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COMPUTER-ASSISTED CARTOGRAPHY: A PROVISIONAL BUT PROMISING SOLUTION

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Abstract

The evolution of the concept of computer-assisted cartography at the French Hydrographic Office over the last ten years is retraced in this article, describing the new interactive cartographic workstations which came into service early in 1989.

1. INTRODUCTION

The first system of computer-assisted cartography (CARTAS) used by the Hydrographic and Oceanographic Service of the Navy (SHOM) was defined in the mid-1970s. It consisted of an interactive graphic terminal and an optical system, linked to a computer, permitting the analysis of any graphic document and its display on the terminal in raster mode. The digitization of the document, in vector mode, was subsequently carried out, either directly by the operator (designation on the terminal screen of the various features represented on the document: soundings, symbols and letters, with the help of a reticule governed by a cursor, and coding of these features by means of a keyboard), or semi-automatically by the optical system itself (simple curves, coastline or isobaths, previously designated by the operator on the terminal screen).

Being still a prototype, this system only made a very small contribution to the production of cartographic documents but it nevertheless made it possible to acquire know-how in the management of cartographic information in digital form, to develop and test the first software for automated cartography and, finally, to establish the beginnings of a cartographic data base which was, however, to be provisionally abandoned in 1984 when the CARTAS system was phased out.

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2. GENESIS OF A NEW SYSTEM OF COMPUTER-ASSISTED CARTOGRAPHY

The many possibilities of interactive graphic terminals in cartography were merely glimpsed at with that first system, partly because of the lack of digital data suitable for generalization, joining, manipulating or simply managing, but also because of its limitations in the field of lettering (choice of letters and layout of words), closely linked with those of the precision plotting tables available at that time.

These experiences led SHOM to examine the problem of what is termed 'automated' cartography from a new angle, stressing plotting to the detriment of the data base, and it is thus that, early in the 1980s, it was decided:

— to create, in digital form, an extensive library of letters and symbols;

— to perfect relevant software for plotting;

— to develop a precision plotting table (BENSON 2532) capable of reconstituting directly on film, using a photo-cathodic head, any character, symbol or contour line previously defined in digital form;

— to acquire large-size digitizing tables (BENSON 6301), directly connected to the main computer (BULL DPS8) (fig. 1), and to develop the relevant software.

The new system, less ambitious than the CARTAS system, was this time conceived as a production tool specialising in fair drawing. The mock-up of the chart continued to be produced by conventional methods, with a large amount of hand drawing, whilst the fair drawing could be entrusted to persons with no particular knowledge of graphic techniques, nor aptitude for draughtsmanship. The mock-up of the chart was, indeed, digitized by an operator who followed scrupulously the instructions given by the cartographer, and the files thus created could be used to produce directly the black and magenta films, one carrying the lines and the other the letters and symbols.

The system entered into service in 1985, at a time when SHOM adopted, for all its cartographic products, international standards developed within the International Hydrographic Organization (IHO).

This system includes seven digitizing tables and is used systematically, not only for the production of all new charts, but also for the updating of existing charts, produced to former national standards, thanks to the extent of the 'library' initially created, and to its evolutive nature.

After a 'running-in' period of several months, profitably used for improving the software and acquainting operators with their tasks, a considerable reduction was noted in the time required for producing the films used for printing. Estimated at an average of 600 hours prior to 1985, it was only in exceptional cases more than 450 hours in 1987, without, of course, counting the time devoted to the construction of the mock-up itself. These encouraging results must certainly not be entirely attributed to the new computer-assisted cartographic system — the dis-

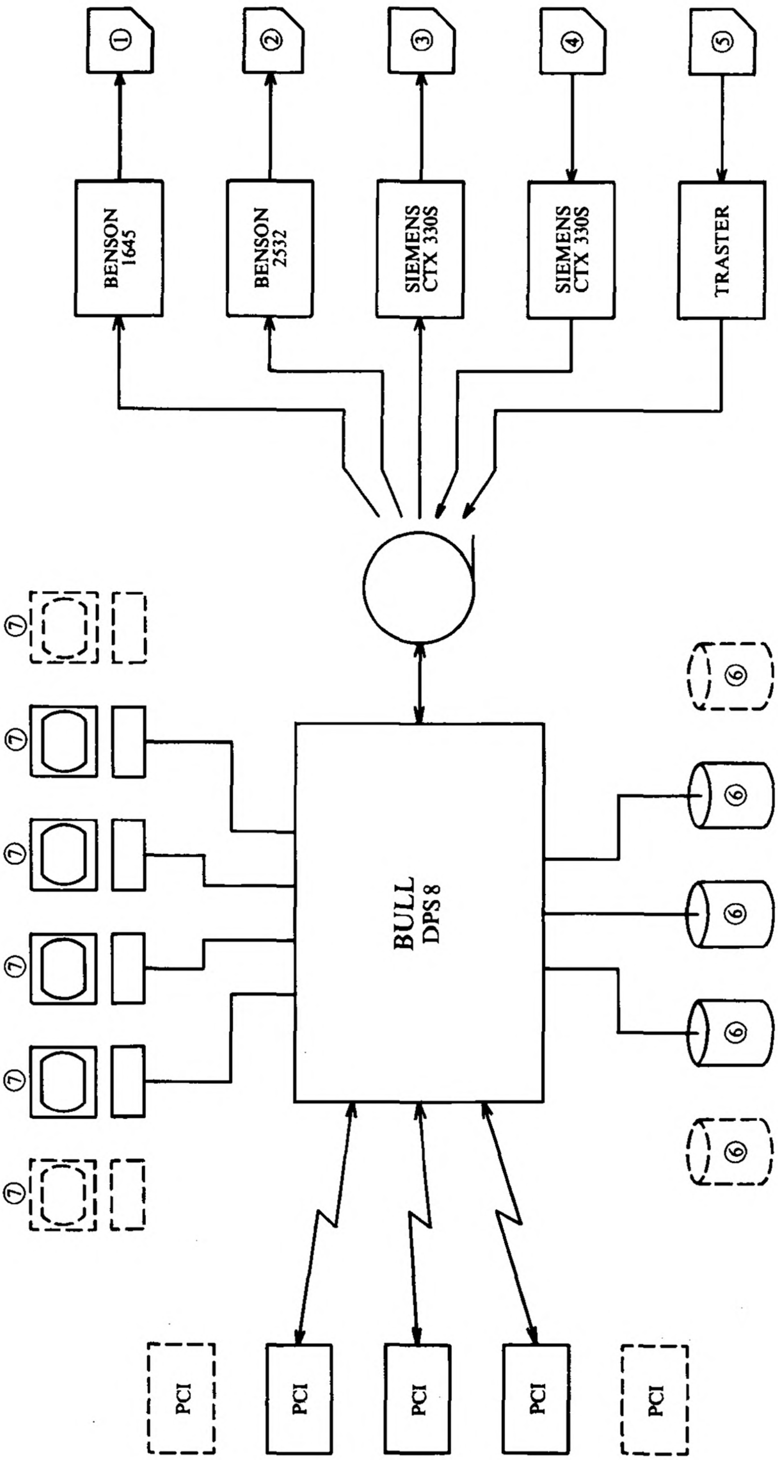


FIG. 1.— Main computer: plan of connections for cartography.
① Paper or tracing ② Film ③ Film ④ Chart, film or paper ⑤ Aerial photographs, film
⑥ Thematic files ⑦ Alphanumeric terminals for consulting and updating thematic files.

carding of national standards in favour of international standards having also appreciably simplified the procedures used (reduction in the number of films, for instance).

3. BIRTH OF THE INTERACTIVE CARTOGRAPHIC WORKSTATION

The principal disadvantages of the system just described are:

— an obligation to create a more perfect mock-up, representing each feature, particularly the lettering, in exact dimensions, in order to avoid clumsy superimposing on the film (lettering and sounding, for instance) in areas where the selected information is dense;

— detection too late of coding errors occurring during digitization (off line on the check proofs rather than in real time on a graphic screen which was not available);

— poorly adapted tools for digitizing and correcting curves (over-long delay in responses from the main computer) and inadequacies in plotting software (intersections of tracks, for example);

— cumbersome correction procedures which were directly derived from the digitizing processes. The final corrections were thus made, more often than not, on the film itself and not in the file.

The reservations expressed concerning digitizing and plotting of curves had, in fact, no effect on the operational use of the system. After mastering the scribing technique, the operators quite naturally continued to scribe simple lines (coastlines, isobaths, channels, rivers, etc.) and digitized only complex lines (sandy coast, danger limits, drying rocky shelf and coral reef, limit of mangroves, etc.), thus deriving the maximum advantage from the tools at their disposal. This procedure obviously required some manual touching up on the film, combining the scribed lines and the digitized ones.

The other disadvantages in the system were linked to the absence of an interactive graphic terminal permitting the display, in real time, of the file contents, both during the digitizing process and during the correction process. It was therefore decided to add such a terminal to the existing system, which, interfaced this time to a specific computer, could be termed an interactive cartographic unit or workstation — ICW (in French: poste cartographique interactif — PCI).

The prototype delivered early in 1988 at once showed itself to be very promising and was put into service almost immediately to correct the files digitized by the former system and to improve the clarity and legibility of the final documents by touching up, wherever necessary, the arrangement of the various features portrayed. In the latter case, the scribing of simple lines is analysed beforehand with the aid of a scanner (SIEMENS CTX 330S) which, using software for reducing to spaghetti linework and vectorizing, enables a file to be created representing the scribed lines. With this new file added to those already digitized, all the cartographic information is thus displayed on the screen of the graphic terminal.

The first standard interactive cartographic workstation, which differs from the prototype essentially in some ergonomic adjustments to both the hardware and the software, was delivered at the end of 1988. The acquisition of three further identical workstations is planned in the near future.

4. DESCRIPTION OF AN INTERACTIVE CARTOGRAPHIC WORKSTATION (fig. 2)

4.1 — Central unit (CELI LOGO 6300-2)

Micro-processor 68030 plus arithmetical co-processor — Read-write 8 Mbyte memory — Real Time Unix (RTU) operating system — Programmable in Fortran and in language C — Fitted with a 5 1/4" diskette reader/recorder of 650 Kbytes, a 313 Mbyte hard disk and a 45 Mbyte cartridge reader/recorder for safeguard of files — Possibility of linking to Ethernet network.

The central unit permits, on the one hand, a dialogue with the main computer (transfers of files) and, on the other hand, the monitoring of three graphic terminals able to function simultaneously and able to be used for various tasks (selection, digitizing, correction). It stores in memory the library of letters and symbols already referred to, slightly simplified to optimize the processing time, and the relevant software for graphic plotting (see §2). In other words, they are practically the same data and the same software as are used to display the chart features on the graphic terminal screen and, subsequently, to reproduce them on film by means of a precision plotting table.

4.2 — Graphic terminal (CELI LOGO 308)

1280 × 960-dot colour graphic screen (resolution 0.3 mm) — 4 Mbyte local graphic memory and arithmetical co-processor — 113-key keyboard — 12" digitizing tablet with 16-key cursor for management of menus, designation and manipulation of data, digitization of symbols and of types of contours — Alphanumeric screen serving only for dialogues (VT 100).

The local graphic memory and the arithmetical co-processor take in hand, directly, without help from the central unit, all the functions specific to the display of data on the graphic screen: zoom, panning, blinking of the objects designated by means of the reticule, management of the reticule, etc.; this enables one to obtain very rapid response times on the display (0.4 Mbyte in 3 seconds). The loading of the local graphic memory from a file of cartographic data of up to 4 Mbytes, available in the central unit, is obviously less rapid, as it takes nearly ten minutes, but the corresponding 'dead' time occurs only once, at the beginning of the process.

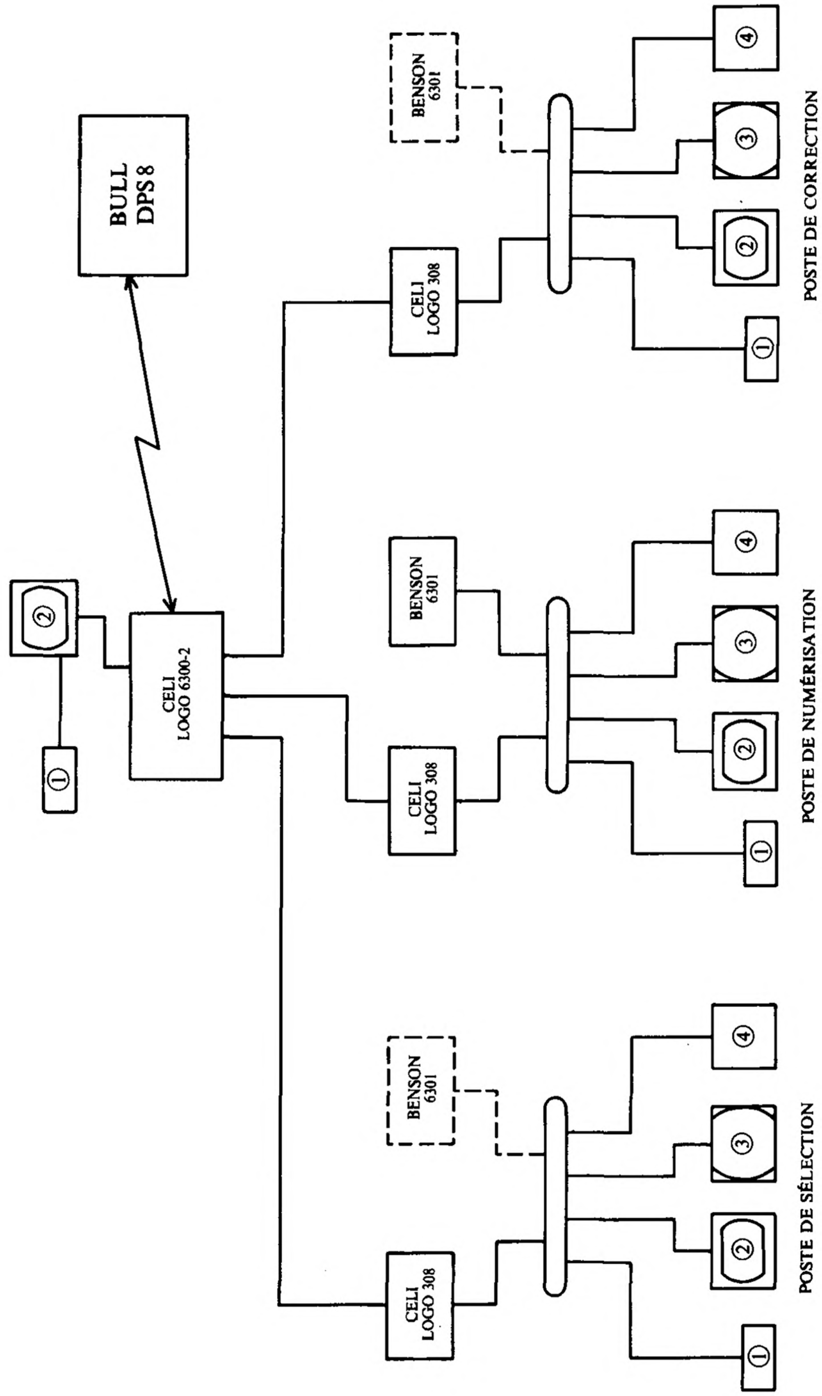


FIG. 2.— Plan of the interactive cartographic workstation (ICW).
① Keyboard ② Alphanumeric screen ③ Graphic screen ④ 12" Digitizing tablet.

Up to 32 different magnifications in 8 separate colours can be displayed and managed simultaneously on the terminal.

The library of symbols and the collection of standard contours appear on the digitizing tablet which can thus be used to designate the type of symbol or the type of contour to be digitized.

4.3 — Digitizing table (BENSON 6301)

1300 × 870 mm work surface — Accuracy 0.1 mm — 16-key cursor (identical to cursor linked to 12" digitizing tablet) with display of coordinates — Direct link (RS 232) with graphic terminal.

This table is, in fact, useful only for the interactive cartographic unit used for digitizing; it is directly connected to the graphic terminal, which allows, among other things, control of the display with the table cursor.

4.4 — Furniture (UNIC KALI RD)

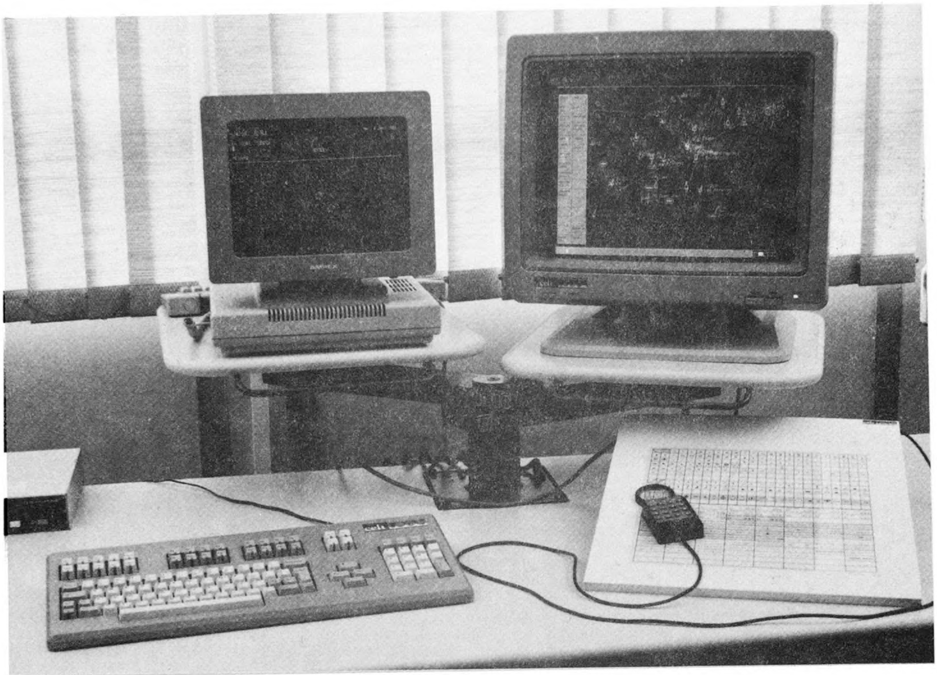
A piece of furniture specific to the digitizing unit makes it possible to set up an ergonomic workstation. This piece supports the top of the digitizing table, which can be positioned and moved in any direction, as well as the graphic and alphanumeric screens, which are arranged on swivelling supports, the height of which can be adjusted electrically. (See fig. 3).

4.5 — Software

According to the purpose for which it is intended, the software is used either in the main computer or in the central unit of the interactive cartographic workstation.

4.5.1 In the main computer, some of the functions available are as follows:

- transformation of rectangular or geographic coordinates into chart coordinates, whatever the projection, and in any geodetic system;
- calculation of limits in various projections (Mercator, Lambert, Gauss, stereographic, etc.);
- extraction of data from files within a defined geographic area and, if required, cartographic interpretation of such data; this function makes it possible, for example, to ensure that the parts common to two adjacent charts are identical;
- generalization of contours;
- transcribing of any file into the format of the interactive cartographic workstations (files from, e.g. the TRASTER analytic stereoplotter or the SIEMENS scanner ...);



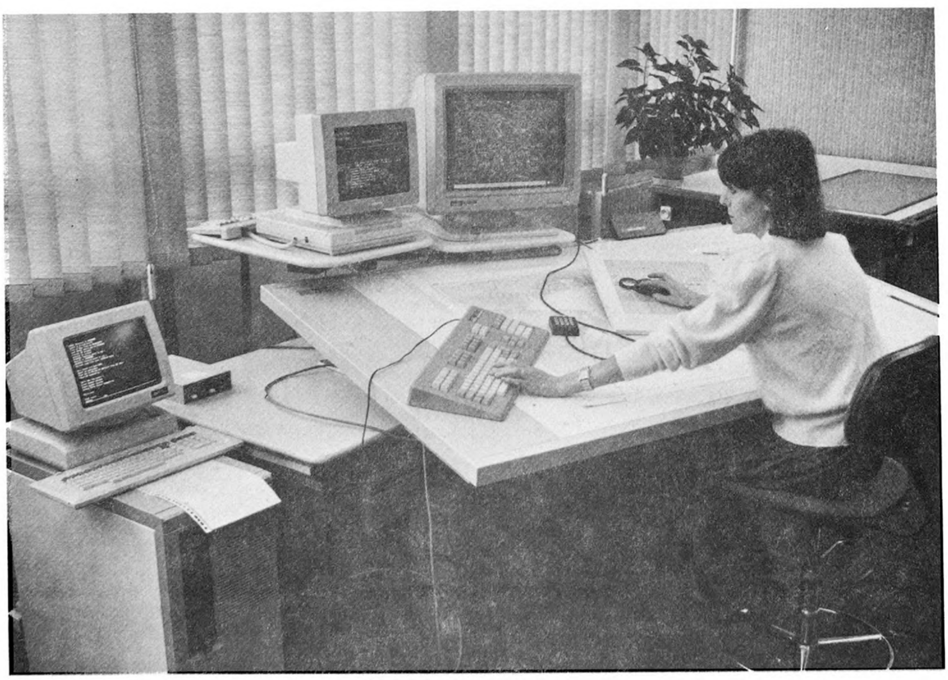


FIG. 3.— Selection and correction unit (above) and digitizing unit (below). On the left of the lower picture, the ICW central unit can be seen, on top of which is the alphanumeric terminal used for transfers to and from the main computer.

— conversion of files from the interactive cartographic workstations into instructions commanding the plotters.

4.5.2 The principal operational functions of the software in the central unit (INNOVAL ROYALE) are:

— correcting the deformations measured on the document to be digitized (refine transformation);

— adding, modifying or deleting contours;

— merging two curves (linking up of extremities);

— adding, modifying, deleting, or shifting of soundings;

— adding, modifying, deleting or shifting of spot heights;

— adding, modifying, deleting or shifting (and possibly changing slant or angle) of symbols (see fig. 4);

— adding, modifying, deleting or shifting of a legend, change of justification or position of lettering (see fig. 5);

— change of magnification or colour of features displayed.

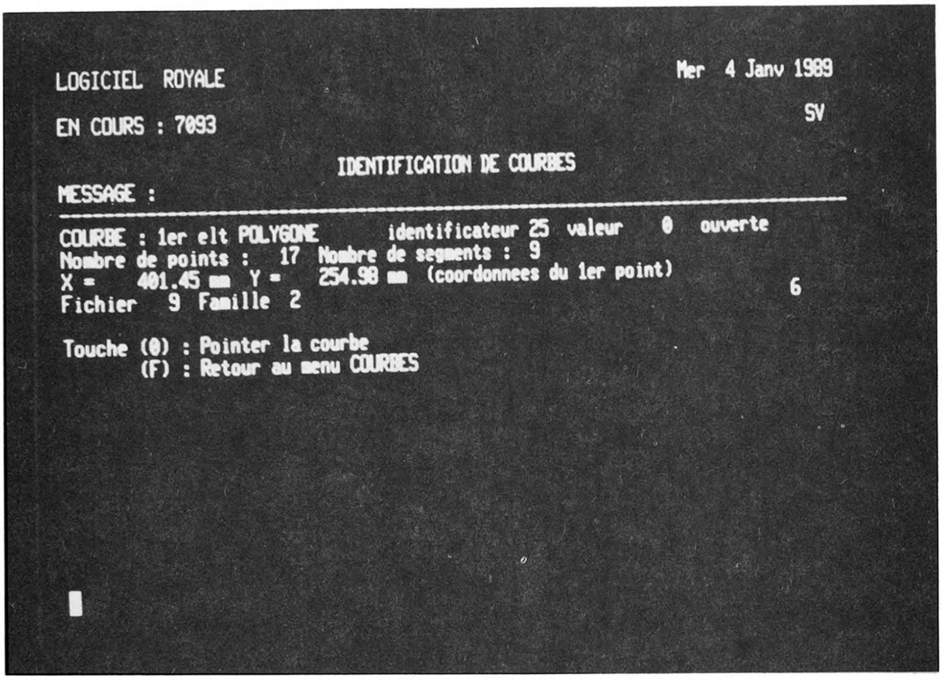
5. USING THE INTERACTIVE CARTOGRAPHIC WORKSTATION

Three types of use are possible: firstly, the selection and the generalization, if required, of the data already existing in digital form; secondly, the digitization of data available in graphic form and their re-arrangement, if required; finally, the correcting and updating of files relevant to a given chart.

5.1 — Selection and generalization

SHOM maintains in the main computer a certain number of descriptive, thematic files which more particularly refer to the coasts of France and concern buoyage, landmarks, wrecks, the coastline and the 'zero' isobath (digitized with the CARTAS system and not updated since 1984), topographic contours and the relevant digital terrain model, submarine cables, limits of military practice areas, etc.

Extracts from these files are made within the limits of any new chart, as soon as its compilation is begun; then, specific software in the main computer produces from the information contained in these files — which sometimes includes the degree of generalization (e.g. files concerning buoyage or landmarks), lines, symbols and cartographic legends at the scale of the chart; lines, symbols and legends which are transferred then displayed on the interactive cartographic workstation grouped into certain themes. Different colours may be used for each theme and, within a single theme (buoyage or landmark), to the same degree of



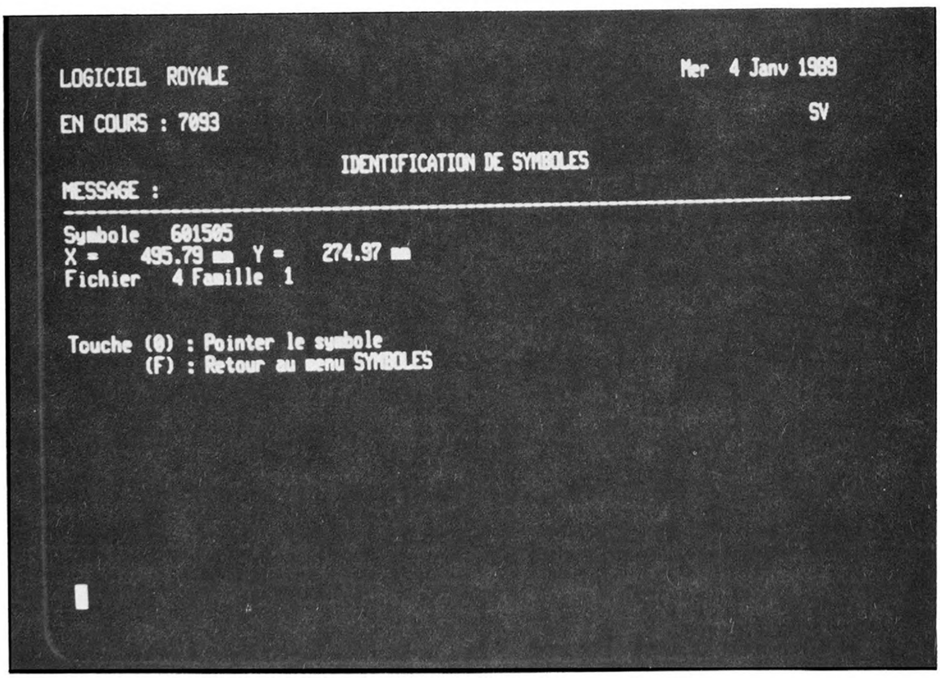


FIG. 4.— Examples of messages appearing on the screen of the alphanumeric terminal in the process of identifying a curve (above) or identifying a symbol (below) on the screen of the graphic terminal.

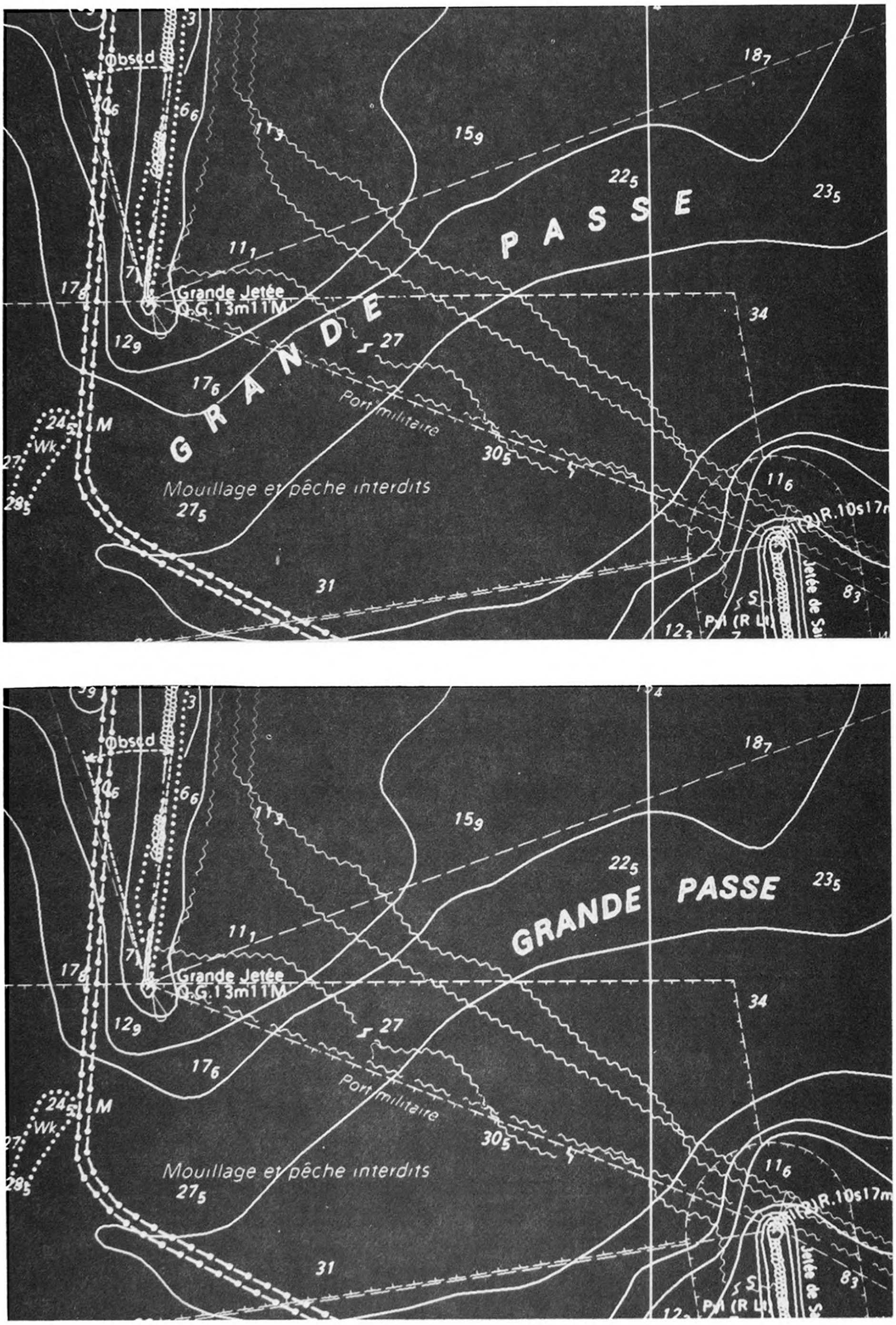


FIG. 5.— Example of modification of the layout of a toponym (GRANDE PASSE) in interactive mode on the graphic terminal: before (above) and after (below).

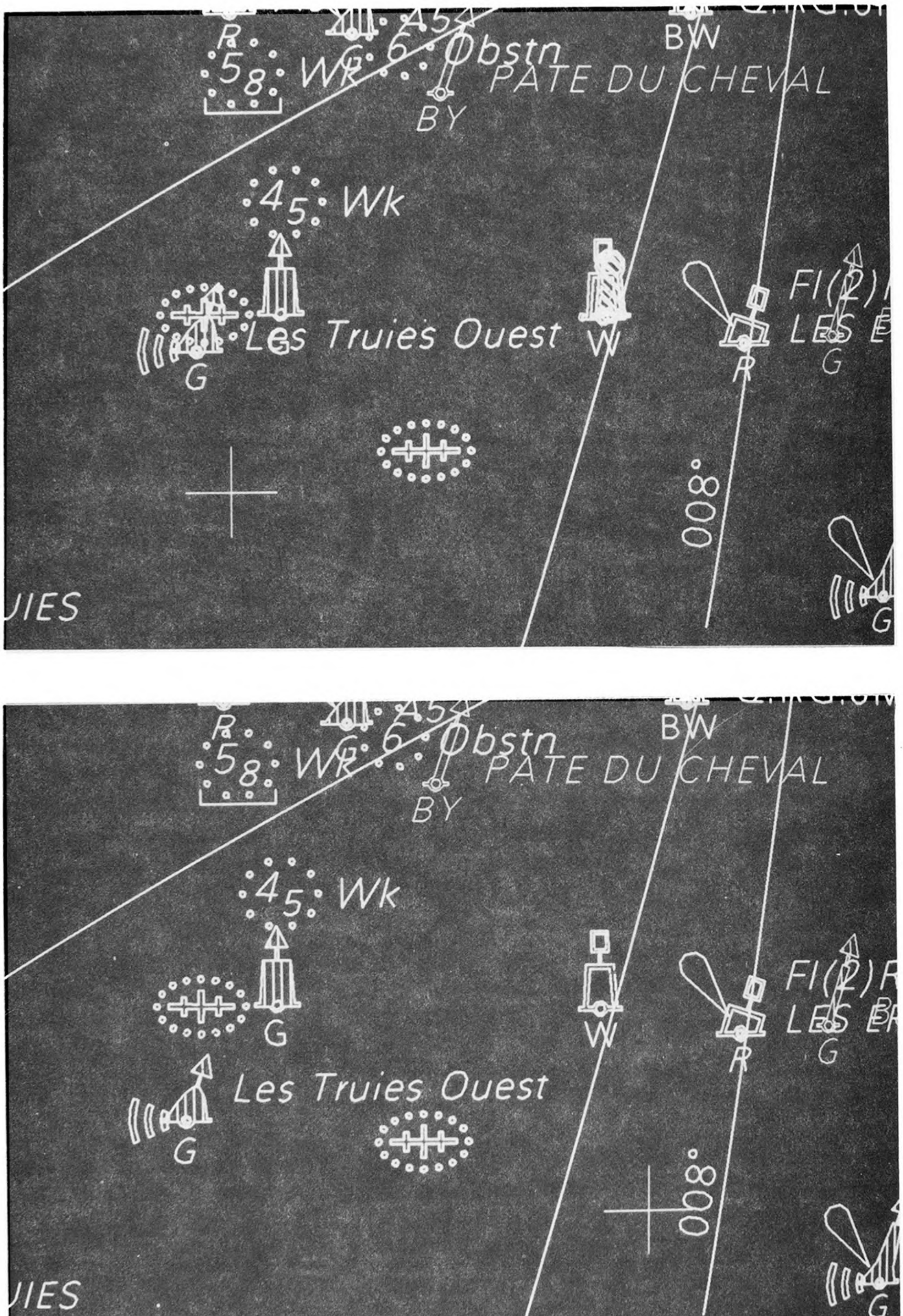


FIG. 6.— Example of selection and generalization carried out in interactive mode on 'Wrecks' and 'Buoyage' files early in the preparation of a chart: before (above) and during (below). The Greek cross represents the reticule, controlled in this case by the cursor of the 12" digitizing tablet.

generalization (*).

As a function of the scale of the chart, the cartographer may subsequently complete on the screen the selection of the most pertinent data (see fig. 6); he may also proceed with some generalization (include two or more wrecks within a single danger line, for instance) and carry out some modification of the layout of the lettering (shift a legend placed astride the border, or which masks a symbol, for instance).

Direct generalization on the terminal screen is also possible in the case of small-scale charts, which are then compiled partly from the files relevant to larger-scale charts covering the same area, when these exist.

5.2 — Digitization

After the preceding stage, the refined files, which contain information provisionally put into acceptable cartographic form, are transferred, along with the dimensions, onto a film which becomes the support for the mock-up of the chart; the mock-up will be completed by the cartographer according to conventional methods.

All the information which is added by the cartographer and which more particularly concerns the description of the sea part (soundings, isobaths, nature of the bottom, etc.) as well as the toponymy, are next digitized directly onto the film, with the help of a digitizing unit.

The information provisionally validated as a result of the phase described above in 5.1 appears on the screen of the graphic terminal right at the beginning of the process.

During digitization, the image displayed on the terminal screen can be controlled by the position of the table cursor, the magnification being chosen beforehand by the operator so as to enable easy checking. The arrangement of some provisionally validated information may be modified, if necessary, at this stage.

Simple curves can be either digitized or scribed, as preferred by the operator.

5.3 — Correction and updating

The digitizing and any scribing required having been completed, the cartographer carries out the usual verifications of the provisional graphic documents (proofs for checking obtained by means of a roll plotter — BENSON 1645 — or a diazoic support, according to the nature of the information: digital or graphic).

(*) Four values have been defined: 1 for specific harbour information, 2 for information necessary for coastal piloting in port approaches, 3 for information useful for coastal navigation, and 4 for the most important information that must be shown on landfall charts.

These verifications lead to corrections, to which may possibly be added updating processes.

These amendments to the files or to the existing plots are made either on an interactive cartographic workstation — with or without a digitizing table — or scribed, if necessary, employing usual techniques.

At this stage, as, incidentally, at the two previous stages, a localized item of information (sounding or symbol) may be introduced into the file by its coordinates.

5.4 — Experience acquired

At the time this article was being written, only the operational capability of the first standard interactive cartographic workstation had been tested and validated with a view to its acceptance; the experience acquired in the use of this new equipment was therefore almost non-existent.

If, however, an attempt is made to extrapolate the observations made on the prototype equipment, which was used for several months by qualified personnel, but only for correcting and updating files that were already digitized (function described in paragraph 5.3, above), the following rough appreciation may be offered:

- its reliability is perfectly satisfactory and calls for no special comment;
- its entry into service is welcomed by all personnel responsible for the work of fair drawing who are eagerly looking forward to using it;
- the time required to make the films used for printing should be further decreased by about a hundred hours in the coming months and should fall to an average of 300 hours during the year 1990.

5.5 — Operators' qualifications

It does not appear to be essential to have a knowledge of computer science — even a basic one — to use the interactive cartographic workstations efficiently. These will be put to use by operators initially trained as draughtspersons, with three or four years' experience in the use of a digitizing table and the relevant software.

The processes which have been automated correspond, in fact, more often than not, to conventional modes of operation for personnel responsible for the fair drawing of a chart. Menus and dialogues which have been validated by a cartographer and a draughtsperson use, moreover, a vocabulary currently employed in cartography.

A training period will nevertheless be necessary, but it will be greatly aided by the interactive nature of the system.

It may be noted that this opinion is a direct result of an initial decision, which led to centralizing and the execution by personnel, especially trained in the very specific tasks involved, such as extractions or transfers of files involving the main computer.

6. EVOLUTION ENVISAGED IN THE SHORT TERM

Apart from the replacement of the precision plotting table now in use, by a laser-head drum plotter (SECMAI), two developments are envisaged in the short term: a minor one concerns the automated production of films for the buff and blue tints of the chart; the other — major — one concerns the structuring into a data base of the existing files and the consideration of topological relationships.

6.1 — Producing films for tints

From such time as the contours outlining a particular colour can be defined digitally and one has a laser-head plotter (plotter linked to the scanner, for the moment), it is possible to obtain the film for printing corresponding to that colour.

Continuous contours can be obtained immediately, using the interactive cartographic workstation, on the screen of which already appear all the contours shown on the chart, whether digitized or scribed. A 'merging' function in fact enables these two types of contours to be joined together, thus delimiting the areas within which, a conventional direction flow having been defined beforehand, the space will be colour-filled by exposure to the plotter's laser beam.

It is estimated that the time necessary for the operator responsible for the merging and identifying of curves delimiting tints on the screen of the interactive cartographic workstation will be about the same as the time required by a draughtsperson to produce screening masks using traditional photo-chemical procedures.

6.2 — Cartographic data base

Without waiting for the various thematic files maintained in the main computer to be organized into a cartographic data base, which is envisaged in the medium term for the purposes of the electronic chart, the addition of a data base management system (INNOVAL ESPACE) to the software in the interactive cartographic workstations would offer new possibilities. First of all, during the selection referred to in paragraph 5.1 above, the cartographer would be able to have access to all known information on a given feature, thus more strongly supporting his choice (which today necessitates having recourse to listings or hand-written file indexes). Then, during the digitization and correction referred to in paragraphs 5.2 and 5.3 above, the operator would be able to manage and manipulate complex features made up of several symbols and several legends (for instance, a floating beacon mark carrying a light and a radar responder), whereas today each basic symbol (buoy, reflector, flare, etc.) and each component of the legend (colour, light, radar, etc.) are managed and manipulated individually.

7. CONCLUSION

No doubt there does not yet exist any one system of computer-assisted cartography that is the perfect answer to the needs of hydrographic offices and the wishes of cartographers.

The interactive cartographic workstation used at the French 'Service Hydrographique et Océanographique de la Marine' appears, however, to be a solid link in the present production chain — a link which should rapidly take on vital importance in the development and maintenance of the hydrographic and cartographic data bases required for the implementation of electronic chart display and information systems (ECDIS), better known, of course, as electronic charts.

References

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