office to provide and electronic chart database; it has stimulated suggestions about how the display should be designed; it has provided a practical model for use in planning IHO specifications — and followed on to test these by implementing them; and it has shared in giving mariners demonstrations of some of the eventual capabilities of ECDIS, so that they can start thinking about what they need from it.

This paper describes planning the Testbed; lessons from early tests; initial ideas on electronic chart data and on display design; and the reactions from mariners who saw the Testbed among six electronic charts on board the Norwegian ship LANCE during the 1988 North Sea Project.

PLANNING THE TESTBED

The Canadian Hydrographic Service (CHS) started to develop an Electronic Chart Testbed in 1984 because it was reasoned that in order to provide appropriate data for electronic charts, to have some say in the design of the display, and to contribute to IHO Standards, it was necessary to find out at first hand how an electronic chart functions and what it may be used for. The Testbed was intended as a tool to test ideas on data content and form, and on display design, and to give demonstrations to mariners and other marine interests in order to have their views on electronic chart performance and applications.

(*) Canadian Hydrographic Service, Department of Fisheries and Oceans, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2.
(**) Universal Systems Ltd., 270 Rookwood Avenue, Fredericton, New Brunswick, E3B 2M2.

From the start, the electronic chart was looked on as an operational navigation display based on essential chart features, intended to improve safety of navigation, and primarily for use in constricted waters. A radar interface was included because it was considered important to explore how this potentially valuable overlay would interact with chart information.

The specifications were drawn up with strong input from mariners, and the development was reviewed at about six monthly intervals by a working-level group from the Pilotage Authority, the Coast Guard, the Navy and the Hydrographic Service.

There were obvious advantages in getting a jump-start by using existing electronic chart expertise. However, to have adapted an existing commercial electronic chart, packaged for sale and hence for economy, would have lost essential flexibility. (A Testbed, by definition, is an adaptable framework into which one can fit various models for trial). Instead, since an electronic chart can be described as a special case of a geographic information system, the CHS decided to adapt its own chart production system, CARIS*, for the purpose, and contracted the makers of CARIS, Universal Systems Ltd., to develop the Testbed from CARIS.

To be effective in demonstration, a Testbed must perform much as an operational electronic chart. However, developing an operational system to full electronic chart specifications would have been far beyond the mandate of the organization and the limited financing, and so some limitations had to be accepted:

- the Testbed used what was a large and expensive computer and display, five years ago. (A modern, relatively inexpensive, workstation now has the same capacity.) When not on Testbed trials, which took up about six weeks a year, this equipment was used for other purposes.
- the radar video was interfaced via a separate minicomputer. Radar target information was not interfaced, but this is technically much easier to handle than video.
- the Testbed was to be capable of carrying out chart-related electronic chart requirements (and later any of the IHO SP-52 Specifications) singly, but not necessarily all on the same demonstration.
- operator interaction, including chart work and chart correction, needed someone familiar with computers and trained in the system and since the Testbed was intended only for trials and demonstrations, operational reliability was emphasized less than flexibility.

EARLY TRIALS

The Testbed was generally taken to sea twice a year to test improvements and to demonstrate the electronic chart to pilots, CHS ships' officers and Navy navigators who might use it; to Coast Guard people interested in its impact on

* Computer-Aided Resource Information System (Masry, 1984)

their work, and to CHS cartographers who might feel both threatened and stimulated by this new way of using their product.

All tests were made in Halifax Harbour and approaches, which was convenient and more comfortable for the 30 m trials ship, and also agreed with the preconceived opinion of the CHS that the main application for the electronic chart will be in narrow waters. This view was supported in 1985 and 1986 with the installation of the Offshore Systems Ltd. PINS electronic chart on ferries entering difficult harbours in low visibility, and on icebreakers clearing a narrow, unbuoyed channel through the middle of a large lake on the St. Lawrence River.

The first trial of the Testbed was made late in 1985, within a year of starting work. Positioning was by LORAN; chart information was in coloured lines on a data background; and radar video was displayed in green.

The Loran gave a ragged track (unless it was over-damped), and jumped across the channel as the vessel went under a power line. A better positioning system was obviously needed for harbour demonstrations.

The chart display was cluttered and confusing. Part of this was due to the mass of streets on shore, which was easily edited out. Much more seriously, it was not immediately obvious which was deep water and which was shallow water of depth less than the safety contour. (It is possible that this failure of a display without colour fill to make shallow water immediately obvious contributed to the grounding of a fishing boat using a 'lines-only' electronic chart in the North Sea in 1988).

By Spring 1986, a colour filled display was introduced, a great improvement that made the distinction between safe water and shoal water very clear.

Positioning by GPS was introduced and it was fortunate that the test time coincided with a satellite window. The results were striking. The procedure was to use the Testbed's 'position adjust' facility to remove datum shift and any systematic or slowly varying GPS errors at the ship's berth, thus simulating differential GPS for the following hour or so. The ship then sailed and, for example, ran up a leading line with the Testbed tracking on the charted line to ±2 mm (at 1:5 000 scale). Following this the vessel circled a buoy, with the display making a neat ring to one side, showing the buoy to be off position. After about an hour the vessel was taken alongside a wharf, with the display showing the manoeuvre correctly. This demonstration merely repeated what the Precise Integrated Navigation System (PINS) and other commercial electronic charts were showing daily — that an electronic chart with precise positioning has the potential to aid ship handling right up to the berth, an application which may affect mariners' requirements for large scale charts.

GPS navigation failed briefly when going under bridges, and there would also be trouble from satellite shielding if a ship was close in under grain elevators.

LESSONS FROM TESTS

Electronic Chart Data

The chart information for these tests came from the CHS digital files for producing paper charts of Halifax Harbour and approaches. As a prime aim of the project, Universal Systems Ltd. fed back annual reports on the way in which data requirements for the electronic chart differ from those for the paper chart.

To a 'non-digital' observer, much of the difference relates to the extra information needed by the electronic chart so that it can compile various types and scales of chart display, as required by the user. This is very different from the single, set-piece, compilation of the paper chart. The differences include:

- scale limitations: a warning is needed when the display scale is zoomed to a larger scale than is appropriate for the accuracy and completeness of the data being used. A warning is also required if the data being used is not the largest scale available in the data base.
- chart feature reliability: in future there will probably be a demand to know the charting accuracy of a critical feature, such as the safety contour, in terms of $\pm x$ metres, in order to determine how close to it a ship can safely go:

  Safe distance off $= [(\text{chart feature error})^2 + (\text{ship's positioning error})^2]^{1/2}$

  (approximately: other factors such as ships manoeuverability and chart display resolution also enter the equation.)
- Features that are part of the standard (default) display need to be identified,
- Hydrographic Office data must be distinguished from non-Hydrographic Office data,
- relations must be defined between linked features or information, for example between light sector bands and the originating light, or eventually between information in sailing directions and the current location of the ship,
- other relations within the database must also be easily traced. For example, when the standard display is on the screen using the IMO Provisional Performance Standards symbol for 'indication of isolated danger' (IMO 1989 — Annex, para 3.2.3), the electronic chart needs to be able to select for display all isolated dangers that are less than the safe depth and outside the safety contour, whether they be rocks, wrecks or shoals (Fielding, 1989).
- chart data must have topological integrity, in order to permit colour fill and area detection,
- the overall amount of information carried in memory should be no more than necessary, particularly on land, and line features should be efficiently digitized with no more points than are necessary to reproduce the line at

the largest scale that will be used. It is important both for storage and for fast manipulation and display of large amounts of digital data that it be 'efficiently' (i.e. economically) digitized, whereas for computer compilation of a paper chart there is minimal gain in this.

- in order to reproduce the chart information in the same form as the Hydrographic Office digitized it, and for efficient data management by the ECDIS, uniform digitizing conventions must be followed by the Hydrographic Office (HO), and made known to the electronic chart manufacturer.

Display Design

Since effective presentation of chart information is even more important on the electronic chart than on the paper chart (see next paragraph), considerable emphasis was put on this topic in developing the Testbed.

The electronic chart display has a difficult challenge to meet. The electronic chart contains far more information, of a more complex nature, than other navigation displays:

- map-type chart information (coastline, depth contours, buoys, etc.),
- navigation-type chart information (leading lines, traffic routing, limits, regulated areas, etc.),
- non-Hydrographic Office chart information from port authority, etc.
- chartwork (including planned route) and navigators notes,
- input from position and heading sensors, including ship's symbol, past track, future track projection,
- input from radar,
- input from the sensors (sounder, anemometer, etc.),
- telemetred information from port authority (real-time tidal stream observations, traffic information, etc.),
- manufacturers value-added information,
- diagrammatic interpretations, graphical warnings, etc. (if these are developed effectively).

With so much information available it is crucial to avoid cluttering the display. The essential information must always appear conspicuously, clearly and free from distractions. ('Clutter' of a different, but equally dangerous sort, resulting from a crowded and confusing control panel or menu system, must also be avoided.) The Testbed programme included a study on the effect of clutter (Kaufmann, in this issue of the International Hydrographic Review (IHR).

Others, with more experience, have stressed the importance of limiting the information shown to 'an amount that is relevant and that can be safely handled by the person in charge of the watch' (Gylden, 1986).

Experience with the Testbed has shown that colour is very effective in making important distinctions. Examples include depth shading to distinguish between safe depths and shoal water, and coloured lines to differentiate between planned route and actual ship's track. But as Kaufmann points out — elsewhere in this issue of IHR, the number of colours that can be clearly distinguished is limited to not more than about ten, and that level can only be achieved with careful colour selection and under good ambient light conditions. The problem is that many more than ten different display features must be distinguished on an electronic chart display.

A further complication arises when, for example, the colour shade indicating traffic routing separation zones must overlie depth shades 'transparently'; or a radar image should not block out chart information.

Various additional methods of information coding have been tried out on the Testbed, to meet these requirements. For traffic separation zones, screened magenta, or a pattern of magenta lines, seems to allow depth shades to show through satisfactorily. However the attempt to use 'transparent green' for radar resulted in various shades of blue-green mix over water, and was a failure. In the end, it was decided to resort to white, a neutral colour, for radar, and provided a 'radar off' switch in case chart data was obscured. (It is a small step to write buoys, coastline, etc., on top of the radar image — see Fig. 1.) Where lines are concerned, the Testbed now, for example, codes the own-ship's safety contour as a markedly broader line than other contours (in addition to the colour shade distinction) and the colour band for a green sector light is a relatively broad band compared with the narrower green line for planned route.

Through their knowledge of visual perception, professional institutes of ergonomics (human engineering) have much to contribute to display design, and advice from the DCIEM*, near Toronto, greatly benefitted the Testbed development.

Radar Overlay

Having a radar overlay on the Testbed gave some insights into its usefulness in an ECDIS. For example, at one stage of Testbed trials, the radar fitted the coastline only when the ship was stopped, and was pushed ahead of the ship by about 30 m when it was underway. The diagnosis was a time-tagging delay, and this was eventually traced, but the lesson remained: a radar overlay is useful for detecting positioning errors.

On one occasion a strong arc-shaped echo appeared on the radar, extending offshore. With the image on the electronic chart display it was immediately obvious that this was a side echo from a charted prominent building.

The master of the trials ship cited another example where radar interpretation would be useful. The causeway across Canso Strait, which separates Cape Breton Island from mainland Nova Scotia, has a shipping lock on the north shore. About a mile west of the causeway a power line crosses the Strait, running parallel to the causeway. This power line returns a strong radar echo, which a ship approaching from the west could easily mistake for the causeway. A navigator unfamiliar with the area, misled by this, could close the north shore to enter the lock a mile too soon, at a point where dangerous shoals extend offshore. An electronic chart would give immediate indication of this error, and a radar overlay would explain it.

* DCIEM: Defence and Civil Institute of Engineering Medicine. (See paper by Kaufmann in this issue.)

Other examples of radar and the electronic chart complementing each other were noticed. The radar does, of course, show bridges clearly, but not the bridge pier; ships making the 0800 shift at Halifax's inner container wharf on foggy mornings would benefit from an electronic chart to show the clear part of the bridge span. Parallel indexing by radar can only be performed on a radar visible point of land, whereas on the electronic chart it can be referred directly to the ship's safety contour or isolated hazards.

However, experience soon showed that to fit only a single combined chart/radar display would be dangerous. Small radar echoes tend to be missed among chart details, and chart information could be blanked out by radar images. A separate radar display, and a 'radar off' switch for the electronic chart, are essential.

During the development and testing of the radar interface the subject of radar positioning was discussed. Using data collected during these tests Austin *et al* (1987) were able to demonstrate that by matching observed and reference radar images the ship's position could be determined to an accuracy of the order of 10 m. A contract was subsequently awarded to McGill Radar Weather Observatory to develop a real-time version of this process. Two references for radar matching were to be investigated: radar matched to the charted coastline; and radar matched to a pre-recorded radar image of the coastline. Mini-Ranger was to be used as the comparison positioning system for these tests.

A radar positioning test was carried out in the fall of 1989 and, although real-time positioning accuracies of about 12 m were briefly achieved by matching the radar image with digital chart data, a considerable amount of development and testing is still required.

THE IHO WORKING GROUP ON ECDIS SPECIFICATIONS

Following up on the 1986 report of a North Sea Hydrographic Committee Working Group (NSHC 1986), the Netherlands Hydrographer organized a two-week working group under IHO auspices at The Hague in January 1987, to draft detailed specifications for an Electronic Chart Display System (ECDIS) 'which may be considered the equivalent of the conventional nautical chart'.

While most members of this group were experts in digital cartography, Canada's contribution was to provide a check list of functional requirements and practical considerations, learned from experience with the Testbed. Some of the display design work of the Testbed was also illustrated at The Hague, on the Netherlands Hydrographic Service's CARIS System, and in addition an Amiga personal computer was used to demonstrate symbol display options. Although a high resolution display is desirable, the Amiga showed that an effective electronic chart can be presented on a relatively low resolution screen, given careful display design.

The outcome of the meeting and subsequent revisions was IHO SP-52 'Draft Specifications for ECDIS' (IHO, 1988), a description of the capabilities required of a chart-equivalent ECDIS. Probably no electronic chart yet exists that can meet these specifications completely, largely because they require quite complex manipulation of very large amounts of data virtually instantaneously. However, SP-52 was used as the target and guide for the major, chart-oriented, part of subsequent Testbed development, with the result that the Testbed can now carry out most of the requirements taken a few at a time. (A detailed breakdown of electronic chart capability with respect to SP-52, including the Testbed, is given in Section III of the 'North Sea Project', Norwegian Hydrographic Service, 1989).

Following the ECDIS demonstrations during the North Sea Project in 1988 (see below), IHO and IMO recognized that clearer definition of both chart and navigation symbols was needed. Experience from the Testbed provided the basis for discussion at a meeting of the IHO Colours and Symbols Working Group at the Hydrographic Office of the Federal Republic of Germany, Hamburg, in September 1989. Testbed software run on the German CARIS system provided working demonstrations of interactions between IMO navigation symbols and IHO chart symbols, and brought out some problems. For example, line-weight for the ship symbol and past track had to be increased, and further work was needed on night dimming. The demonstration was repeated at the meeting of the IHO/IMO Harmonization Group on ECDIS in November 1989.

THE NORTH SEA PROJECT

Organized by Norway and Denmark starting in late 1987, the North Sea Project was the first major demonstration of the electronic chart. Digitized harbour charts from seven participating North Sea Hydrographic Offices were assembled by the Norwegian Hydrographic Service, which also provided the survey ship LANCE for a one-month trial cruise in October-November 1988 (Norwegian Hydrographic Service, 1989). The Testbed was fortunate enough to be one of six electronic charts demonstrated on LANCE.

One aim of the project was to test the suitability of the Hydrographic Office chart database. Unfortunately this did not at that time permit colour fill and area identification to be used, and since it was considered that these were important ECDIS features which the Testbed was capable of demonstrating, data was digitized in-house, in CARIS format. The opportunity was missed to gain experience in changing the format of the Norwegian data; however it was possible to use CARIS format data from the Netherlands and German Hydrographic Services, once differences in digitizing conventions were understood. It was found that data from all sources had to be very carefully checked before it could be relied on for colour filled display; this was a tedious process, which should, if possible, be done by software in future.

In keeping with its experimental nature, the Testbed had some features not available on the electronic charts on LANCE. The most evident was an optional radar overlay, from a standard Decca radar fitted for this purpose. This overlay could be switched on or off at will. Lack of money limited the efforts in high-speed data throughput in the Testbed configuration, with the result that the radar image displayed was about 10 seconds old, and the radar resolution was limited to 256 pixels, one quarter of the screen resolution. However, the overlay served its purpose of demonstrating radar on ECDIS, and the fact that chart information was on the screen to aid radar interpretation compensated for low resolution to some extent: it was obvious whether a small target was a rocky islet, a buoy, or a small boat, without the need for a high resolution display of radar.

The Testbed was able to switch on and/off various information layers, such as soundings; buoy characteristics and names of features; etc., with one keystroke. It could also give attribute information by cursor-pointing for such lights, pilot stations, etc., for which attribute information had been entered into the data base.

The Hydrographic Office data was segregated and protected, and features forming part of the Standard Display were recognized. Chart compilation scale was also recognized, and a warning given if the display was zoomed to overscale or underscale (this would also be obvious from the size of the symbols, which are at present shown at standard size only when the display is at compilation scale.)

The Testbed searched ahead of the ship for change in the chart scale, and on detecting this gave the operator warning and automatically preloaded the data at the next scale. The scale of the display, however, was only changed on operator command.

Other area warnings, for approaching or infringing the safety contour; being inside a regulated/prohibited area etc., were available for areas specifically set up for this in the data base. Area search was used for this, rather than depending on detecting line crossing, because area search can be continually checked, whereas a missed line-crossing is lost completely.

Finally, the Tesbed demonstrated updating. For manual chart correction the CARIS 'edit' facility was used; (this at present requires some operator training). To demonstrate automatic updating, the Norwegian Hydrographic Service arranged transmission via INMARSAT Enhanced Group Call (EGC), of a batch-file chart correction from Stavanger to LANCE at sea, as she approached each port of call. From the INMARSAT receiver the correction was linked via a microprocessor directly to the Testbed, where it was entered in a display over-write file, separate from the main chart memory. There , it was ready for display when the affected part of the chart was called up on the screen. Because at that stage there was no standard instruction text for chart correction, the batch-file contained commands for entering a CARIS edit in the Testbed, plus the new data for a small update, such as a new bridge, in CARIS format. This in fact exemplifies one possible method for handling corrections in the long run, and so although the demonstration did not provide a full operational test, it did show that automatic updating via satellite is technically feasible.

With over 500 visitors in ports of seven countries, the North Sea Project gave wide exposure to electronic charts, which seems to have resulted in a noticeably more positive attitude towards electronic charts among users in the past year. It also gave an excellent opportunity to get a first impression of electronic charts from potential users. A summary of the responses to a questionnaire given to visitors onboard the LANCE is reprinted elsewhere in this issue of IHR ('North Sea Project — Abstract of Questionnaire on ECDIS'). Here are some additional comments from mariners, which are not in that abstract, and which apply to the Testbed:

'Daylight (low sun) viewing should be improved.'

(Note: this is a problem with a CRT. See paper by Kaufmann in this issue.)

'The Testbed emits too much light at night.'

(Note: this was a comment from LANCE's bridge; a very low-light emission display has recently been developed, but with some limit on the amount of information shown.)

'I liked the light tone colours and overall clarity of the Canadian Testbed.'

(Note: 14 similar comments; unsaturated colour fill is easier on the eye, and a high quality screen helps.)

'I liked: the ECDIS ability to delete data not relevant to the operation at hand, and to show a clear and unambiguous picture; the radar overlay for anti-collision and position verification; the facility to receive automatic corrections.'

'Having seen the demonstration, I consider there are advantages in having radar and ARPA as optional features.'

'The hydrographic and topographic information on the ECDIS must be of the same order of accuracy as GPS. This is not the case at the moment, and could lead to dangerous situations if the full accuracy of GPS is relied on.'

'Full use should be made of the warning capabilities of ECDIS, since even the most experienced will make mistakes at times.'

(Note: there is much work to be done on this broad topic.)

'Own ship symbol must be more prominent.'

(Note: this has been darkened on Figure 1.)

'Size of own-ship should be drawn to scale.'

(Note: Many mariners made this point.) (More than one electronic chart on LANCE had this capability.)

'It is not easy to assess ECDIS scale at a glance.'

(Note: the Testbed in fact has a latitude scale bar, as required by SP-52.)

'Generation of a new chart should be as fast as possible.'

'Need capability to add features not on the chart, such as leading lines used in local pilotage.'

'An earlier concept of ECDIS as a one-stop source of all navigation information may run into conflicts .... The fact that the information on ECDIS moves and changes makes it more difficult to interpret than the static paper chart. We need to develop ways of showing the information more simply, even diagrammatically, instead of the present map-type presentation.'

'Operator interaction should be geared towards the least computer-oriented person liable to use it.'

One of the many impressions that come out of reading such comments is of the potential versatility, and hence potential complexity, of ECDIS. But the last comment brings matters back to the bottom line: ECDIS must above all be safe, and hence it must be reliable and easy to operate. Literal compliance with IHO SP-52 will require considerable flexibility, and so careful design of software and the operator interface will be needed to satisfy SP-52 and at the same time keep operation simple. Another possibility is that the initial trend of commercial electronic charts pre-programmed for specific types of operation, with relatively limited options, may continue. These could be chart equivalent for the operation at hand.

THE NEXT STAGE

The CHS Testbed had a limited purpose: to gain first hand experience and feedback from mariners, primarily on chart-related aspects of ECDIS. (However, Universal Systems Ltd. are now developing an 'ECDIS Manager' — a data base and display management package for ECDIS — based on Testbed experience.)

As seen by the authors, the next stage should be to carry out **operational** testing that investigates all potential applications of the chart - equivalent ECDIS over an extended period, to learn what ECDIS will be used for and how it should be operated. Norway and the Federal Republic of Germany are starting this process in 1990 with their SEATRANS and SUSAN projects.

The experience from the commercial electronic charts now entering service will also be very useful. In this connection, a comment from one manufacturer, Offshore Systems Ltd. of Vancouver is relevant. They find that users quickly develop new ways of applying electronic charts soon after the first fitting and modify their requirements accordingly. As another commentator to the North Sea Project Questionnaire put it: '--- *Like radar, ECDIS may give reason to reconsider navigation procedures.*'

It is to be hoped that the IHO and the IMO will be able to find a way of developing the essential provisional guidelines and legal underpinnings to provide a framework for this test period, and meanwhile hold off setting final standards until there is a clearer understanding of the potential and the mode of operation of ECDIS.

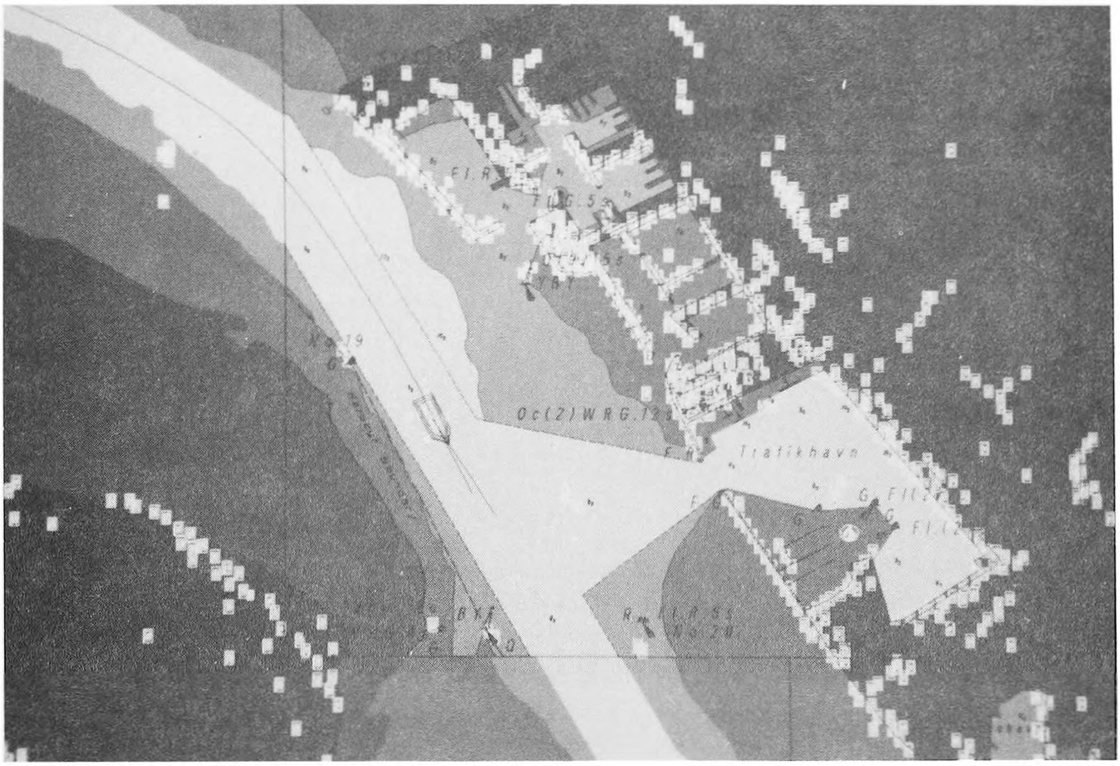

FIG. 1.—The LANCE at Esbjerg. Simulation of the Testbed display on LANCE at Esbjerg, Denmark, during the North Sea Project.

This was copied from a video camera picture taken at the time, after the chart and radar recording had been lost (-a lesson in the need for security in handling ECDIS data and records!) The 'text' option has been switched on, giving buoy characteristics and some feature labelling. The separate ship's head line and course made good line indicate the start of the turn into the Trafikhavn. The ship symbol, scaled for a 150 m ship, gives a feeling for the manoeuvring space available. (The original colour display is a great deal clearer than this black and white print.)

References

AUSTIN, G.L., 1987: 'Sea Trials of a Navigation System Based on Computer Processing of Marine Radar Images'. *Journal of Navigation*, Vol. 40, No. 1, January 1987.

EATON, R.M., S.E. MASRY and B. SHAW. 1986: 'An Electronic Chart Testbed', Hydro '86, Southampton, December 1986. Reprinted in *CISM Journal ACSGC*, Vol. 42, No. 4, Winter 1988, pp. 353-359.

FIELDING, Paul, U.K. Hydrographic Department, personal correspondence, October 1989.

GYLDEN, Sven, G., 1986: 'Some Aspects of Instrument Navigation'. *Seaways*, August 1986.

IHB (International Hydrographic Bureau), 1988: 'Draft Specifications (third) for Electronic Chart Display and Information Systems (ECDIS)', Monaco, October 1988.

IMO MSC/Cir. 515, 13 April 1989: 'Provisional Performance Standards for Electronic Chart Display Systems (ECDIS).'

KAUFMANN, Roy, 1990: 'General Guidelines for the Use of Colour on Electronic Charts.' In this issue of the *International Hydrographic Review.*

MASRY, S.E., Y.C. LEE, T. MCCARTHY and R. MULLEN, 1984: 'CARIS: a geographic information tool.' Papers and Proceedings, FIG International Symposium, Edmonton, Alberta, October 1984. (Published by the Canadian Institute of Surveying, Box 5378, Ottawa K2C 3J1).

NSHC (North Sea Hydrographic Commission). 1986: 'Working Group on Electronic Chart Display Systems, Final Report'. Edited by the Hydrographic Office, Royal Netherlands Navy, The Hague, February 1986.

North Sea Project — 'Abstract of Questionnaire on ECDIS' from 'the North Sea Project — Experiences and Conclusions.' 1989. Norwegian Hydrographic Service, Stavanger, March 1989. Reprinted in this issue of the *International Hydrographic Review.*

NORWEGIAN HYDROGRAPHIC SERVICE, 1989: 'The North Sea Project — a test project for the Electronic Navigation Chart — Experiences and Conclusions' Stavanger, 28 March 1989.