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# COMPUTER ASSISTED CARTOGRAPHY AT THE HYDROGRAPHIC AND OCEANOGRAPHIC SERVICE OF THE CHILEAN NAVY

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## 1. INTRODUCTION

In recent years, technological development in systems engineering has introduced significant changes in the traditional methods of cartographic compilation, in particular in those related to computer assisted production of nautical charts, allowing a reduction in compilation time, an enhanced overall quality, a standardized presentation, an improved reliability and an ease of updating.

The system 'AUTOCARTA' of the Hydrographic and Oceanographic Service of the Chilean Navy, for computer assisted nautical chart compilation and drafting, was designed to enhance the capability of the Service to satisfy the increasing demand for cartographic products and to support maritime and defence requirements.

## 2. THE 'AUTOCARTA' SYSTEM

Once the manual procedures performed during traditional chartmaking were analyzed, it was seen convenient to introduce Geographic Information Systems (GIS) technology into cartographic compiling and editing, colour separation and other ancillary operations, such as projection computing, grids, special lattices, lettering and nautical roses engraving.

**2.1 Preliminary Design Parameters** - A working group began to develop a system design, based on the following preliminary parameters:

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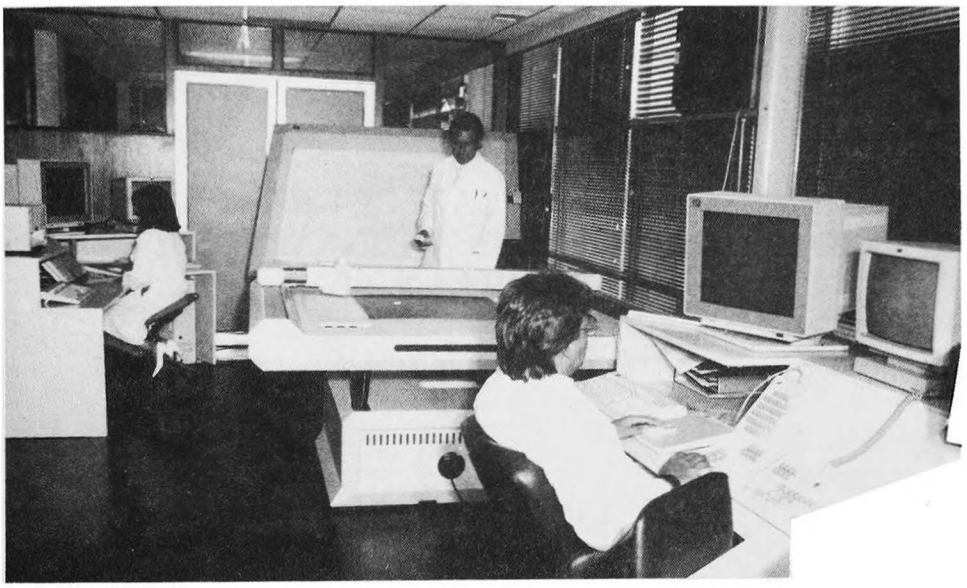

FIG. 1.- AUTOCARTA Room.

2.1.1 The system should be developed by cartographers and software specialists of the Service, thus assuring a thorough understanding of the code generated, making maintenance and updating easier and at a minimum cost;

2.1.2 The system should be developed using 'off the shelf' hardware and software, fully compatible with the Service's mainframe computer, in order to take advantage of proven cartographic algorithms and data files already existent, keeping development costs low;

2.1.3 The system should be capable of generating, operating and maintaining a nautical chart data base, thus providing the ability to produce the cartographic products required by the Service;

2.1.4 The system should be operated by the same personnel at present engaged in the traditional process, thus providing a smooth transition to the new environment without any need to increase the Service staff.

## 3. SYSTEM DEVELOPMENT

'AUTOCARTA' global design concept is based on the merging of a relational data base (where geographic coordinates data and related attributes are stored as a collection of SQL tables) to a vector graphics data base (where an image of a nautical chart is built from SQL data processed in a 'workspace'). Accordingly, the system development was structured into five main groups of closely related activities.

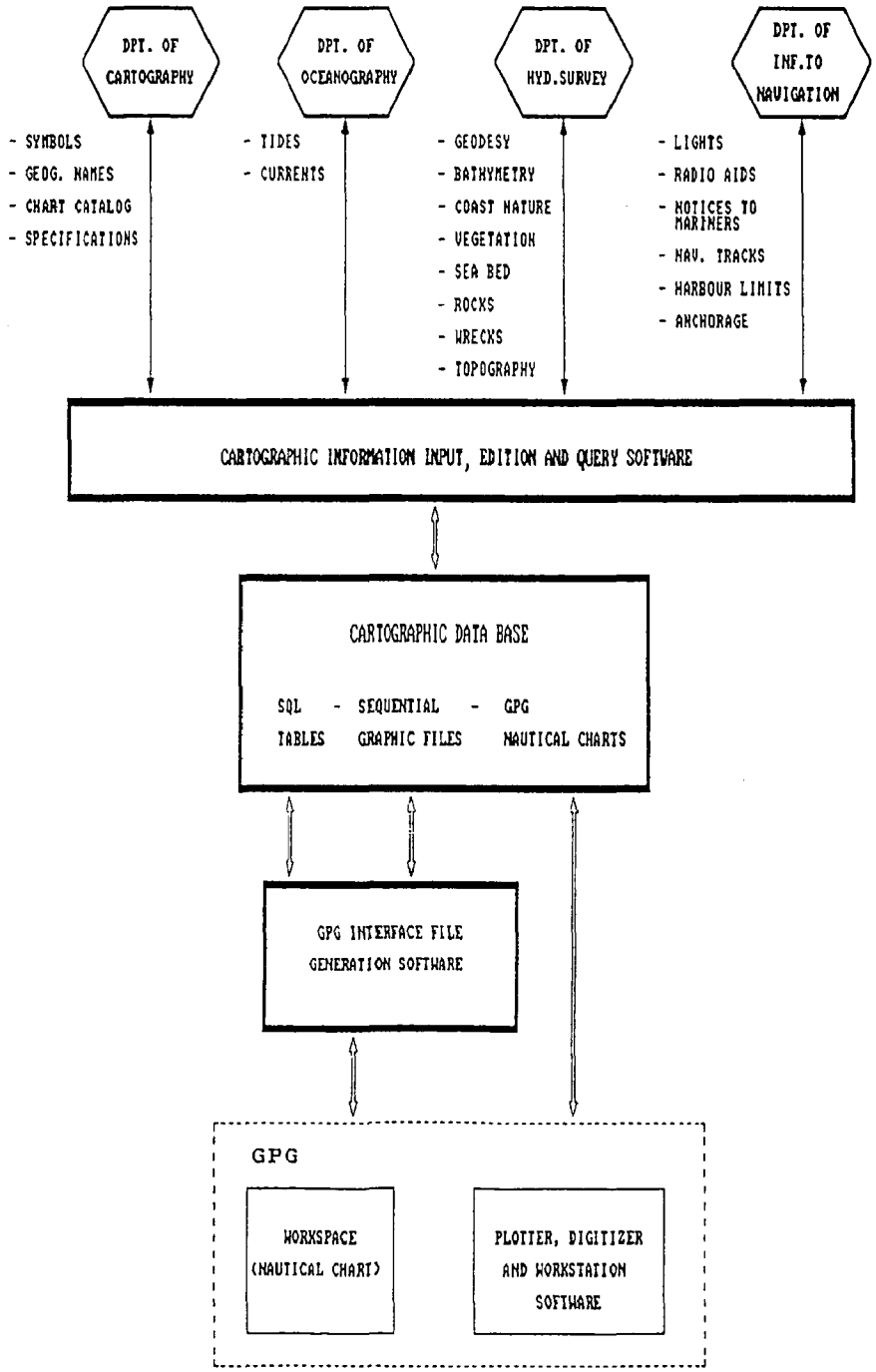


FIG. 2.- 'AUTOCARTA' System Development.

**3.1 Relational Data Base Development** - In this group of activities, the main effort was focused on the definition of SQL tables, needed to store cartographic data and attributes, such as depth and position, coastline, topographic and depth contours. A thorough treatment was given to the conversion of SQL data to a format compatible with the input to the graphics data base.

**3.2 Graphics Data Base Development** - The principal tasks were the definition of geometric objects and attributes associated to cartographic data, according to IHO specifications; the conversion of digitally obtained photogrammetric stereoplotter data to a format compatible with the graphics data base, and the design of a simple but user friendly interface to manage the cartographic data base.

**3.3 Chart Digitizing Subsystem** - Point and line digitizing was conceived as a secondary input to 'AUTOCARTA', in order to provide complementary graphics information to digital photogrammetric data. No automatic topology generation capabilities were provided, since 'AUTOCARTA' was designed as a low cost traditional nautical chart computer assisted production system. (For ECDIS digitizing, a new subsystem will be developed in the near future as part of 'ELECTROCARTA', an electronic chart system project).

**3.4 Cartographic Editing Subsystem** - This module is designed to provide the cartographer with total control over the graphics work station, through a user friendly interface. Besides the classic work station functions, a full line, lettering and nautical chart international symbols handling capability were provided, making it possible to compile and edit the graphic information contained in the cartographic data base until the new chart is ready for engraving at the flatbed plotter.

**3.5 Engraving of Colour Separation Originals** - Through a user friendly interface, the system provides full control over plotter functions, including messages helping the operator to select the size of pen or tool and the pressure for each kind of line, letter or symbol. Stabilene films produced by the engraving head plotter are ready for photomechanical transfer to offset plates, including chart borders, margins, titles, numbering, scaling, special lattices, roses, etc.

## 4. SOFTWARE AND HARDWARE SELECTION

**4.1 Software Selection** - Generalized basic software selected for the 'AUTOCARTA' system development were:

- IBM/SQL Relational Data Base Manager;
- IBM/GPG Graphic Program Generator, and
- IBM/VS/FORTRAN Compiler and Library.

SQL was selected to manage large sets of alphanumeric data in tabular format, similar to the data organization used in the traditional chartmaking process.

GPG was used to develop interactive FORTRAN subroutines for compiling and editing cartographic data, getting the most of the work station graphics capabilities. GPG was also used to develop a limited capability to digitize existing nautical charts, suitable to be added to the data base, and for driving the engraving head flatbed plotter attached to the mainframe computer.

FORTRAN was used to develop complex mathematical algorithms. Advantage was taken of the previous experience in the use of FORTRAN by the development working group, including its characteristics of portability and the possibility to use, with minor modifications, cartographic programs already in use in the traditional batch processing mode.

**4.2 Hardware Selection** - The hardware configuration shown in Figure 3 was selected as a production platform prototype, fully supported by the Service mainframe, an IBM 9375 Model 50 computer.

Each IBM 5080 Work station is formed by an IBM 5086 local graphics processor, a 19" (1024 x 1024 pixels) colour display, a 13" digitizer pad (menu selection and graphic cursor control), an A4 size RGB thermal colour display printer, and an alphanumeric standard terminal.

Both work stations can be assigned to compilation and edition of cartographic data, to digitize existing nautical charts and to perform minor editing to photogrammetric digital input data.

The standard terminal, attached directly to the mainframe, is used for software control, system messages and manual input of data requested by the 'AUTOCARTA' core resident in the mainframe.

The digitizing of existing nautical charts is performed by means of an IBM 5084 A0 size digitizer. General cartographic drafting and final engraving of colour separation Stabilene film are performed by a WILD TA10 flatbed plotter. A second WILD TA2 flatbed plotter is also available in reserve at the Photogrammetry Section for offline work.

## 5. NAUTICAL CHART DATA BASE

**5.1 Catalogues and Files** - The nautical chart data base used by 'AUTOCARTA' was organized as a relational model, formed by 16 SQL tables managing all the alphanumeric data related to a specific chart project, geo-referenced to a geographic coordinate system following a schema of Catalogues and Files.

Due to the large disk storage required to maintain on line a 'seamless' representation of the Chilean maritime territory (about 400 nautical charts), it was decided to keep the largest data files on magnetic tapes, referring to them in the data base through an online catalogue. Only the smallest files and those generated by the users during the compiling process are kept online. Thus, the storage required to support two concurrent work station sessions was reduced to approximately 600 Mbytes.

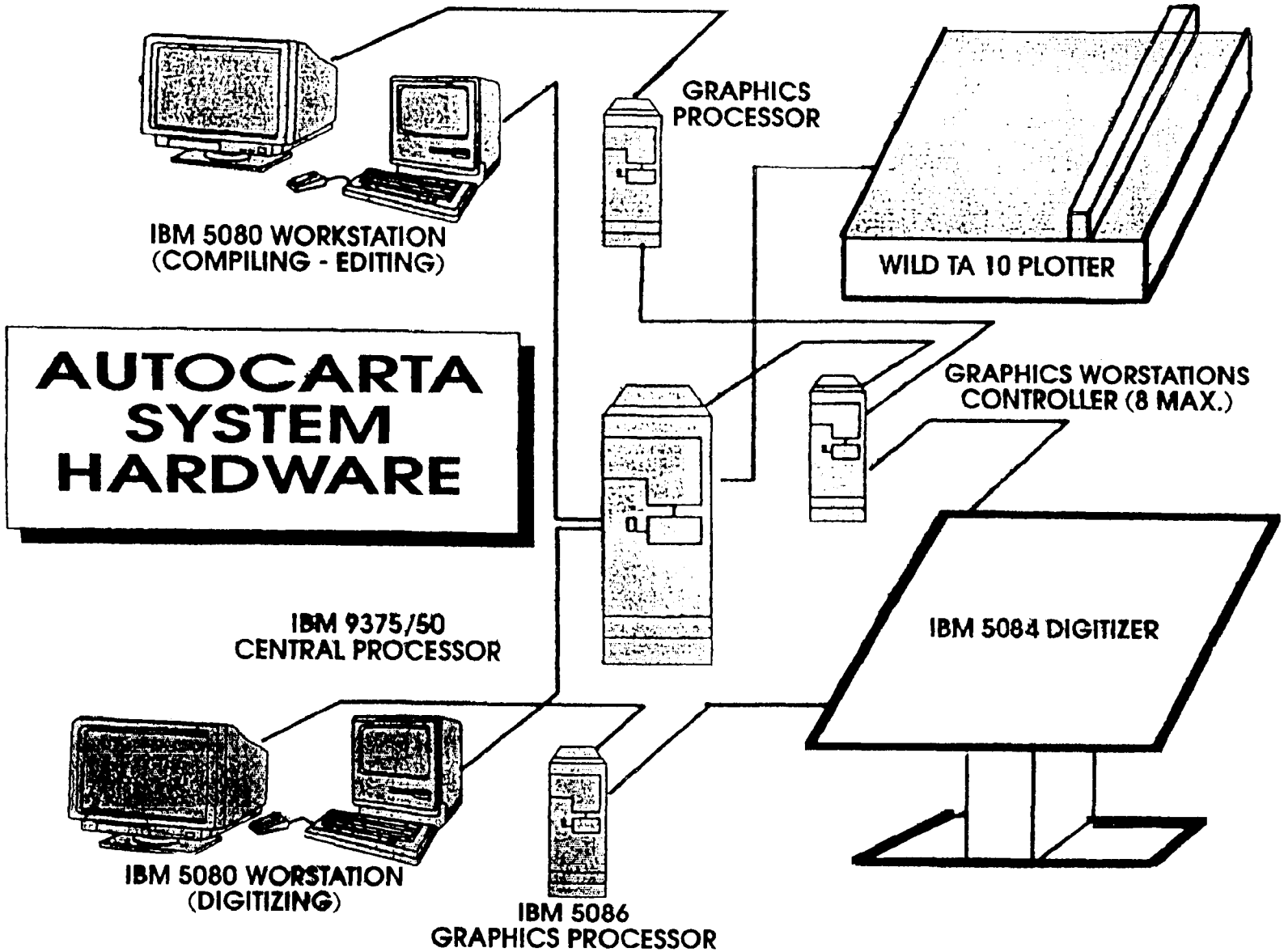


FIG. 3.- Hardware Configuration.

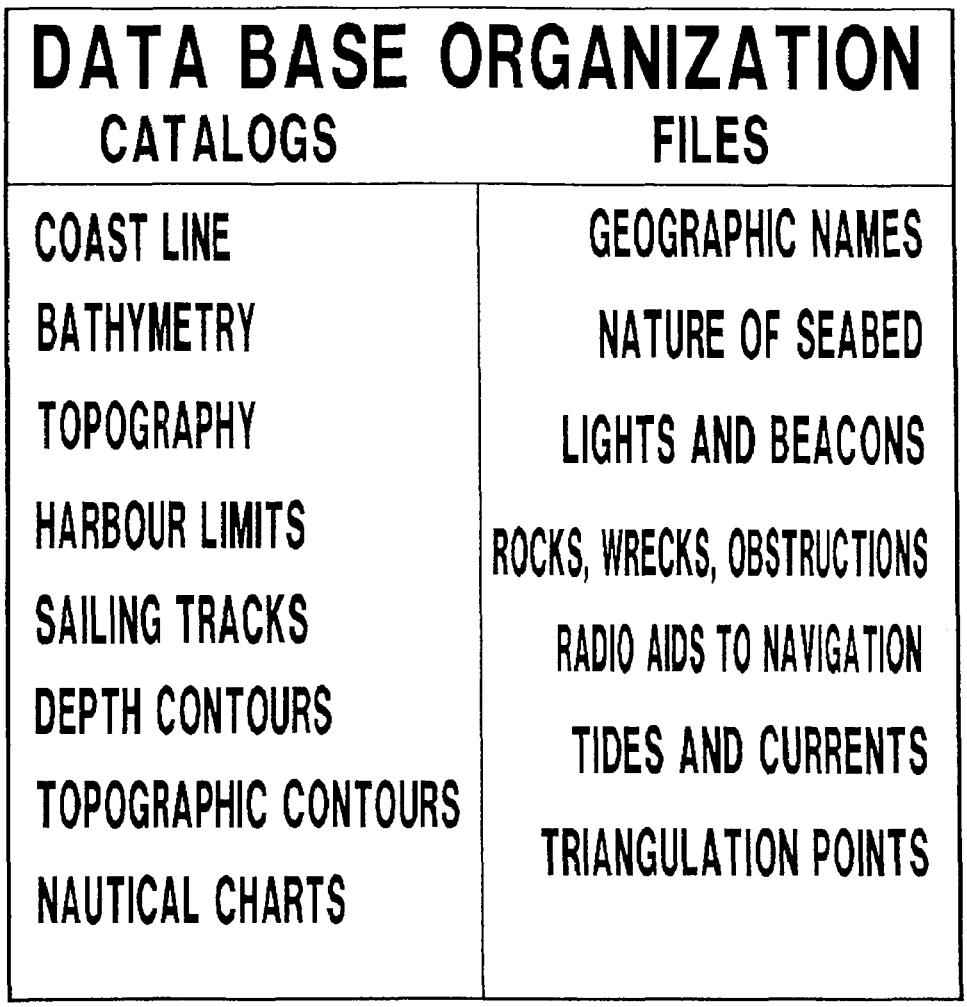


FIG. 4.- Data Base Organization.

According to this schema, the cartographer at the work station selects from the catalogue and downloads to disk only the tapes that contain information about a specific geographic area of the chart to be compiled. GPG assigns him a 'workspace' equivalent to a small data base, to manage the information related to a certain nautical chart identified by its official chart number, making overall quality control easy, since chart compilation responsibility is thus clearly assigned to a single cartographer.

5.2 **Graphic Layers** - Due to the special characteristics of cartographic work, the selection of graphic layers of the data base is fundamental to the work of the cartographer at the work station. Increasing the level of aggregation of nautical chart information also increases the amount of editing needed to store in the data base only the information required for an adequate representation of geographic data at a given chart scale. Figure 5 shows the layers of cartographic data defined for the 'AUTOCARTA' system.

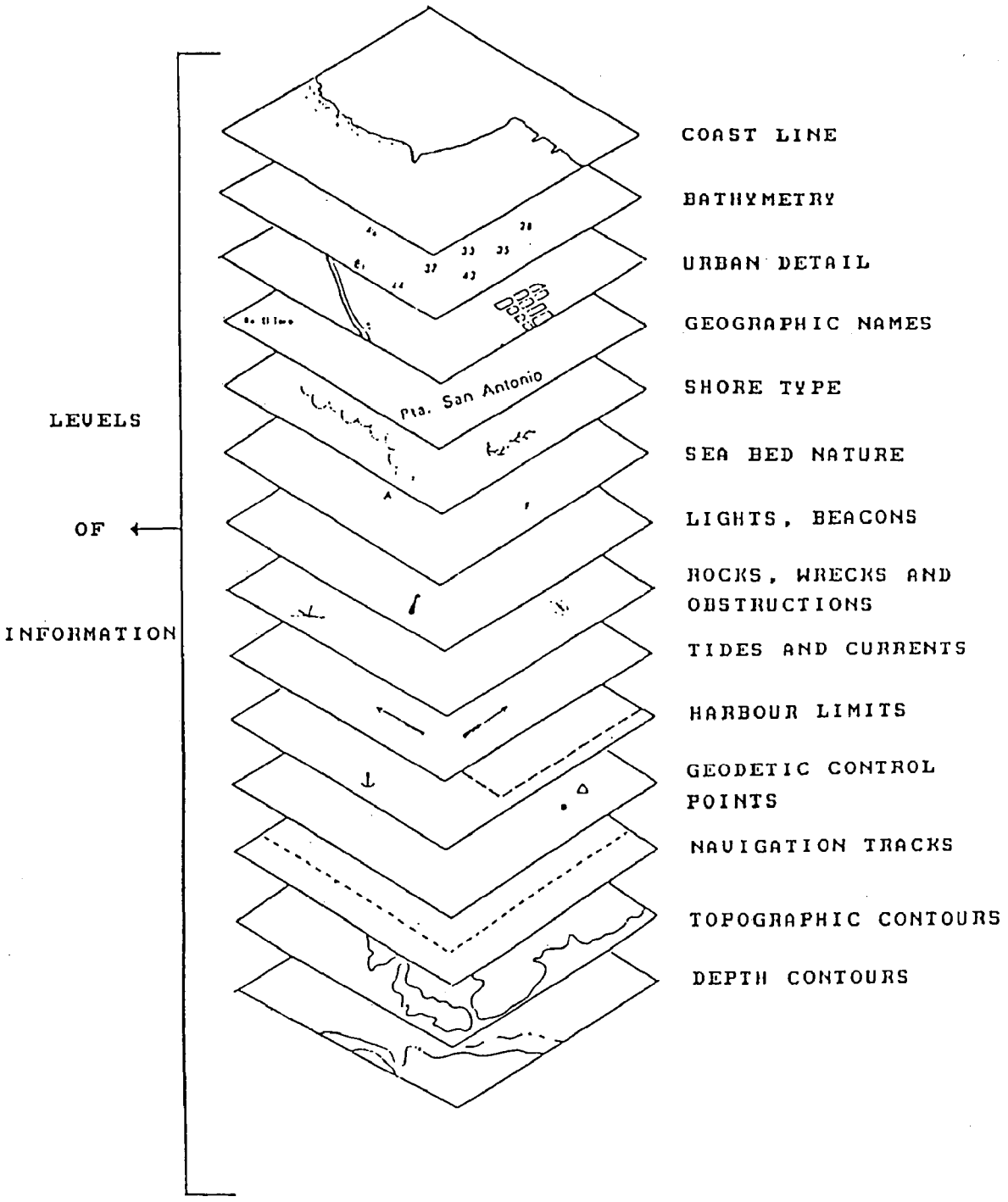


FIG. 5.- Selection of Graphic Layers.

## 6. SYSTEM INPUT

During the practical operation of 'AUTOCARTA', the input to the system depends on the document type. The system capabilities are more suitable for new charts than for new editions. New editions require the digitization of existing nautical documents, a manual time consuming activity which has an adverse effect on the efficiency of 'AUTOCARTA'. In the following paragraphs, input required for the processing of new charts will be described.

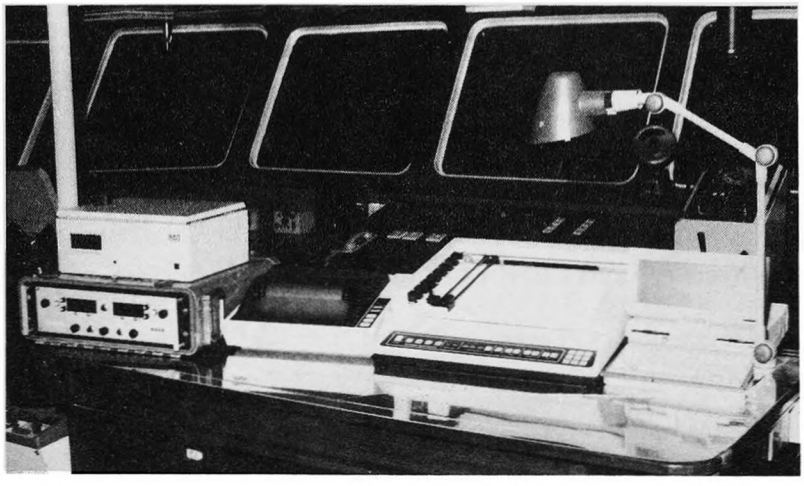

FIG. 6.- The 'AUTOBAT' System.

**6.1 The 'AUTOBAT' System** - Is a simple real-time data acquisition and logging hardware and software 'blackbox', designed by specialists of the Service, which integrates data generated by electronic positioning field equipment to echo sounding devices, producing floppy disks with bathymetry of the area covered by the survey, in a format compatible with the SQL tables of 'AUTOCARTA' (Fig. 6).

**6.2 Regular Bathymetry** - In this case, sounding records are digitized off line by PC controlled 'CALCOMP' A0 size digitizing tables. Quality control is performed by combining software and visual checking of 'CALCOMP' 1044/GT drum plotters output of sounding sheets. Once the procedure is completed, a computer tape is produced, and the relevant information is added to the Bathymetry Data Catalogue in the 'AUTOCARTA' data base.

**6.3 Coastline and Topographic Detail** - This information is generated directly in digital format by photogrammetric stations WILD BC1 and WILD B8. The tape produced is fed directly to 'AUTOCARTA' for final editing at the IBM 5080 work

station. Finally, the edited tape is archived, after the relevant information is added to the Data Catalogue of 'AUTOCARTA'.

6.4 **Other Information** - Information such as geographical names, dangers to navigation, tides and currents, lights, etc. is added to the SQL data files, directly by the respective Departments responsible through standard terminals attached to the IBM 9375 mainframe.

Relevant information to be included in catalogues and files of the data base is provided in specially designed forms to be entered by the 'AUTOCARTA' system manager.

## 7. SYSTEM OUTPUT

Once the compiling and editing work of the cartographer responsible is verified and approved by the Head of the Cartography Department, 'AUTOCARTA' generates the following film proof originals through the 'WILD' TA10 engraving plotter. These are revised by the technical departments responsible for the original information. The proofs are:

7.1 **Bathymetry Layer** - Revised by the Hydrographic Surveying Department.

7.2 **Photogrammetry Layer** - Revised by the Hydrographic Surveying Department.

7.3 **Oceanography Layer** - Revised by the Oceanography Department.

7.4 **Navigation Aids Layer** - Revised by the Information to Mariners Department.

7.5 **Aggregation of Layers** - Revised by the Cartography Department.

As a result, the observations formulated by the technical departments are analyzed by the cartographer responsible for the chart and correction action is taken as necessary. This cycle is repeated, until no further observations are formulated.

The next step is the automatic engraving of Stabilene film originals required by the offset printing process (Fig.7):

- **Black Colour Plate**: Is the aggregation of all black colour information in the nautical chart such as coastline, titles and legends, geographic names, sounding figures, nautical roses, etc.

- **Sepia Colour Plate**: Is the aggregation of all sepia colour information, including topographic and bathymetric contours.

- **Magenta Colour Plate**: Is the aggregation of all navigation aids information, such as legends, symbols, traffic separation schemas, etc.

- **Earth Colour Mask**: Is a plate with the masking of polygons representing land areas that must appear in ochre colour in the nautical chart.

- **Blue Colour Mask**: Is a plate with the masking of polygons representing risk areas to navigation, including river and lake areas that must appear in blue colour in the nautical chart.

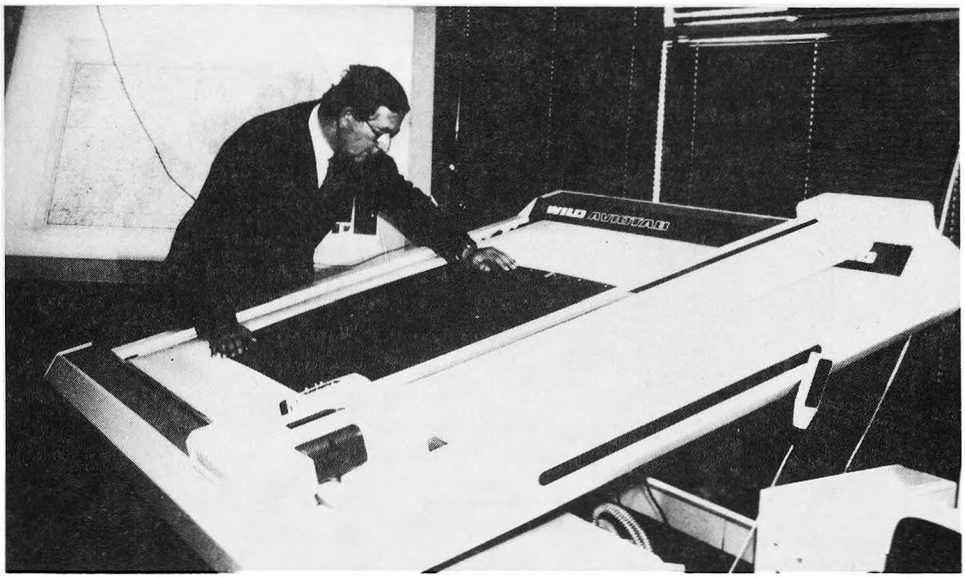


FIG. 7.- Engraving of Originals.

## 8. FINAL PROOF

Once the originals are approved at the departmental level, the next step is to produce a final colour proof for the Director's approval. The magnetic tape with the content of this proof is archived to be used later, in the production of new editions and reprints of the same chart.

The traditional offset printing process of the nautical chart was maintained. Colour separation originals produced by 'AUTOCARTA' are transferred through photomechanical procedures to offset plates for final printing.

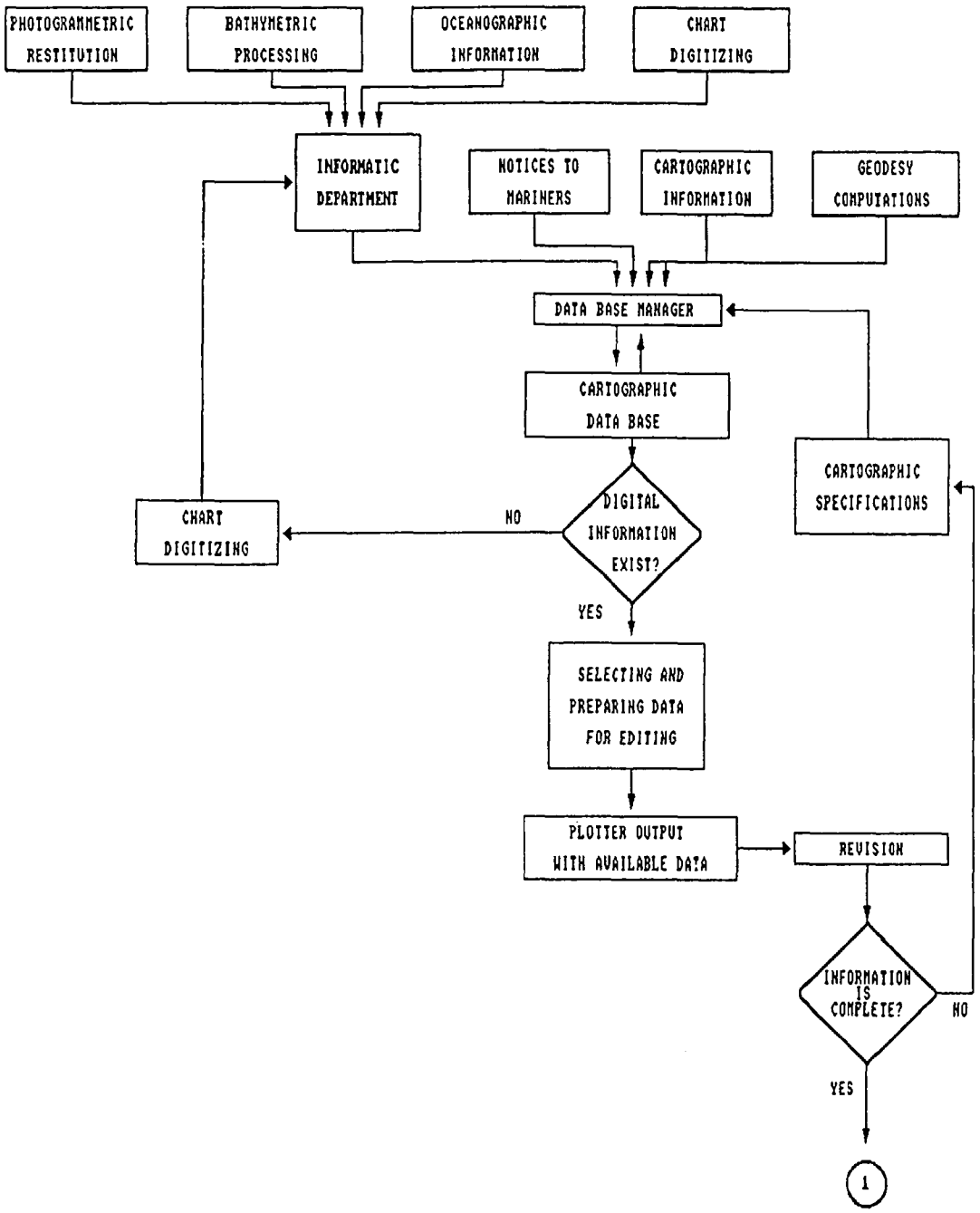


FIG. 8.- 'AUTOCARTA' Data Flow (1).

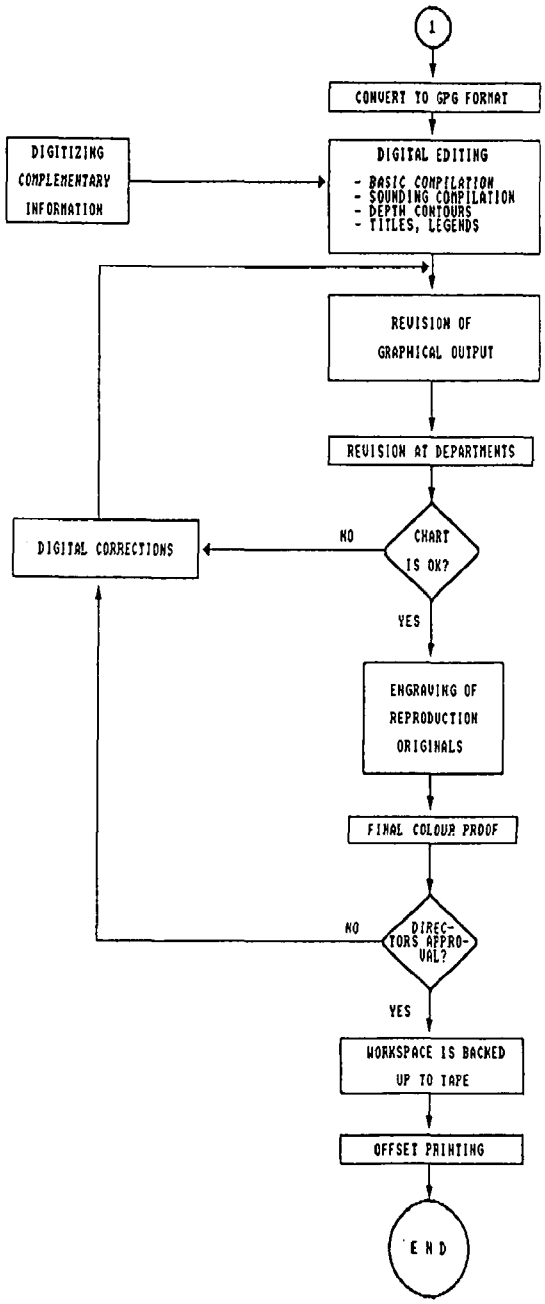


FIG. 9.- 'AUTOCARTA' Data Flow (2).

## 9. FLOW OF CARTOGRAPHIC INFORMATION

One of the main aspects considered during the 'AUTOCARTA' design was the flow of information under a new environment of cartographic automation, keeping in mind that the design parameters called for an efficient use of highly qualified specialists who were already available at the Service.

On the other hand, the starting of the production phase of the new system should be gradual, keeping a high degree of parallelism with the traditional method of producing nautical charts.

As a result, it was possible to define four levels of activity areas related to the interdepartmental flow of information, as shown in Figures 8 and 9.

**9.1 Information Generation Area** - In this area of activity, the various technical Departments process the original information through distributed mainframe terminals, or manually transform the data to a format acceptable by 'AUTOCARTA'. Once done, all the information is handled to the data base manager.

**9.2 Cartographic Data Base Area**- The data base manager adds to the cartographic data base the information relative to the new chart. Next, he must decide if complementary digitizing of nautical documents is needed and, after consulting the technical departments, he must certify that all information needed to compile the new chart is finally stored in the data base.

**9.3 Digital Edition Area** - In this area, the cartographer at the work station assigned to the production of a new chart compiles and edits the available data. Two cycles of verification must be completed: a) the revision of preliminary graphical output by the technical departments and, b) the approval of the final colour proof by the Director.

**9.4 Chart Printing Area** - The data base manager makes a backup tape of the 'work space', containing the graphical, output of the new chart, sending the colour separation sheets to the Cartography Department, where the printing process must be performed. Finally, the 'workspace' is cleared from mainframe storage, leaving space for a new chart.

## 10. CONCLUSIONS

The 'AUTOCARTA' System was authorized for experimental production service in August 1992. Since then two new nautical charts at scale 1:50,000 have been produced and several special charts for internal use of the Service. Six new charts are scheduled up to December 1993. Traditional production time cycle for a new chart was reduced by 50% and can be reduced further as experience is gained by the users of the automated system.

The adoption of a functional model preserving the essential characteristics of the traditional model together with a thorough personnel training programme have proved to be successful for a smooth transition to the new system.

In the extent that the coverage of the cartographic data base is increased through the normal operation of 'AUTOCARTA' System, the production time related to new editions and reprints will be further reduced.

The cartographic data base will also make possible the production of special cartographic products such as fishing, recreational, thematic, training and military charts.

The decision to develop the system with specialists of the Service was highly rewarding, keeping costs low and getting self efficiency in maintaining and upgrading the 'AUTOCARTA' System.