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CURRENT DEVELOPMENTS IN COMPUTER ASSISTED CARTOGRAPHY AT THE UK HYDROGRAPHIC DEPARTMENT

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Abstract

Since the introduction of Computer Assisted Cartography (CAC) techniques into the chart production process at the UK Hydrographic Department in the early 1970s, automation has come to play an increasingly important role. Current policy is to make use of such techniques wherever they offer benefits in terms of cost-effectiveness or production efficiency. This policy has been pursued since combination of the separate CAC production and development units in 1981. The aim of this paper is to summarise the development of the digital production flowline since 1981, to outline the current objectives for further development of the flowline, and to review the progress that is being made towards achieving those objectives. The paper deals specifically with the use of CAC to support production of the conventional paper chart. Expertise gained in the use of CAC is now being applied to experimental work related to the 'electronic chart' concept, but those developments fall outside the scope of this paper.

1. SUMMARY OF MAJOR DEVELOPMENTS TO 1987

In earlier papers by DRINKWATER (1985, 1986), current developments in CAC at the UK Hydrographic Department have been traced back to 1981 when the Department took delivery of its second-generation verification and interactive edit system, a Laser-Scan Interactive Graphical Editing System (IGES). Digitising tables have been used in the Department since the mid-1970s to convert selected elements of hand-drawn chart compilations into digital form in order to generate a reproduction quality image on positive film suitable for subsequent plate-making. Prior to 1981, however, production digitising involved little more than the capture of soundings on selected new chart compilations.

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With the installation of the Laser-Scan IGES, two alternative approaches were considered for the development of the digital flowline:

i. to convert as much as possible of the compilation into a reproduction quality image using digital techniques;

ii. to identify those compilation features which can be converted into a reproduction quality image more quickly and with less effort by digital techniques than by manual ones, and to digitise only those features.

It was decided to adopt the latter approach and progressively extend the use of digital techniques, taking full advantage of the potential for faster chart production and less labour intensive practices. Consequently, since 1981 there has been a significant increase both in the range of chart features routinely digitised and in the total number of compilations handled via the digital flowline. The major developments in the use of CAC in chart production between 1981 and 1987 are listed in Annex 1.

In order to implement these developments it was necessary to increase the volume of software held within the main memory of the DEC PDP-11/60 computer which controlled the Laser-Scan IGES. By the end of 1985, the cumulative effect of these increases was such that the computer was operating very close to the limit of its capacity. This had already resulted in the adoption of less than satisfactory operating procedures. It was not possible, for example, to display both land and sea symbols simultaneously on the IGES's graphics screen. The major consequence of having reached this limit, however, was that it placed severe restrictions on any further development of the digital flowline. It was therefore decided to initiate procurement action to replace the IGES.

2. THE THIRD-GENERATION VERIFICATION AND INTERACTIVE EDIT SYSTEM

In April 1987, the Department took delivery of its replacement for the IGES, a Laser-Scan Interactive Editing System (LITES). The hardware configuration of this system, as delivered, is shown in Figure 1. The LITES provided many new and improved software facilities and its modern high resolution graphics terminals offered three particularly significant advantages over the IGES screens:

i. The display of chart detail in colour, rather than in monochrome. Despite the fact that only four colours are generally used on the British Admiralty chart (five if the green inter-tidal tint is counted separately), the ability to colour code different chart features on the graphics display is a highly useful aid when checking that the correct feature codes have been assigned.

ii. The ability to portray compilation detail in its proper charted style to a high degree of fidelity, whereas only a very simplified representation was possible on the IGES because of the memory limitation referred to above.

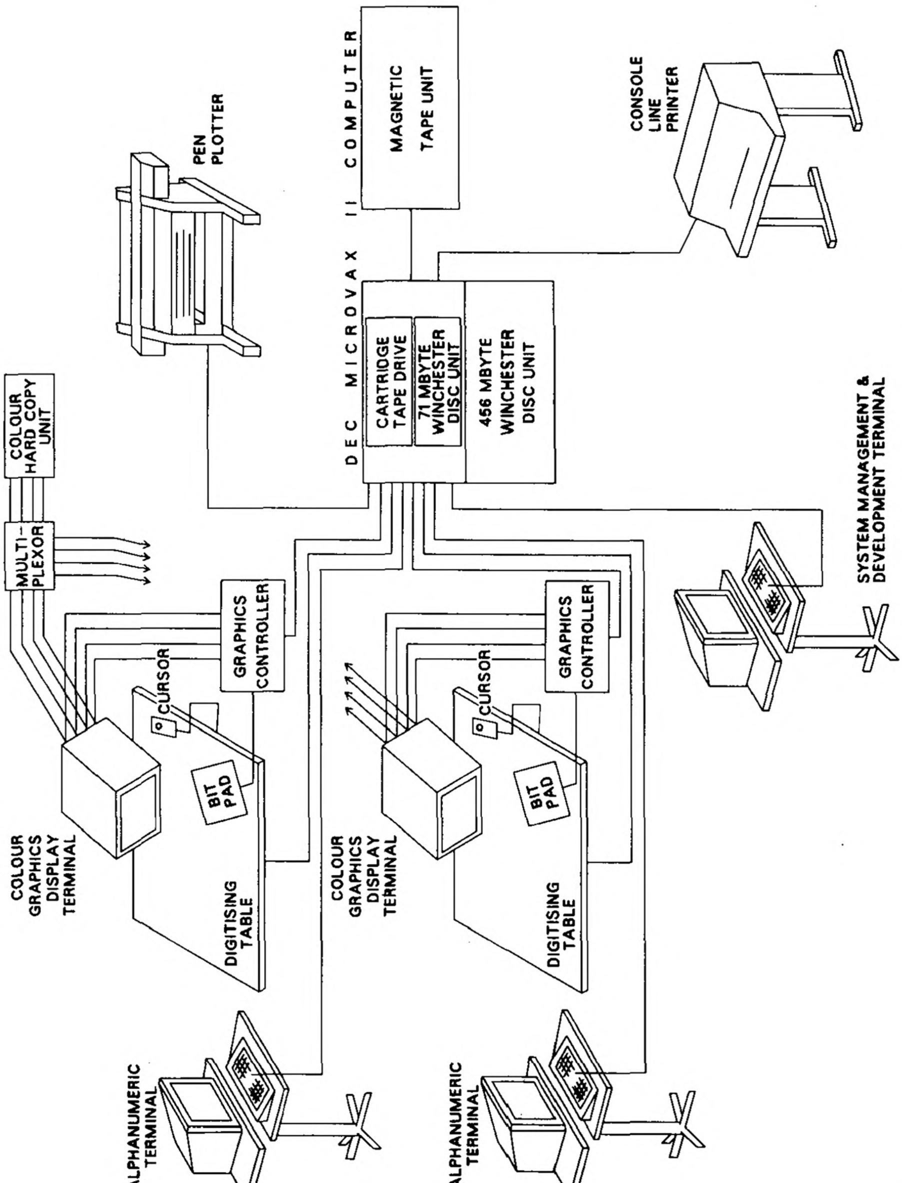


FIG. 1.— Hardware configuration of the Laser-Scan Interactive Editing System (1987).

Several hundred different kinds of complex symbols appear on British Admiralty charts and more than 50 types of pecked and patterned symbolic linestyles are used. Text, whilst using relatively few typefaces, can appear in a wide range of point sizes, and the positioning and spacing of characters is of critical importance in ensuring clarity in areas of dense detail. For interactive verification and editing to be effective, all these charted features need to be depicted as they will appear on the reproduction quality plot. Otherwise, clashes of detail may be detected on the film positive, making it necessary either to revert to interactive editing stage and replot or to correct the film positive manually.

iii. Much faster 'windowing' of the digitised data to display only a selected rectangular area, enlarged to occupy the whole of the graphics screen. A window of data which might have taken several minutes to redraw on the IGES could now be redisplayed in seconds on the LITES. This enables the operator to move quickly from window to window, making any necessary edits at a display scale appropriate to the density of detail or the level of accuracy required.

3. REVIEW OF POLICY AND OBJECTIVES FOR THE USE OF CAC TECHNIQUES

Having removed one major obstacle — the limitations of the IGES equipment — it was considered an appropriate time to review the Department's policy in the CAC field and to plan the way ahead. The review was carried out in the latter half of 1987 and confirmed the policy of making use of CAC techniques wherever they offer benefits in terms of cost or efficiency in the chart production process. The outcome of the policy review was the identification of three main objectives:

i. To streamline the digital production flowline.

ii. To achieve total digitisation of compilation detail.

iii. To create and maintain a single digital database to support both paper chart and digital chart production.

The achievement of these objectives will obviously have a significant effect on the Department's modus operandi and it is pertinent therefore to ask how they are being pursued and in what timescale they may be realised.

4. STREAMLINING THE DIGITAL PRODUCTION FLOWLINE

Computer assistance is used at two separate stages of the chart production process:

i. The plotting of 'mathematical' elements of charts, such as graduated chart borders, linear scales, and lattices for use in conjunction with electronic position fixing aids. These items are produced with great accuracy on three off-line flatbed plotters, from instructions generated by graphical applications programs run on the Department's Data General MV20000 computer.

ii. The conversion of selected compilation detail into a reproduction quality image suitable for plate-making. Compilation detail is encoded into digital form on digitising workstations fitted with voice recognition equipment, operating in 'blind' mode (i.e. without a graphics display). Until early 1989 this data capture task was normally performed off-line (Fig. 2). The digital data is next verified and, where necessary, edited on the LITES. After further processing on the Data General computer, plotting instructions are generated for the flatbed plotters to produce the requisite high quality images.

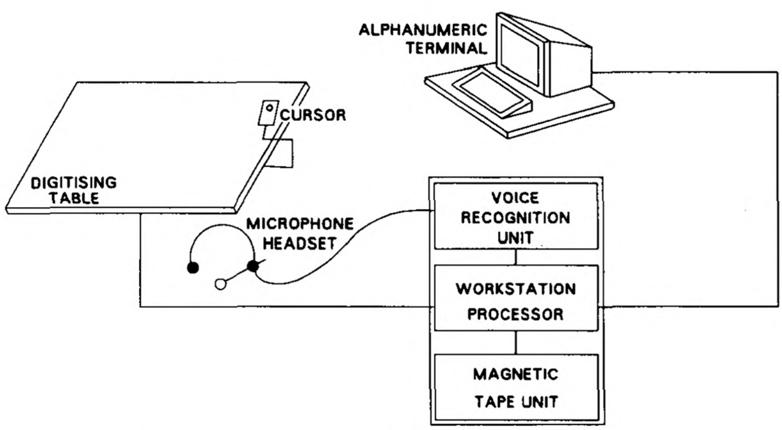


FIG. 2.— Blind off-line digitising workstations (1985-88).

The digital flowline, as it was in 1987/8, is described in greater detail in Figure 3. All new charts (about 85 compilation drawings per annum) and approximately 70% of all new editions (about 170 compilation drawings per annum) are processed through the digital flowline. The current situation with new charts is that approximately 70-80% of black plate detail and 90-95% of magenta plate detail is routinely converted into digital form. With new editions it should be stressed that use has not generally been made of previously digitised data; instead the revised portion of the chart is treated as if it were a new chart, with new detail only being digitised. Compilation detail which cannot yet be digitised is converted into a reproduction quality image using conventional manual techniques and so, for the time being, chart production remains a part digital and part manual process.

Efforts to streamline the digital flowline have been directed towards five main areas, outlined below.

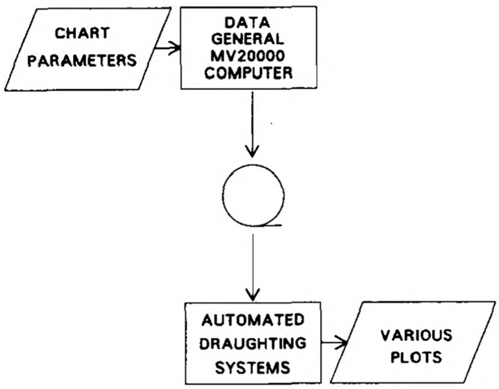
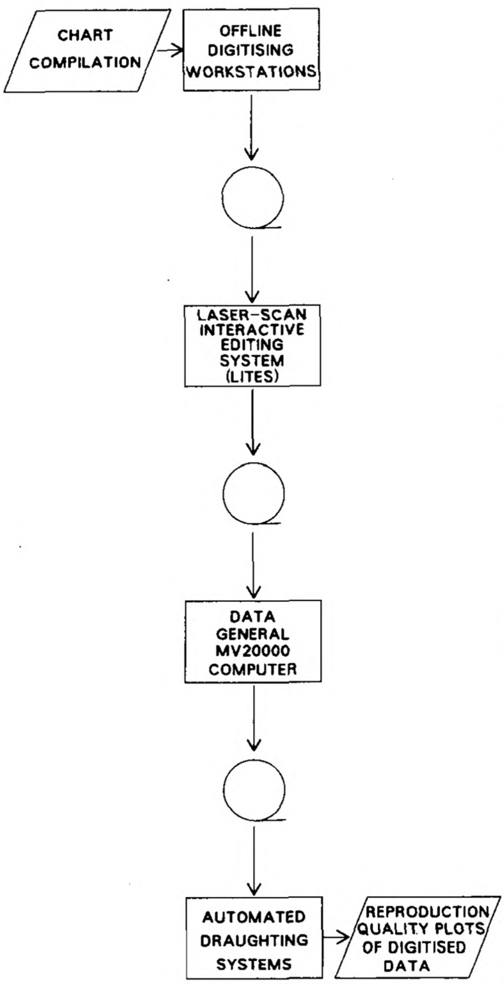


Chart parameters (scale, projection, limits etc) are entered via on-line terminals. Subsequent processing produces magnetic tapes containing plotting instructions to construct chart borders, graticules, grids, scales and lattices.

Plotting instructions drive flatbed plotters to produce required plots on a variety of media. Chart borders plotted on scribecoat are used to obtain a blue stain on ozatex for the compilation drawing.



On receipt of a finished compilation from the drawing office, selected detail is converted into digital form. Point and line symbols are digitised using a table-mounted feature code menu; soundings and text are captured using voice recognition equipment.

Digitised data are transferred to the LITES and processed through software to perform various 'automatic' edits (eg. filtering of double digitised text). Data then plotted on paper using on-line drum plotters and checked against the compilation. Errors identified are corrected by interactive editing on a graphics workstation.

Data then transferred to the Data General computer for further processing to generate magnetic tapes containing plotting instructions for the flatbed plotters.

Reproduction quality plots of black and magenta plate detail are produced on positive film; urban area mask limits are plotted on "cut and peel". Plots are passed to Reproduction Branch for manual addition of all detail not digitised, prior to production of the printing plates.

FIG. 3.— The digital production flowline (1987-88).

4.1 Changeover to on-line data capture

With continually increasing demands being made on the digital flowline, there was a requirement to expand the Department's digitising capacity. Following the standing down of the IGES equipment in September 1987, the two Altek digitising tables from that system were connected to the new LITES equipment and used to capture data directly on-line (though continuing to work in 'blind' mode). Production trials using these tables clearly demonstrated the significant advantages of on-line data capture over the off-line methods used hitherto:

i. Off-line digitising involves capturing data on magnetic tape, which then has to be loaded onto the LITES for subsequent processing. On-line data capture eliminates this use of magnetic tape as a transfer medium.

ii. On-line workstations use the standard Laser-Scan LITES2 software, whereas the off-line workstations use a software package written specifically for the UK Hydrographic Department which is both difficult and expensive to maintain.

iii. Since on-line workstations do not require separate processors and magnetic tape units, they provide a much cheaper means of expanding digitising capacity to meet future requirements for ditigal data (providing that the host system has sufficient processing power to handle the extra loading).

Early in 1989, all of the Department's data capture workstations will be interfaced to the LITES via a local area network. The enhanced system will be supported by a VAXcluster, with two DEC MicroVAX computers sharing the processing workload and having common access to all of the system's resources (i.e. disc drives, tape decks, drum plotters, etc.). The new hardware configuration of the LITES is shown in Figure 4; this includes a further two editing workstations and four data capture workstations which have been added to the digital flowline since the original LITES equipment was installed in 1987. Details of all the CAC hardware currently in use are contained in Annex 2.

4.2 Merging of digitised compilation detail with the 'mathematical' elements of charts

Hitherto, graduated chart borders have been plotted on scribecoat and then a clean sheet of ozatex, with a light-sensitive blue dye coating, has been exposed in contact with the scribed image. On development, this gives a blue stain of the graduated border on the sheet of ozatex, on which the compilation drawing is subsequently produced. At a later production stage, the scribecoat is given a blue dye coating and exposed in contact with the finished compilation drawing, accurately registered to the graduated border. This provides a key image of the compilation on the scribecoat, enabling non-digitised black plate linework (coastline, contours, etc.) to be added by manual scribing.

A new method is currently being developed which involves merging all the

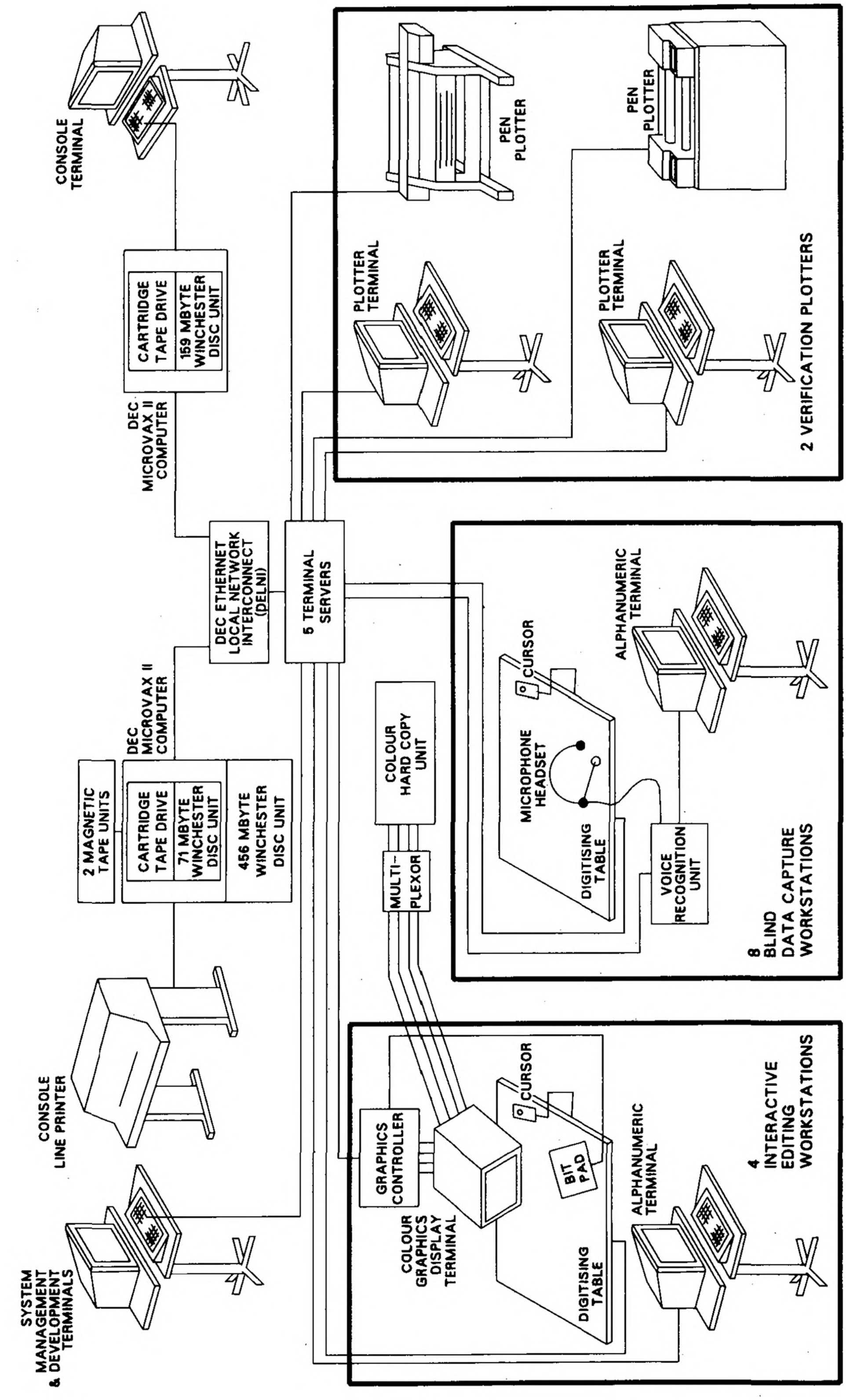


FIG. 4.— Current system configuration (1989).

'mathematical' elements of the chart in digital form with compilation detail digitised on the LITES. The method will make various changes to the present production flowline:

i. The compilation will be drawn on a plotted border (ink on ozatex) instead of on a blue stain from a border scribe, thus dispensing with one staining process.

ii. The 'mathematical' elements of the chart will be incorporated on the reproduction quality film plots, thus ensuring a more accurate fit of the digitised detail to the chart border.

iii. Coastline and other manually scribed detail will be inserted on an unmarked sheet of scribecoat which can be easily registered to the compilation.

When the new method is fully developed, it is intended that meridians and parallels will be automatically broken for symbols and text, and the graduation will be easily edited to allow diagonal or L-shaped borders, using software on the LITES.

4.3 Increasing the range of software-controlled editing facilities

As a greater proportion of chart features is captured per compilation, so the verification and interactive editing task is becoming increasingly time-consuming. This task involves plotting the digitised detail on paper, examining the checkplot against the original compilation drawing and correcting any errors identified by interactive editing on a graphics workstation. Software is continually being developed to automate some routine aspects of editing and to construct certain special features, enabling digitiser operators to concentrate on the more complex aspects of their work where interactive editing is essential. This 'automatic' editing software currently includes the following functions:

i. To search for and correct instances of soundings or text digitized more than once in the same approximate position, and to reposition bottom qualities, if necessary, to ensure that they do not clash with associated soundings.

ii. To break leading lines into their constituent pecked and solid parts.

iii. To construct light sector limits radiating out from the digitised position of a light, with arrow symbols added where the sector arcs meet or cross sector limits.

iv. To break certain linestyles for symbols and text.

v. To select the appropriate size of dotted 'danger circle', swept depth symbol or 'no bottom found' symbol to fit correctly around soundings or rock symbols.

vi. To centralise text strings within anchor berth symbols.

vii. To accurately position topmark symbols on buoys and beacons, having first verified that the chosen combination is legitimate (for example, that a starboard hand topmark has not been digitised in association with a port hand buoy).

viii. To construct True and Magnetic compasses complete with degree labels and magnetic variation text. For Magnetic compasses, the inner rose is automatically generated in the correct orientation.

ix. To generate all the textual information which appears in a fixed layout around the outer border of the chart (e.g. chart number, inner neatline dimensions, standard 'boxed' note, etc.).

Planned extensions to this range of editing and feature generation functions include the automatic breaking of meridians and parallels for soundings and text, and construction of the metres/fathoms and feet conversion tables.

4.4 Use of macros to extend the LITES2 command language

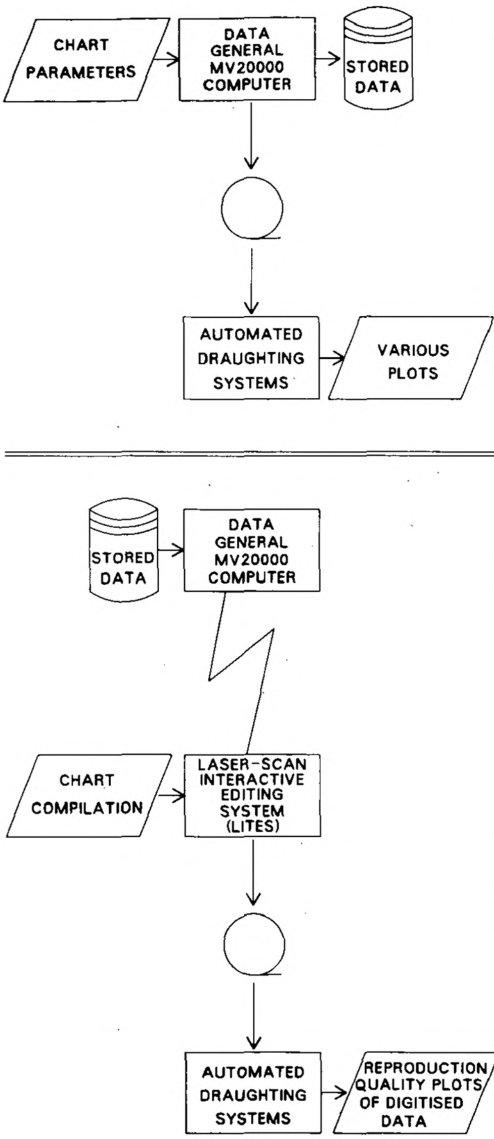
Within the LITES2 software a macro facility is available to enhance editing performance by grouping commonly repeated sequences of interactive editing commands, so that they may be invoked by a single command. Macros may be defined in permanent command files on disc and are then available to all data capture or editing sessions on the system. These macros are fully user-definable and enable the editing software to be tailored specifically to the nautical charting application. For example, simple macros have been written to create and assemble the text in Source Data Diagrams, to position corner co-ordinates in their correct orientation, and to centralise characters within tidal stream diamonds and berth symbols.

The macro facility has also been used to good effect in the interfacing of voice recognition equipment to the LITES, to enable the digitising of soundings and text features using the 'blind' on-line data capture workstations. For example, a sounding value of 7_2 may be entered by speaking the characters 'seven point two', then the single voice command 'Go' invokes a LITES2 macro to create the sounding feature at the current table cursor position. Another voice command 'Ditto' may be used to copy any sounding or text feature to a new table cursor position.

4.5 Generating plot tapes for the flatbed plotters directly from the LITES

Laser-Scan's 'Fast Plotter Program' (FPP) is designed for producing graphical plots from digital cartographic data held on the LITES. Different versions of the FPP software exist for various plotting devices; on the Hydrographic Department's system, it is used to drive two on-line drum plotters which produce the paper plots for verification purposes. Laser-Scan were commissioned to develop a version of FPP to drive the Department's flatbed plotters, but in-house work is needed to transfer some processing tasks from the Data General computer to the LITES before the new version of FPP can be fully implemented in the digital flowline. When this work is completed, it will be possible to bypass the Data General computer and thereby speed up production of the final reproduction quality plots.

The developments described in sections 4.1 to 4.5 above should result in a streamlined digital production flowline, as illustrated in Figure 5, within the coming



Plotting instructions generated as in Fig.3 to construct borders and other 'mathematical' elements of charts. Chart parameters are now stored on disc for use again later in the production flowline.

Chart borders are plotted in ink on Ozatex (instead of on Scribecoat) and supplied directly to the drawing office for compilation purposes.

On receipt of a finished compilation from the drawing office, the stored chart parameters are reprocessed and the digital data for the various 'mathematical' elements are transferred to the LITES via a PC.

Further processing converts this data into Laser-Scan's vector format and adds the standard textual information to the chart border file. Selected compilation detail is digitised on-line using 'blind' LITES workstations with table-mounted menus and voice recognition equipment. 'Automatic' editing, verification checking and interactive editing are then carried out as described in Fig3.

Magnetic tapes containing plotting instructions for the flatbed plotters are produced directly from the data on the LITES, so bypassing the Data General computer and speeding up production of the final reproduction quality plots.

FIG. 5.— Future 'streamlined' digital production flowline.

year. In the longer term, however, the aim is to completely eliminate the use of magnetic tape as a means of data transfer within the flowline by having direct communication links to the automated draughting systems.

5. EFFORTS TO ACHIEVE TOTAL DIGITISATION OF COMPILATION DETAIL

New digital techniques introduced over recent years have brought with them real advantages (in terms of both speed of chart production and staff numbers required), compared with the conventional methods they have replaced, and it seems clear that full digitisation of compilation detail offers further potential for increasing production efficiency. Efforts to achieve this aim may best be described by considering compilation detail categorised into point, line and text features. The drawing instructions for these features currently have to be defined, in two very different formats, on both the Data General computer (for generating plot tapes for the flatbed plotters) and on the LITES (for displaying on the graphics screens and plotting using the FPP software). Only the latter will need to be maintained, however, once it becomes possible to generate plot tapes for the flatbed plotters using the new version of FPP mentioned in 4.5.

5.1 Point Symbols. Prior to 1981, only a very small number of point symbols were digitised and each of these was produced on film using the techniques of 'flashing' a beam of light through an image of the actual symbol on the plotter's lighthead disc. The majority of point symbols are now produced by 'drawing', making use of a number of geometrical shapes (dots, slits and squares) on the lighthead disc. This method of working, described by DRINKWATER (1985, 1986), has the advantage over 'flashing' that a single disc can be used to produce an unlimited number of symbols, so dispensing with the need to change discs during plotting and the need to acquire new discs if new or amended symbols are introduced.

The point symbol library on the LITES is held in a 'Symbol Representation' file, with a format very similar to that used to store chart data. New symbols can easily be added to the library by digitising the symbol design directly into the Symbol Representation file, using any combination of lines, curves, arcs and infilled areas. Only a small number of the less common chart symbols remain to be designed and digitised in this way.

5.2 Linear features. Those which are not yet routinely digitised fall into two categories: symbolic line styles for which there are currently no drawing algorithms, and simple continuous line styles which can be converted into a reproduction quality image more quickly and cost-effectively by manual scribing. Most symbolic line styles are defined on the LITES in a 'Pattern Table' which contains, in ASCII format, the necessary parameters for display or plotting purposes (e.g. parameters for scaling lines between digitised points and for incorporating regularly spaced point symbols from the Symbol Representation file). One limitation of this pattern facility is that lines can only have a maximum of two repeating components. It has therefore been necessary to develop special software to handle more complex line styles such as the power transmission line symbol (-•-ϟ-•-ϟ-•-ϟ-•-). Some complex line styles, such as the rock and coral foreshore symbols, will probably also require simplification before they can be produced via the digital flowline.

The cost-effective capture of sinuous linear features such as coastline and contours remains a major obstacle, even though the line styles themselves are simple to specify in graphical terms. Recent trials have demonstrated that satisfactory results can be obtained using a 'point mode' digitising approach (where the operator uses his skill and judgement to arrive at a suitable spacing of digitised points), but the capture of such intricate linear features in this way is a time-consuming process. The Department is currently investigating two alternative approaches to overcome this obstacle. One involves using a special scribing cursor to digitise sinuous lines in continuous 'stream mode' (where points are automatically sampled as the operator traces the cursor along the line). The second approach involves the automatic scanning and vectorising of linework prepared on a separate document (which, if adopted, will necessitate a change in current compilation practice). At this stage, however, it would be premature to predict the outcome of these investigations.

5.3 Text features. Prior to 1985, production digitising of text features was restricted to soundings and a few dozen standard abbreviations for buoy colours and bottom qualities (each abbreviation being allocated a separate box on the table-mounted feature code menu, and thus treated as point symbols rather than as true text strings). In 1985, the Department's plotting software was developed to enable genuine text strings to be plotted at any orientation and scaled, if necessary, between user-defined points on either a straight line or a curve. Feature code menu boxes were allocated to frequently occurring legends such as 'Anchoring Prohibited', but other text strings had to be defined by means of the digitising workstation keyboard. At that time, voice recognition equipment was used only for the capture of soundings, which required the training of a very limited vocabulary consisting mainly of the digits 'zero' to 'nine'. The programmed vocabulary has since been considerably extended to enable any text feature to be captured either by using standard words such as 'Chimney', or by building the string character by character using the phonetic alphabet ('alpha, bravo, charlie', etc.).

Text fount libraries on the LITES are held in a 'Text Representation' file, similar to the Symbol Representation file for point symbols. So far, however, founts have only been designed for the various 'sans serif' typestyles which appear on British Admiralty charts (i.e. Univers Light and Medium, in both upright and italic styles). All other text is currently phototype-set on thin positive film which has to be manually patched onto the reproduction quality image. In order to reduce and eventually eliminate the need for this manual process, two particular aspects of text handling within the digital flowline are being addressed:

i. ***Text founts with serifs.*** Important geographical names traditionally appear on British Admiralty charts in Times Roman type, either in upright or italic style. These typestyles cannot be reproduced using our existing plotting software which selects a single lighthead disc symbol to draw characters in a uniform lineweight. However, having digitised the outlines of Times Roman characters in the Text Representation file, it is possible, using Laser-Scan's FPP software, to fill in the outlines to reproduce letters of variable lineweight (including serifs). With the Department's present generation of plotters which operate in vector mode (i.e. with plotting instructions defining a series of light on and light off movements in both the X and Y axes), character outlines can only be filled in by hatching. It is likely, however, that with the future introduction of plotters operating in raster mode (i.e. with plots defined by individual pixel dots in a series of straight lines, comparable to the way an image is formed on a television screen), the plotting of Times Roman text will become significantly more efficient.

ii. ***Accents and diacritical marks.*** On the British Admiralty worldwide series of charts, geographical names are rendered according to the official spelling of the appropriate national authority, or according to an approved system of transliteration, retaining any accents or diacritical marks. All of the standard marks are being designed and digitised as special characters in the Text Representation file so that they may be captured as an integral part of any text string. Each mark is assigned a keyboard character and is then called up for display by adding the prefix $ to that character. For example, if '$a' represents the circumflex, then 'Ch$aateau' will be displayed as 'Château'. Once included in the Text Representation file, it is intended to add the various accents to the vocabulary of the voice recognition equipment so that the appropriate combination of keyboard characters may simply be entered by saying, for example, 'circumflex alpha'.

6. PLANNED CREATION OF A DIGITAL CHART DATABASE

The digital flowline has been developed specifically to support the production of paper charts. As it is not yet possible to convert the entire contents of a chart compilation into digital form, and as new information received post-digitising is incorporated manually onto the bases from which printing plates are made, the digital data and the contents of the published chart are never in complete agreement. It is considered that such incomplete and possibly superseded data could be potentially dangerous and so, as mentioned earlier, use has not generally been made of previously digitised data. In fact, prior to 1987, none of the data generated by the digital flowline was permanently retained, although it has since been decided to begin databanking of magenta plate detail (almost 100% of which is digitised) for possible use on new editions.

With the achievement of total digitisation of chart detail envisaged within the next 5 years, and with the increase of interest in the 'electronic chart', future requirements for the creation and maintenance of a full database of digital chart information are now being studied. Preliminary work is aimed at carrying out a full assessment of the desirability and feasibility of implementing such a database. If the conclusion of this work is that the use of database techniques is justified, then further work will be required to:

i. Investigate the various database techniques available.

ii. Define the required data structure and format, which should be as compatible as possible with the standards agreed by the IHO Committee on the Exchange of Digital Data (CEDD).

iii. Achieve the capability to digitise in, or convert to, the required data structure and format.

iv. Determine the scope and content of the database.

v. Determine the maintenance procedures for the database.

It is likely that a future digital database will assist not only in the production of new charts and new editions, but also in the handling of incoming hydrographic data, in the chart compilation and maintenance processes, and in the fulfilment of data requirements for other Hydrographic Department products, both digital and analogue. In the longer term, it seems probable that a digital chart database will be used to support a 'print on demand' chart production system, possibly using high resolution, large format, colour electrostatic plotters.

7. CONCLUSION

The object of this paper was to review the Hydrographic Department's current plans and objectives and to report on the recent progress made in the field of computer assisted cartography. CAC techniques are now firmly established in the chart production process but, by the very nature of the step-by-step development approach that has been pursued, those tasks which were easier to automate have tended to be tackled first, while some of the more difficult aspects are left outstanding. The pace of progress will ultimately depend, firstly, upon future technological developments and, secondly, upon the further application of existing technology. The Department must continue to monitor developments and liaise with systems suppliers and other users in order to find solutions to the problems which lie ahead.

The views expressed in this paper are those of the author and are not necessarily those of the Hydrographic Department or the Ministry of Defence.

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ANNEX 1

USE OF COMPUTER ASSISTED CARTOGRAPHY IN CHART PRODUCTION

MAJOR DEVELOPMENTS 1981-1987

1. CAC facilities extended to be suitable for use with all chart compilations, not just a selected few.
2. Digitising of all soundings (full sized, reduced, hairline).
3. Digitising of all dashed linestyles, including danger line.
4. Digitising of complex linear symbols, for example seabed pipeline, seabed cable, prohibited area limits, mangrove coastline.
5. Increase in the number of point symbols which can be digitised, made possible by the decision to draw rather than flash symbols. (Total now exceeds 350).
6. Digitising of lettering. Initially selected items e.g. bottom quality, buoy colour identifiers, etc. Now extended to almost all magenta plate text and much black plate text. Development of software to allow operators to quickly specify pointsize, justification and orientation (including curvature) of text string and to scale it between any two points.
7. Introduction of the symbol orientation facility.
8. Ability to construct composite symbols, for example buoys, from constituent elements.
9. Use of voice recognition equipment to specify spot heights, contour labels and a wide range of text.
10. Use of digital techniques in the production of new editions.
11. Digital production of urban area masks on cut and peel.
12. Introduction of automatic, i.e. software controlled, editing.
13. Ability to generate magnetic compass detail automatically by software.

ANNEX 2

COMPUTER ASSISTED CARTOGRAPHY EQUIPMENT
(JANUARY 1989)

1. LASER-SCAN Interactive Editing System (LITES2), comprising:

a. DEC MICROVAX II computer (DH630 Q5-A3) with:

- *i.* 16 Mbytes memory.
- *ii.* DEC RD53 71 Mbyte Winchester disc unit.
- *iii.* DEC RA81 456 Mbyte Winchester disc unit.
- *iv.* DEC TK50 magnetic cartridge tape drive.
- *v.* 2 KENNEDY 9600 magnetic tape units.
- *vi.* DEC LA120-AB console line printer.

b. DEC MICROVAX II computer (DH630 Q2-HE) with:

- *i.* 9 Mbytes memory.
- *ii.* DEC RD54 159 Mbyte Winchester disc unit.
- *iii.* DEC TK70 magnetic cartridge tape drive.
- *iv.* DEC VT320 alphanumeric terminal and keyboard (console).

c. DEC Ethernet Local Network Intercomment (DELNI).

d. 5 DECSERVER 200 terminal servers.

e. D-SCAN CH 5301 colour hardcopy unit (A4 size).

f. BENSON 1645R drum pen plotter (8 pens).

g. CALCOMP 1051 drum pen plotter (4 pens).

h. 4 interactive verification and editing workstations, each comprising:

- *i.* ALTEK digitizing table with AC40 controller and 16 button cursor.
- *ii.* SIGMEX 6264-34 colour graphics display terminal (with 348 × 246 mm screen area, 6 Mbytes local memory).
- *iii.* SUMMAGRAPHICS 'Bit Pad Two' data tablet with 4 button cursor.
- *iv.* DEC VT220 alphanumeric terminal and keyboard.

i. 8 data capture (digitising) workstations, each comprising:

- *i.* ALTEK digitising table with AC40 controller and 16 button cursor.
- *ii.* Marconi 'MACROSPEAK' voice recognition unit (with 640 word vocabulary).
- *iii.* DEC VT220 alphanumeric terminal and keyboard.

2. AEG 3012 automated draughting system, comprising:

   a. ARISTOMAT 8340 plotting table (1200 × 1500 mm plotting area; ±0.04 mm accuracy; draughting tools for drawing by pen, scribe or lighthead).
   b. AEG-Telefunken 60/10 minicomputer with 24 K memory.
   c. AEG MBS 3630 magnetic tape unit.
   d. GEOGRAPH 3012 operating panels and TELEPRINT 390 teletype.

3. KONGSBERG 1825s automated draughting system, comprising:

   a. KONGSBERG 1825s plotting table (1800 × 2500 mm plotting area; ±0.075 mm accuracy; draughting tools for drawing by pen, scribe or lighthead).
   b. KONGSBERG SM402S minicomputer with 32 K memory.
   c. PERTEC T6660 magnetic tape unit.
   d. CIFER 2605-02 G VDU terminal and keyboard.
   e. EPSON FX-85 dot matrix printer.

4. ARISTO 306 automated draughting system, comprising:

   a. ARISTOMAT 306 plotting table (1800 × 1700 mm plotting area; ±0.06 mm accuracy; draughting tools for drawing by pen, scribe or lighthead).
   b. ARISTO 300 series controller incorporating DEC LSI 11 microprocessor and memory.
   c. DIGI-DATA magnetic tape unit.
   d. TAS2 'intelligent' keyboard display unit.