

AUTOMATION OF OCEAN CHARTING

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Note on Authors

Mr. Robert J. BEATON received a B. S. degree in Forest Biology at the University of Maine, class of 1942, and attended George Washington University 1956-58, majoring in Engineering Administration. From 1942 to 1946, Mr. BEATON served in the Caribbean and Pacific area on board the U. S. Navy survey ship U. S. S. *Bowditch* as Officer-in-Charge of the Ocean and Lakes Division. At present he holds the rank of Commander in the Naval Reserve. Robert BEATON was first employed at the U. S. Navy Hydrographic Office (now Oceanographic Office) in 1942, and then after military furlough, resumed his duties in 1946. He is now the Director of the Nautical Chart Division and has been a frequent representative of the Navy Department at various international charting conferences. He is also a past Chairman of the Technical Division on Cartography, American Congress on Surveying and Mapping.

Mr. Robert C. STIRLING studied engineering and photogrammetry at Johns Hopkins University, class of 1941, and following his service in the U. S. Navy from 1942 to 1945, he has studied cartography and oceanography at George Washington University and the U. S. Department of Agriculture Graduate School. Robert STIRLING was first employed at the U. S. Navy Hydrographic Office (now Oceanographic Office) in 1942. Following three years service in the Navy, he resumed his civilian duties at the Oceanographic Office in 1945. For the past nine years he has held various positions related to research and development, and is now on the staff of the Director, Technical Production Department as Special Assistant for Research and Development. He is also a past chairman of the Technical Information Committee of the American Society of Photogrammetry.

Maximum automation of ocean charting is viewed by the U.S. Naval Oceanographic Office as a vital objective in the conduct of its complex operations to collect, process, and display data for Fleet users and other maritime interests. When we think of the oceans in terms of naval operations, foreign trade, food resources, etc., it is difficult to appreciate the scope and nature of knowledge required to exploit this watery medium. Greater mobility of nuclear powered ships, electronic navigation systems, and new designs using hydrofoil and air cushion principles are indicative of technologies that will help man to understand and maximize operations in the environment of the sea. Significant achievements are affected, however, by the quality and timeliness of data collected, digested, and presented to planning and operational personnel.

The difficulty lies in devising equipments and techniques that will record and analyze required information concerning vast, multi-layered expanses of ocean regions; also, the system must feed back promptly the findings of hydrographic and oceanographic surveys. Accumulated data are of little value unless it is processed and made readily available as reference material for further research or in product form compatible with modern instruments.

We find ourselves, at present, in a transitional stage between traditional marine survey methods and new underdeveloped techniques utilizing space-time concepts (electronic and optical systems with satellites for determining geographic positions) and various parameters of the ocean environment (bathymetric features, temperature layers, magnetic anomalies, etc.). One concept called the Anti-Submarine Warfare Environmental Prediction System (ASWEPS) provides for automatic collection of oceanographic data and display of several parameters simultaneously in real time as the data are being generated. In this system, which is currently being developed, the data are adjusted and condensed onto tape for transmission over standard radio teletype equipment aboard ship. Other instruments and techniques that are still in use collect hydrographic data such as bottom profiles and soundings. Unfortunately, this information recorded in analog form on curvilinear graph paper is incompatible with digital plotters until converted and programmed properly. Solutions to this problem are being developed and tested in the United States and Canada, based on new hydrographic survey shipboard systems that record and correct position and depth data in digitized form.

By way of underlining the importance of possessing compatible field surveying-office processing capabilities, I would like to discuss some aspects of the overall problem that concern the prompt feedback of information to the potential user. Specifically, I intend to focus on the role of the cartographer who finds himself between the surveyor or data collector and the eventual user of the end product.

Perhaps more than anyone (except historians) the cartographer is most sensitive to the compelling demands for recording conditions and trends of our times. Professor Dr. IMHOF, the Swiss cartographer, stated in 1961 :

“ Nowadays we are witnesses of a so far unknown increase in population, in the mechanization of human institutions, and consequently of a rapid increase in building activities, in traffic, etc., in almost all regions of the world. This development is reflected by the vehemently increasing necessity to have reliable and currently revised maps at one's disposal.. ”.

“ Very often the existing mapping facilities, methods, and techniques are unable to comply with such an increase in task and demands. In spite of all progress the necessity prevails everywhere to realize further improvements and savings in time and money with mapping methods and techniques... ”.

The American geographer, Professor SHERMAN, defines new horizons in cartography relative to functional analysis, automation, and presentation. He states that research in these three broad areas is required to 1) make decisions, based on human perceptions of multidimensional space,

as to whether the cartographic, mathematical, or written word form of expression is most pertinent; 2) apply automated data processing equipment to cartographic problems in terms of time-saving compilation procedures; and 3) translate ideas into graphic form through discrete selection of data and skillful applications of principles of design.

Cartography employs the scientific-method in the form of reason and logic and uses geodesy, geography, and psychology in constructing maps and charts, according to Professor ROBINSON. It must also keep pace with advances in technology and instrumentation in order to cope with functional cartometric and cartographic display problems. Consideration of automation in cartography is broadening in scope because of pressure to introduce new equipment and methods to display information more rapidly and adequately. Professor TOBLER has noted the relationship between graphics and computers by calling a map or chart a type of input or data storage in a data manipulation system. The extent, however, to which artistic creativity and mental processes can be applied in producing a functional map or chart by automation remains uncertain.

It has been demonstrated that computers are capable of handling programs for map, chart, and statistical compilations of basic detailed surveys of terrain and sea areas. They are employed, also, for programming applied cartographic items like synoptic charts, industrial product flow diagrams, political maps, etc. Many existing maps, charts, and photographs can have coordinate point values read off by programming devices and the data stored on tape or cards. Special projections can be designed to best fit project requirements. Coordinate data files on coastlines, boundaries, and railroads can be established with scale change factors and filed for convenient plotting or tabular purposes. Many more examples could be identified, particularly photogrammetric analyses of ground control, wave heights, ice formations, and satellites photographed against star backgrounds. Nevertheless, the advantages of computers are reduced when some part of the production cycle is delayed or stretched because of hand operations like drafting and type stickup for numbers and place names.

It is with the above described background that the U.S. Naval Oceanographic Office is attempting to maximize the usefulness of computers by automating certain functions associated with the collection of data and preparation of end products suitable for reproduction and distribution. The description of the following new digital coordinatograph system, which was delivered on 12 January 1963, is that of an essentially office-oriented facility and is unassociated with other concepts such as ASWEPS previously mentioned.

The Model E-51 Automatic Digital Coordinatograph, shown in Fig. 1, is a large, high speed, cartographic production facility manufactured by Concord Control Inc. in Boston. Utilizing 7-channel IBM 729 magnetic tape, 5-channel Bendix G-15 punched paper tape, or keyboard input information, an electronic control system, and a coordinatograph equipped with a number of interchangeable instrument heads, the system is capable of drawing or scribing continuous straight or curved lines of 0.004 or 0.008 inch in width; printing points and numerical soundings; and photographic-

ally exposing names, symbols, control, and marginal data on positive or negative overlays.

The system consists of four units. Shown on the left of Fig. 1 is the coordinatograph with one of its interchangeable instrument heads mounted in the carriage. In the background is the magnetic tape unit used to operate the system from computer-prepared magnetic tape programs. Next to it is the director, a special purpose digital computer, which controls the coordinatograph and also houses the paper tape reader. In the right foreground is the keyboard unit used to control the coordinatograph manually and to prepare special paper tape programs.

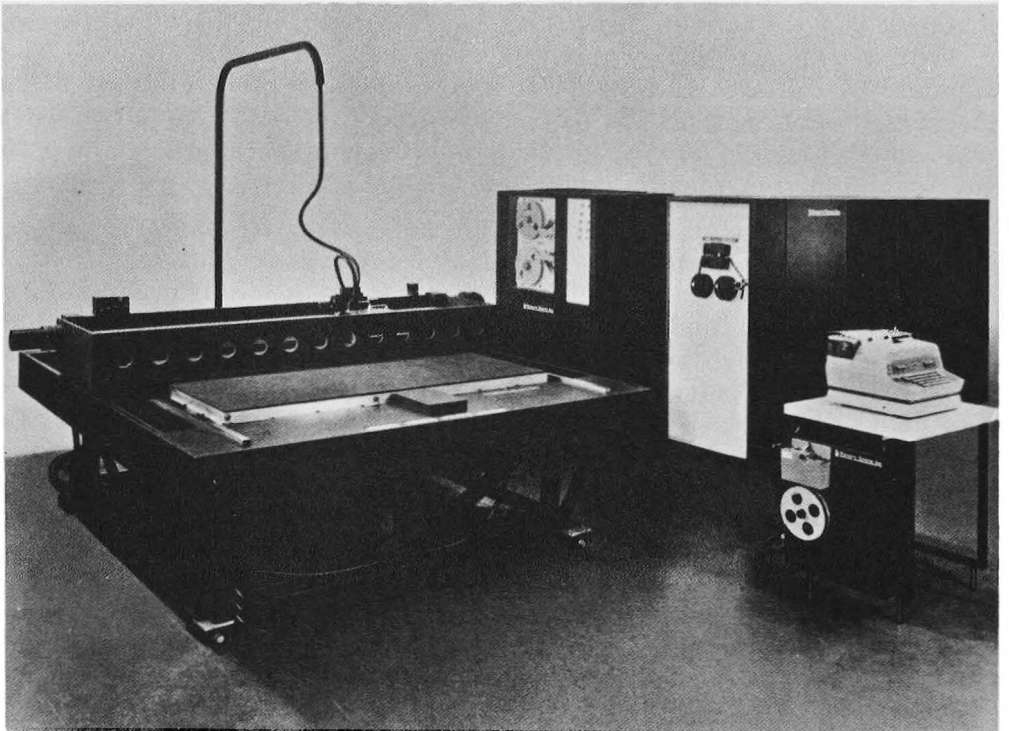
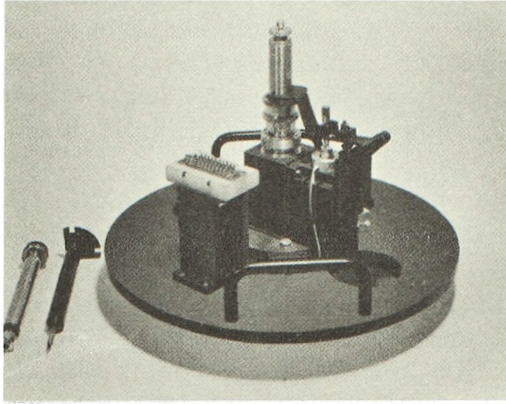


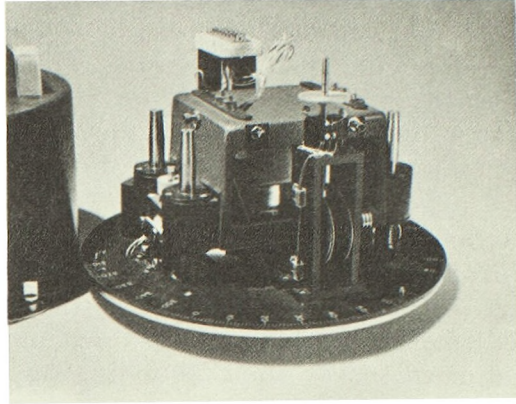
FIG. 1. — Model E-51 Automatic Digital Coordinatograph

There are four interchangeable instrument heads supplied with the system. The universal ruling head, shown in Fig. 2a, is used for scribing and point plotting. The speed of the "plotter" as it's commonly called is 1 inch per second for scribing and 6 inches per second for point plotting. The mechanical print head, shown in Fig. 2b, is used for printing soundings consisting of 3 digits plus an index dot for the true X and Y position. The system prints a point and a 3 digit figure every 6 seconds or 600 per hour. The projector head, shown in Fig. 2c, exposes soundings, alphanumerics, and symbols from a roll of 70 mm film onto large sheet film. The soundings total 5 digits, including subscripts, spaced on 2 mm centers. The maximum alphanumeric or symbol size is 0.3×2.0 inches. The projector head operates at a speed of 400 exposures per hour. The line-drawing projector

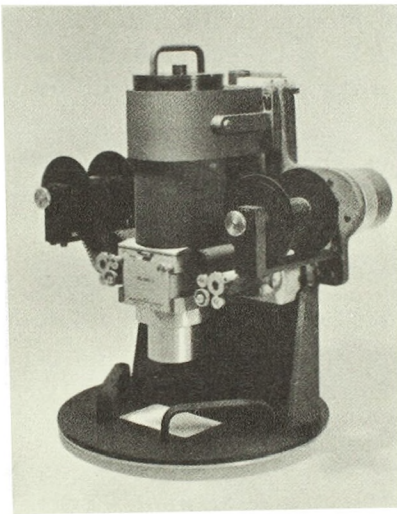
head, shown in Fig. 2d, makes use of a point light source to draw lines photographically on large sheet film. As in the case of scribing, the head draws at 1 inch per second. When either of the photographic projector heads is being used, the system operates with the room darkened and safe lights turned on.



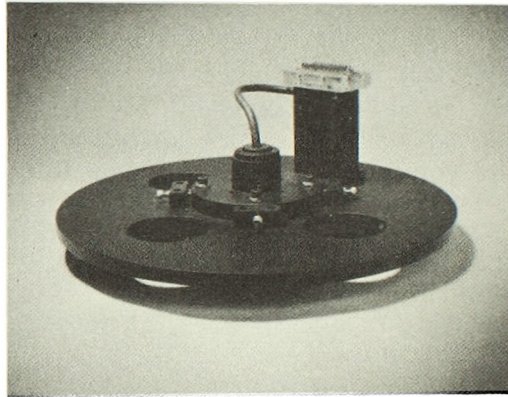
a. Universal Ruling Head



b. Mechanical Print Head



c. Projector Head



d. Line-drawing Projector Head

FIG. 2. — Instrument Heads

Regardless of the input medium used, the input information to the system consists of a series of X and Y coordinate positions describing the desired path of the instrument head, together with extra function commands describing the operations to be performed by the instrument head. The output of the system consists of a sheet of paper, scribecoat, or photographic film up to 60 × 60 inches containing the required lines and alphanumeric characters which are used in the preparation of hydrographic survey sheets and nautical charts. The system uses self-checking circuits to indicate unacceptable conditions and areas of failure and to prevent further automatic operation of the system until these errors or failures are corrected.

Positioning commands are specified on an incremental basis, i.e. each successive position is expressed as a ΔX and ΔY which represents the change in the X and Y coordinates from the previous position. The system

then moves the instrument head in a straight line from the previous position to the new position. By careful selection of increments, it is possible to cause the system to position the instrument head along a straight line approximation of any curve within a tolerance limited only by the accuracy of the system. Tolerance is established in the program at 0.0012 inch. Commands for X and Y positions are given to the nearest 0.01 mm, and X, Y accuracy is ± 0.0025 inch. The taped information is fed to a digital data-processing director which translates the code into electrical signals suitable for controlling servomechanisms. These in turn cause the plotter to which they are connected to execute the motions and operations called for on the input tape.

Test programs run on the plotter demonstrate the feasibility of automating at least two major, recurring cartographic programs that involve several hundred items annually: 1) construction of electronic navigational survey hyperbolic (loran, lorac) or circular (Raydist, Shoran) lattices for charts and preprinted survey plotting sheets; and 2) plotting of adjusted survey ships' sounding tracks. The line scribing or point-plotting techniques, applied to pre-survey sheets or areas covered by electronic navigational systems, illustrate a type of quick feedback to the user based on ship-furnished electronic control data characteristic of the survey system to be used. The second stage feedback will occur when completed survey smooth sheets or charts are automatically plotted based on adjusted digitized data for grid positions and depths.

Preliminary determinations of costs per sheet for plotting electronic navigational or survey lattices by automated and conventional techniques are compared in the following table:

	Lorac Sheet		Shoran Sheet	
	Time	Labor	Time	Labor
Hand Plotting and Drafting in ink along splines	15 h	\$ 56.25*	5 h	\$ 18.75*
Automatic Plotter (Scribing mode)	1 h 50 m	\$ 7.86**	0 h 30 m	\$ 2.13**
Savings	13 h 10 m	\$ 48.39	4 h 30 m	\$ 16.62

* GS-9, 10

** GS-11

(Program preparation times, which are somewhat greater for plotter input than for hand plotting are excluded from the above table. Identical typeset number stickup operations are omitted also).

Costs for plotting smooth hydrographic survey sheets have not been determined because tests with the projector head for the plotter have not yet been run. In anticipation, however, estimates are being prepared on the expense involved in preparing punched card data from a survey made by electronic control methods but with conventional echo-sounding equipment. Depending on costs, plans will be made to use the automatic plotter for showing on the smooth sheet either the tracklines run by the survey ship or the corrected soundings.

When charts with two or three color plates each are produced in series, greater economies are predicted by programming the plotter to handle each set of curved lines representing one rate or color on all sheets in succession. This method eliminates the necessity of switching tape inputs to complete all sets of lines on one sheet before starting the next sheet. Also, while the lines are being scribed by the plotter, additional sheets that have been automatically point-plotted previously can be inked in the conventional manner by draftsmen using spline curves.

Several months are expected to pass before the plotter can be termed fully operational. Testing and experimenting is currently underway and new programs are being written for the IBM 7070/1401 computer. The gradual automation of routine or repetitive tasks should release a number of professional and technical personnel to other cartographic projects. Operating personnel have become familiar with the plotter by trips to the manufacturer's plant and by working with mechanical engineers and electronic specialists in "debugging" the equipment. The superior quality and accuracy of the automatic line plot, coupled with relief from tedious hand plotting and inking operations, have convinced our cartographers of the plotter's value. Other personnel in the area have been invited to view it in operation as a means of dispelling any rumors that exaggerate the machine's versatility and manpower replacement potential.

Automation in cartography has many extraordinary and challenging aspects associated with design concepts, production methods, and user requirements. The nautical cartographer, for example, who prepares computer programs and operates automatic plotting equipment has indeed entered into a new and dynamic environment. He must strive to interpret and display multi-dimensional data in graphic form to support work being done in surveying, navigation, oceanography, gravity, magnetics, geography and numerous other fields. As a general rule, he now finds himself operating in a tight production schedule, pressed between the surveyors with increasing volumes of collected data and the chart users who may be uncertain of what type of product is required or practicable to produce. The field is open to develop additional computer programs for automating the production of graphics that portray symbols, alphanumeric, bathymetric contours, isothermal layers, shorelines, various grids and projections, etc. And now in this era of expanding automation, cartographers, too, can derive immense satisfaction in harnessing problems to a machine that works swiftly and accurately toward the solution, with resultant completion of projects on a more timely and quality-controlled basis.

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