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TOWARDS A TOTAL NAVIGATION CONTROL SYSTEM

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INTRODUCTION

Most survey companies at present have navigation computer systems based around a desktop calculator. The pre-job preparation work and post-processing take place on an office-based computer. To increase production and improve the speed of producing the final report and charts, I intend to examine the requirements for an offshore computer package which will meet these needs. To many surveyors, the navigation computer is a black box that seems to absorb information, then spit out the results. To design a complex computer package, it is essential to have knowledge of the capabilities of the hardware as well as the structure of the software.

1. HISTORY AND PERFORMANCE OF DATA ACQUISITION AND PROCESSING EQUIPMENT

1.1. Hand plotting and data logging

In the 1960's and early 1970's, the use of computers was almost non-existent, and it was the role of the surveyor to record navigation pattern readings on specially prepared log sheets. Most of the available accurate navigation systems had only two position lines; there was no redundancy, so it was difficult, if not impossible, to keep a check on the performance of the system. A survey line would

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be run along one position line and a fix would be taken at the intersection of whole lanes on the other. At every fix, the surveyor would hand plot the position on a lattice chart and would annotate the geophysical records. The lattice chart would have to be drawn up on the office main frame computer before the commencement of the job.

1.2. The introduction of computing systems to the survey business

By the mid 1970's, hydrographic surveyors working for the major oil companies were requesting more acceptable positional reliability. This resulted in the use of at least three simultaneously observed pattern readings to determine a position. The increased amount of data could no longer be processed manually, and dedicated navigation desktop calculators were developed to automatically log the data and provide the onboard surveyor with position information in rectangular or geographical coordinates, both on a display and on a track plotter. This meant the surveyor was able to devote more time to monitoring the data quality and to stationing the vessel relative to a survey line.

1.3. Computing systems being used today

With the development of the desktop calculator, the survey programmer has been able to develop more sophisticated navigation software, reading data from many more navigational aids, and outputing the computed data to many more peripheral devices. This has meant the surveyor is now supplied with quality control information relating to the navigation of both primary and secondary systems. Navigation guidance information can also be displayed on a Visual Display Unit (VDU) positioned on the bridge.

2. TECHNICAL ASPECTS OF A COMPUTERIZED SYSTEM

2.1. Computer hardware

Today the small computer is an integral part of a navigation processing system. It provides a relief from drudgery. Almost every general-purpose digital computer has the same basic structure — the central processor, the memory unit and the input/output units. Many survey companies find that their needs are adequately met by one of the commercially available systems, supplied ready to work as soon as the machine is switched on. (A "turn key" system). Alternatively, it is possible to purchase separate components and, armed with the necessary expertise, to put together a complete system. (A "modular" system). (See Figure 3).

2.1.1. The Central Processing Unit (CPU)

If a machine is to be called a computer, it must have the capabilities of performing arithmetic and logical operations. The element of the CPU that meets this requirement is called the arithmetic and logical unit (ALU). For the ALU to be able to do its required task, it must be told what to do, thus a control unit is necessary. The control unit oversees information entering the machine and decides how and when to perform operations. It tells the ALU what to do and where to get the necessary data. It knows when the ALU has completed an operation, and tells it where to store the result and which operation it must perform next. The control unit itself decides which functions to perform by interpreting a set of instruments (a program) which are stored in the computer memory.

2.1.2. Memory unit

The memory unit contains information for the control unit (instructions) and for the ALU (data). The memory is divided into sections called locations, and an element of data (an instruction or part of an instruction) can be stored in each location. Instructions and data may be stored together in the same memory with each location reached and specified as rapidly as any other; this is often referred to as random-access. The computer memory is organized so that its basic unit, the word, is a collection of bits large enough to hold a worthwhile amount of information; a word normally contains sixteen bits. The size and speed of operation of internal storage units vary greatly from computer to computer.

2.1.3. Input/output

It would be impossible to operate a computer system without electronic communication wires between each unit. This system is called a BUS HIGHWAY structure. Every unit, peripheral and register, is connected to a common bus of parallel lines, and data transfer is accomplished by connecting the outputs and inputs of the desired units to the bus. There are subsidiary buses on the ALU, since for many functions two input paths and one output path are required at the same time. Only one device at a time can control the bus, normally the CPU.

2.2. Software

2.2.1. Programming languages

A programming language is a subset of the English language that allows the programmer to give unambiguous commands to the computer. Two different types of programming languages exist : assembly and high-level languages. Assembly language is a symbolic representation of the binary instructions the computer understands. This language is difficult to use since the programmer must specify internal registers and detailed internal operations. Assembly language is used whenever execution speed is essential; however, it makes programming difficult.

High-level languages have been developed to facilitate writing computer programs in specific environments. One of the earliest languages to be defined was FORTRAN (FORmula TRANSlator) and this is a commonly used language in the field of scientific computation. Over the years FORTRAN has become a complex collection of facilities that is useful, but cumbersome to learn.

An attempt was made to define simple languages directly inspired by FORTRAN which would be easy to learn and could also be executed in an interactive conversational manner. The result was BASIC (Beginner's All-purpose Symbolic Instruction Code). The BASIC language is easy to implement on a computer and requires only a small amount of memory. Because of these two advantages (ease of implementation and ease of learning), BASIC has become the most widely used language on microcomputers. However, it has many limitations due to its rules of usage (its "Syntax") and is often inadequate for writing complex programs.

Another language, ALGOL (ALGOrithmic Language) resulted from an attempt to define a computer language other than FORTRAN that would be consistent and well suited for use with complex algorithms. ALGOL gained great popularity in educational circles yet was never widely used by industry. Although the ALGOL language provides an excellent tool for describing algorithms, it is somewhat complex to learn and difficult to implement on a computer.

PASCAL was inspired by ALGOL and PL/1, and represents an attempt at defining a programming language that is simple to learn, yet well suited for the specification of algorithms and the definition of data structure. PASCAL can be implemented in a small amount of memory, and when low-cost microcomputers equipped with limited memories appeared in the late 1970's, a number of PASCAL computers became available. The name of the language is a tribute to the French mathematician, Blaise Pascal, who in 1690 at the age of 18 invented the first mechanical calculating machine.

2.2.2. *Program development* (see Fig. 1)

2.2.2a. Step 1 : Designing the program

This stage is one of the most important phases of the programming process. When outlining a solution to a problem or describing a sequence of actions to be performed, an algorithm should be specified. Next, the algorithm must be transformed into a program. A high-level language allows the programmer to specify instructions in a language that is similar to the English language, but is highly restricted. Programming requires ingenuity and intelligence. It also requires strict discipline. Every instruction or statement in a program must strictly follow a set of rules, called the syntax. Any instruction that violates the rules will cause the program to fail with no exceptions and, therefore, it is essential to understand and strictly adhere to the rules of the syntax. A single misplaced dot or comma will cause the program to fail. The single largest source of failure in all computer programs is negligence. The importance of a highly disciplined approach toward computer programming cannot be emphasized enough. By using proper design steps and checking the handwritten program, the programmer can often save a

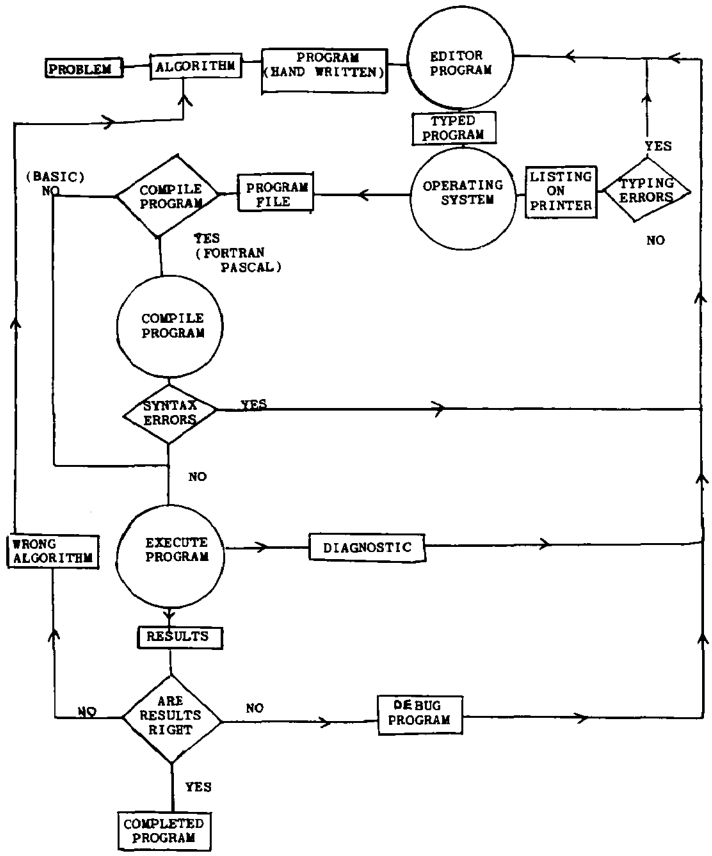

FIG. 1. — Programming.

significant amount of time during the debugging (identifying and correcting errors) phase.

2.2.2b. Step 2 : Entering the program

The program must now be entered into the computer system as a file. The program that allows the convenient typing of text into a file is called the editor. It allows the programmer to erase characters or words, insert or append text, substitute letters or words, and search for given character combinations. The more powerful the editor, the more convenient is the program entry phase. Once the handwritten program has been typed into the computer system, it is stored on either a tape or disc as a file.

2.2.2c. Step 3 : Listing the program

The next step is to examine the file to ascertain that no errors have been introduced by the entry process. The file will need to be listed on the printer. A part of the operating system allows the transfer of a program file to the printer, as well as the transfer of files from one recording medium to another, and various other functions. A printout is a convenient method of checking the program file against the handwritten listing. Once the program is presumed to be correct, it is ready to be executed.

2.2.2d. Step 4 : Running the program

Step 4.1. : Compilation

A program written in a high-level language such as FORTRAN or PASCAL cannot be executed directly by the computer since the processor can only understand a set of binary instructions. The high-level instructions are translated into a set of equivalent machine language instructions by the compiler program. The resulting translated program is called the object code file. If the program contains syntax errors, the compiler will generate diagnostics or error messages which inform the programmer as to the type and location of the errors. BASIC is an interpretive language (All-purpose Symbolic Instruction Code) and does not need to be compiled.

Step 4.2. : Execution

The program can now be run. If the program is correct, results will be displayed or printed. If the program was incorrect, diagnostics will be generated. If diagnostics are generated as a result of either compilation or execution, the programmer must correct them in the original program. The programmer must then go back to step 2 and type in the corrections. In severe cases, it may be necessary to return to step 1 and modify the algorithm. Once the corrections have been made, hopefully the program works. The program must be executed as many times as possible with different data, so that its correct operation can be verified in all cases. If some cases are overlooked at the design stage, problems can arise at a later date and can be costly.

2.2.2e. Step 5 : Debugging the program

Technique One

Each function and each procedure used by a program should be tested separately in "typical cases" until each one proves to work satisfactorily.

Technique Two

Insert a number of print statements throughout the program, so that a trace of program execution is automatically printed. The values of crucial variables may be printed at every stage of computation, and it is then usually possible to determine the exact group of instructions when something goes wrong.

2.2.3. Writing a program

There is almost never a unique way in which to devise a program solution for a given problem. The program designer must choose techniques which will improve the program's efficiency and optimize the size of the program. A program should be clearly documented and well formulated. Descriptive comments should be included wherever possible. The operation of each program module should be thoroughly explained by comments embedded in the proper place in the program. This aspect is crucial to the debugging of a program, as well as to the re-use of that program by another person or by the designer later on, in case any changes should be required.

2.3. Interfacing

2.3.1. The task of an interface

A computer by itself is not a very useful device. Its power comes from its ability to accept inputs from an outside source, modify these inputs according to a given set of rules, and output the results of these computations to some external device. Some typical input devices are tape readers and navigation interface units. Output devices would include printers, X-Y plotters, and VDU displays.

Ideally, every such device that was built would conform to some standard that specified all the characteristics of its I/O (input/output) connection, thus making all such devices "plug-to-plug" compatible. Unfortunately, no such standard exists.

2.3.2. Communication codes

There are several standard representations of data. The choice of which one to use depends on the particular job. (See Figure 2).

Binary coded decimal (BCD)

If only numeric data is to be transmitted, it is often convenient to transmit these numbers in their binary form. A group of four bits is capable of representing $2^4 = 16$ states. Since there are only 10 decimal digits to be represented, we do not use 6 of the possible states. The problem of converting large decimal numbers to binary is overcome if, instead of the whole decimal number being converted, each digit in turn is converted and transmitted sequentially.

ASCII

One of the most general and widely used encoding schemes for data exchange is known as ASCII, which is an acronym for American Standard Code for Information Interchange. ASCII is defined with seven bits ($2^7 - 128$ states) to give 128 characters with an eighth bit available as a check (parity) bit. These 8-bit packages are so convenient for data representations that they have been given the name byte. Indeed, it is now quite common to measure memory sizes in terms of these 8-bit bytes. There are 32 control codes for such things as carriage return, linefeed, tabs and ringing a bell. The remaining 96 characters contain space, delete, and 94 printable characters which cover the decimal digits, the alphabet both upper and lower case, punctuation marks, and special symbols.

2.3.3. Transmissions

A line or channel is a path for the transmission of information between two or more points. In parallel transmission, each element of a character or code is

ASCII Char.	EQUIVALENT FORMS			ASCII Char.	EQUIVALENT FORMS			ASCII Char.	EQUIVALENT FORMS			ASCII Char.	EQUIVALENT FORMS		
	Binary	Octal	Decimal		Binary	Octal	Decimal		Binary	Octal	Decimal		Binary	Octal	Decimal
NULL	00000000	000	0	space	00100000	040	32	@	01000000	100	64	`	01100000	140	96
SOH	00000001	001	1	!	00100001	041	33	A	01000001	101	65	a	01100001	141	97
STX	00000010	002	2	"	00100010	042	34	B	01000010	102	66	b	01100010	142	98
ETX	00000011	003	3	#	00100011	043	35	C	01000011	103	67	c	01100011	143	99
EOT	00000100	004	4	$	00100100	044	36	D	01000100	104	68	d	01100100	144	100
ENQ	00000101	005	5	%	00100101	045	37	E	01000101	105	69	e	01100101	145	101
ACK	00000110	006	6	&	00100110	046	38	F	01000110	106	70	f	01100110	146	102
BELL	00000111	007	7	'	00100111	047	39	G	01000111	107	71	g	01100111	147	103
BS	00001000	010	8	(	00101000	050	40	H	01001000	110	72	h	01101000	150	104
HT	00001001	011	9	)	00101001	051	41	I	01001001	111	73	i	01101001	151	105
LF	00001010	012	10	*	00101010	052	42	J	01001010	112	74	j	01101010	152	106
VT	00001011	013	11	+	00101011	053	43	K	01001011	113	75	k	01101011	153	107
FF	00001100	014	12	,	00101100	054	44	L	01001100	114	76	l	01101100	154	108
CR	00001101	015	13	–	00101101	055	45	M	01001101	115	77	m	01101101	155	109
SO	00001110	016	14	.	00101110	056	46	N	01001110	116	78	n	01101110	156	110
SI	00001111	017	15	/	00101111	057	47	O	01001111	117	79	o	01101111	157	111
DLE	00010000	020	16	0	00110000	060	48	P	01010000	120	80	p	01110000	160	112
DC1	00010001	021	17	1	00110001	061	49	Q	01010001	121	81	q	01110001	161	113
DC2	00010010	022	18	2	00110010	062	50	R	01010010	122	82	r	01110010	162	114
DC3	00010011	023	19	3	00110011	063	51	S	01010011	123	83	s	01110011	163	115
DC4	00010100	024	20	4	00110100	064	52	T	01010100	124	84	t	01110100	164	116
NAK	00010101	025	21	5	00110101	065	53	U	01010101	125	85	u	01110101	165	117
SYNC	00010110	026	22	6	00110110	066	54	V	01010110	126	86	v	01110110	166	118
ETB	00010111	027	23	7	00110111	067	55	W	01010111	127	87	w	01110111	167	119
CAN	00011000	030	24	8	00111000	070	56	X	01011000	130	88	x	01111000	170	120
EM	00011001	031	25	9	00111001	071	57	Y	01011001	131	89	y	01111001	171	121
SUB	00011010	032	26	:	00111010	072	58	Z	01011010	132	90	z	01111010	172	122
ESC	00011011	033	27	;	00111011	073	59	[	01011011	133	91	{	01111011	173	123
FS	00011100	034	28	<	00111100	074	60	\	01011100	134	92	|	01111100	174	124
GS	00011101	035	29	=	00111101	075	61	]	01011101	135	93	}	01111101	175	125
RS	00011110	036	30	>	00111110	076	62	^	01011110	136	94	~	01111110	176	126
US	00011111	037	31	?	00111111	077	63	_	01011111	137	95	DEL	01111111	177	127

FIG. 2. — ASCII character codes.

transmitted along its own line so that the total character is transmitted at the same instant, for example an 8-bit character needs 8 lines. In serial transmission, the information in the form of characters or code is transmitted one element at a time along one line. An ASCII 8-bit code would be transmitted one bit at a time.

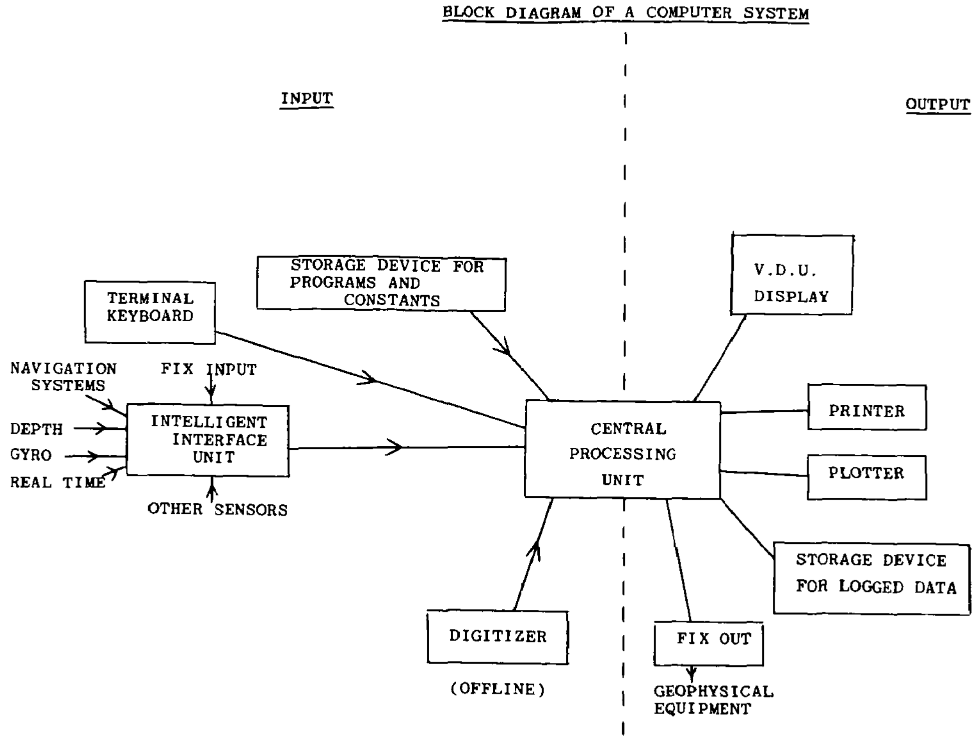

FIG. 3. — Hardware layout.

2.3.4. *Types of interfaces*

Sixteen-bit parallel interface

If 8-bit ASCII data is transmitted, 8 lines would be used to transmit each character. When all eight data lines are set to the proper pattern of ones and zeros to represent the character, the device is told that the data on the lines is valid. Once the device has completed the transfer of the character, it indicates to the computer it is ready for the next character, and the computer then changes the data lines to represent the next character in the message. The cycle repeats. This method of data transfer is sometimes called "bit-parallel, character-serial transmission". If the computer used all sixteen lines to receive or transmit data, the decimal equivalent of a value would be a number in the range -32768 to $+32767$ or 0 to 65535.

BCD Interface

BCD interface accepts in parallel from the device up to eight 4-bit BCD digits and a 4-bit multiplier, and then converts this reading into a sequence of ASCII characters that can be directly read by the computer's ASCII read statement.

Serial interface

Serial I/O interfaces are used to send data over long distances. Not only are the characters of the message sent in a serial fashion, but also the bit pattern for each character is sent serially, one bit after another along a single data line.

General-purpose interface

An HP-IB or GP-IB or IEEE 488 interface is an attempt to make a standard interface. It has become popular, and dozens of manufacturers are providing hundreds of devices which conform to a set of specifications and can be interfaced to one another by simply plugging items together. There is no special representation which must be used for data message on this bus, although the vast majority of IEEE 488 devices have implemented ASCII as their encoding scheme.

2.4. Computer peripherals

2.4.1. Terminals

A keyboard or terminal is similar to a typewriter but with a few special features. It is through this that communication with the machine takes place. There are several different types of terminals. Some display characters typed by the user and the output of the computer on a T.V.-style screen while others have a built-in printer. When the terminal is on-line, there is communication between the terminal and computer, but there is no direct communication between the keyboard and paper or screen. When a printing character is typed, it is a monitor program, not any mechanical response of the terminal that causes its output to the terminal paper or screen, echoing the characters.

2.4.2. Printers

The most important source of permanent computer output is a printer. There are three basic mechanisms in a printer :

(a) to move the paper vertically,
(b) to locate the printing mechanism horizontally, and
(c) to produce the printed character.

Vertical movement

All printers use basically similar mechanisms to move the paper vertically to the correct line. An electric motor is arranged, so that the paper moves in very small steps or in a complete one-line movement at a time. The drive is either a pinched roller, or a sprocket feed.

Horizontal positioning method

(a) A serial printer prints one character at a time, and then the printing mechanism moves on to the next position.
(b) A line printer accumulates the character codes for a whole line in a buffer and then prints the whole line.

Character impression

(a) An impact printer makes physical contact between the typeface and the paper using an ink or carbon ribbon so that the characters appear.

(b) A thermal printer uses special paper which is chemically coated and which turns black or blue when heated by a thermal print head. Thermal printers are quieter and generally more reliable than impact printers.

Character formation

(a) The characters are fully formed in minor image on a drum, wheel, golf-ball or train. This type gives superior character quality, but can only be used by impact printing.
(b) Thermal printers use a matrix of tiny dots to build up a character. This type of printer is often simpler to drive, but the characters lack quality.

Operating speed is measured either in characters per second (cps) for serial printers or in lines per minute (lpm) for line printers.

2.4.3. Visual display units (VDU)

Visual display units produce a soft copy which can be overwritten or erased so that the screen can be used to display more information. A classification of displays divides them into alphanumeric displays which are able to display numerals, letters, certain punctuation and other symbols or graphic displays which are able to display plots and diagrams as well as alphanumeric characters. Alphanumeric character displays can be made by using a dot matrix of light-emitting diodes, or a gas discharge tube, but these are normally limited to a few characters. The standard displays are cathode ray tubes (CRT). Alphanumeric displays have up to 40 lines of up to 80 characters per line on the screen. Graphic displays are categorized by the number of addressable points on the screen.

2.4.4. Plotters

There are two basic types of X-Y plotters available : the drum and the flat bed.

The drum plotter

The drum plotter movement in one axis is provided by the chart passing over a sprocketed drum while movement in the other axis is caused by a pen moving along a stationary carriage. The paper is kept taut by take-up spools on either side of the drum. A drum plotter is relatively compact. The width of the plotter varies from 25 cm to a metre. The length of a chart, in theory, can be the length of the roll of plotting paper, but as the length increases, the accuracy of the plotter decreases, and about one metre is a practical length. Whilst the drum plotter is plotting, only the portion on the drum can be viewed. Inspection is also hindered since the chart is constantly moving.

Flat bed plotter

The flat bed plotter is faster than the drum plotter with movement being provided by the pen in one axis and the pen carriage in the other. The paper is kept in position either electrostatically or by suction. The chart can be viewed as a whole, and it is possible to make measurement on the chart without removing it from the plotter. Generally the accuracy of a flat bed plotter is better than a drum plotter. Flat bed plotters are considerably more expensive than drum plotters. The sizes of flat bed plotters vary from A0 down to A3. These plotters are consequently not as compact as drum plotters.

2.4.5. Data storage

Data storage devices can be used to either load a program file or store data. Most recording devices perform a read-after-write operation to check that data has been recorded correctly. Peripheral data storage devices buffer data and record it in a block, making most efficient use of the recording medium.

Magnetic tape cassette

Two main types of tape systems are common, the standard cassette which is similar to the audio type and the cartridge which contains all the necessary tape guidance and tensioning equipment within it. The cartridge can be driven by a single motor, but the complexity makes the cartridge much more expensive than a cassette. Cartridges do have greater bit density, 1600 bpi as opposed to 800 bpi. They can have four tracks and have higher speed and transfer rates. Data cassettes and cartridges have a limited life, but their ease of use and portability makes them one of the most popular data storage mediums.

Magnetic tape, industry compatible

It is usually half an inch wide and is housed on seven- to ten-inch diameter spools, containing from 600 to 3600 feet of tape per spool. At 800 bpi or 1600 bpi, tapes are formatted to hold data which are the industry standards. Data is recorded in parallel, thus a character is recorded across the tape, seven or nine tracks, and at 800 bpi a full tape holds more than 20 megabytes (million characters), enabling large volumes of data to be stored and to be transferred to other computers.

Floppy disc

A very cheap disc, known as a floppy disc, is now widely used in minicomputer systems. Typical floppy disc drives rotate at only 100 rpm, take 10 ms to move the head one track, and take a third of a second to move across from outer to inner tracks. With bit densities from 1000-3000 bits per inch, data can be transferred at up to 9.6 thousand characters per second. The advantage of random access to tracks at about the same price as a data cartridge makes the floppy disc very popular. To operate successfully, floppy disc drives require a stable power supply.

2.4.6. Navigation interface unit

For a computer, it is time-consuming to control and read data from external devices, such as navigation systems, echosounders or a gyro. Each device normally requires an individual interface, and the type of data output varies. The computer is restricted by the number of I/O ports available. Also, the more ports used, the longer it takes to service each one. Once an individual interface has been configured, the data has to be decoded and manipulated into a readable format.

Some data will not be complete : for example, a missing pattern identifier. The additional data will have to be added by the computer. There are now available dedicated navigation interface units which are microprocessor-based and are designed to provide the computer, via one interface, all the required data in a standard format. This data is transmitted at regular intervals, normally once a second. Some interface units include a real time clock, and the data can be time tagged, which is especially important when depth data is logged. The microprocessor can also be used to send an accurately-timed fix interval and a fix closure simultaneously to the navigation computer and the geophysical equipment which can be used to help correlate the navigation information and geophysical records.

2.4.7. Digitizers

The first step in all computer data processing applications is to provide the computer with the basic data. When the source of this data is graphic such as a side scan record or pinger record, it must first be converted into digital form before it can be input to the computer. The easiest and most convenient way of converting graphic data into digital form is by digitizing. As a cursor or stylus is moved over the graphic source on the digitizing table, the movement is resolved into its X and Y components by a built-in sensing system. The resolution and accuracy of this sensing system will depend on the type of digitizing table. The components of cursor movement are relative to a datum point which can be set anywhere within the working area of the table. The output of the data can either be recorded for computer processing at a later stage or fed directly into a computer for processing as it is generated. An advantage of an on-line system is that there can be a two-way exchange of data between the digitizer operator and the computer.

3. THE COMPLETE SURVEY PACKAGE

3.1. Overall design of the system

The object of a hydrographic survey is to depict the relief of the seabed, show pinnacles, pockmarks, wrecks, pipelines, cables, and other features. It is also important to identify the nature of the seabed and its underlying structure. To achieve this, the surveyor must have the ability to accurately locate or position the survey vessel and, hence, the geophysical sensors with their associated results. It is also necessary to navigate the survey vessel along the desired course to cover the area to be surveyed. This gives methodical coverage and reduces the risk of areas being missed. Data must be collected and logged from both navigation and geophysical sensors at a rate appropriate to the scale of the final survey.

The amount of information handled and the required update rate vary according to the task the navigation computer has to perform. As memory size and speed of a computer increase, so generally does the price. It is, therefore, important to select a machine capable of meeting the job specification and still remain within budget. The selection of peripheral devices is important since the surveyor and helmsman should have readily available enough information to keep the position of the vessel within specification and also to monitor the performance of all the navigation aids.

The navigation software should be versatile and simple to operate, with the surveyor requiring little computer knowledge. All possible errors should be trapped, and the surveyor informed of type of error and the action to take to correct the situation. Finger trouble is the most common source of error. Therefore, all forms of manual data entry should contain checks to prevent the surveyor from entering the wrong data. If the surveyor does make a mistake entering, he/she should have the ability to easily change the data. The software can be divided into five suites of programs :

a) Prejob preparation;
b) Chart drawing;
c) On-line data acquisition and processing;
d) Off-line post-processing and geophysical interpretation;
e) General utility programs.

3.2. Prejob preparation suite

Spheroid, projection, datum and navigation chain parameters should be able to be entered and amended by the surveyor from the keyboard. This data should then be stored as a data file on either magnetic tape or floppy disc. This concept greatly reduces the risk of errors being made when entering the data. The storage of the parameters aids the surveyor to rapidly reaccess the data from any computation program with minimal amount of effort. The surveyor should be able to enter details about the survey, i.e., scale, line spacing, size and orientation of the area, and the program should compute the start and the end of line coordinates as well as the best set of charts to cover the area. Together with platform position, this data should be stored as chart, survey line and target point libraries for use by either the on-line or chart drawing programs.

3.3. Chart drawing suite

The style and size of chart will depend on the nature of work carried out and the choice of plotter. For both work and final charts, the program should be able to perform at least the following tasks :

a) Produce a base chart at any rotation and scale for a given survey area. The base chart normally will be comprised of two parts : an inner box which covers the survey area and an outer border which contains title information, scale and other relevant details. The sides of the inner box should be annotated with the grid and/or geographical coordinates with intersection points at suitably selected scale.
b) Produce a lattice chart within the inner box of the base chart for any type of navigation system. The line spacing and annotation interval should be operator-selectable (See Figure 4).

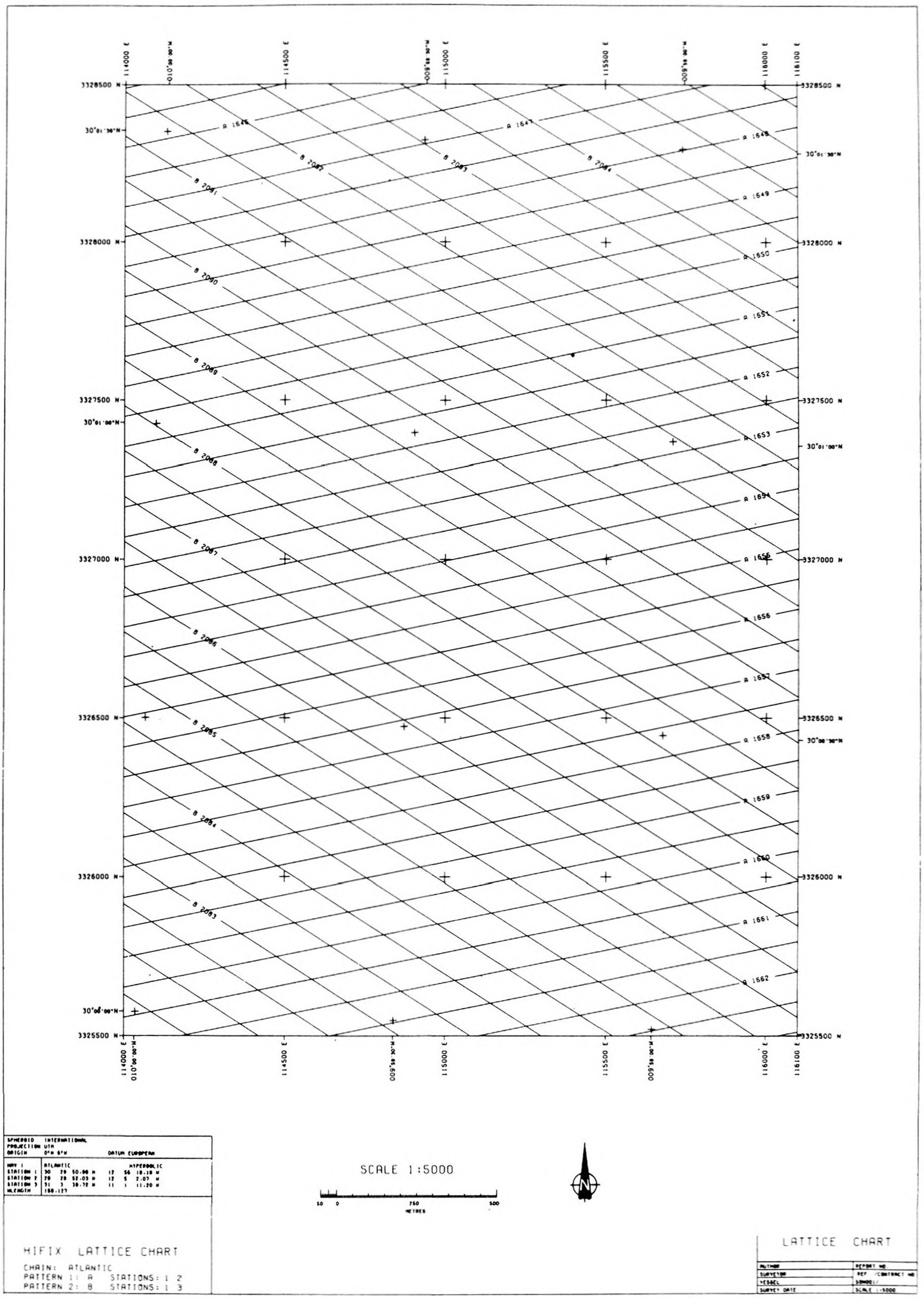

FIG. 4. — Lattice chart.

c) Plot the position of target points, buoys, rigs, wellheads, etc., with a specified symbol.
d) Plot predetermined survey lines, pipelines and telephone cables as either solid or dashed lines, and should be able to plot lines and curves to enclose an area.

3.4. On-line data acquisition and processing (see Figure 5)

The basic parameters for the survey should be loaded from data files which have been previously created by the prejob preparation program. This data together with C – O errors, weights, antenna offsets, etc., should then be recorded as an on-line navigation parameter file. This once again reduces the risk of errors being made. It also enables the surveyor to rapidly restart the on-line program if it has halted for any reason.

The on-line program should operate in real time and should be used to gather information from navigation systems, echosounders and gyros. This data should be transmitted to the computer, typically once a second, and logged on magnetic tape or floppy disc at frequent intervals.

All computations can either be carried out on the defined projection or on the spheroid. Spheroid formulae are more complex, and this option is only available with fast machines. However, spheroid computations are preferable, particularly when the survey is on the edge of a grid zone or the survey stretches across two or more grid zones.

The software should be designed to process data from any navigation system commonly used for hydrographic surveys. During every processing cycle of the on-line program, the position of the vessel should be computed and all navigation aids updated. The position for each navigation system should be derived using the method of least squares from a preselected combination of position lines. Using the residuals of each pattern, the standard error of position, the standard error of observation and the size and orientation of the error ellipse should be computed. The surveyor should be able to select the primary navigation system, and for all secondary systems the surveyor should be supplied with information relating to the offset from the primary system and the theoretical lane count based on the primary position.

At an interval either based on elapsed time or distance travelled, a pulse should be output to all analogue traces, a special record output to magnetic tape, all fix information printed out and the plotter annotated. This is to correlate the vessel's position with a fix mark on the analogue trace. If the fix interval is based on distance, the surveyor should be able to select either distance travelled along a survey line or distance travelled between fixes. When fixes are generated on time, the distance interval between fixes may vary slightly if the ship velocity varies. When shots are fixed on distance, the time between shots may vary slightly if the ship velocity varies.

There are several types of survey lines or grids that can be used, including rhumb lines, constant latitude lines, geodetic lines and grid lines. There are five values computed with respect to the survey line : distance along the survey line from the start (Distance Along Course), distance to the end of the survey line

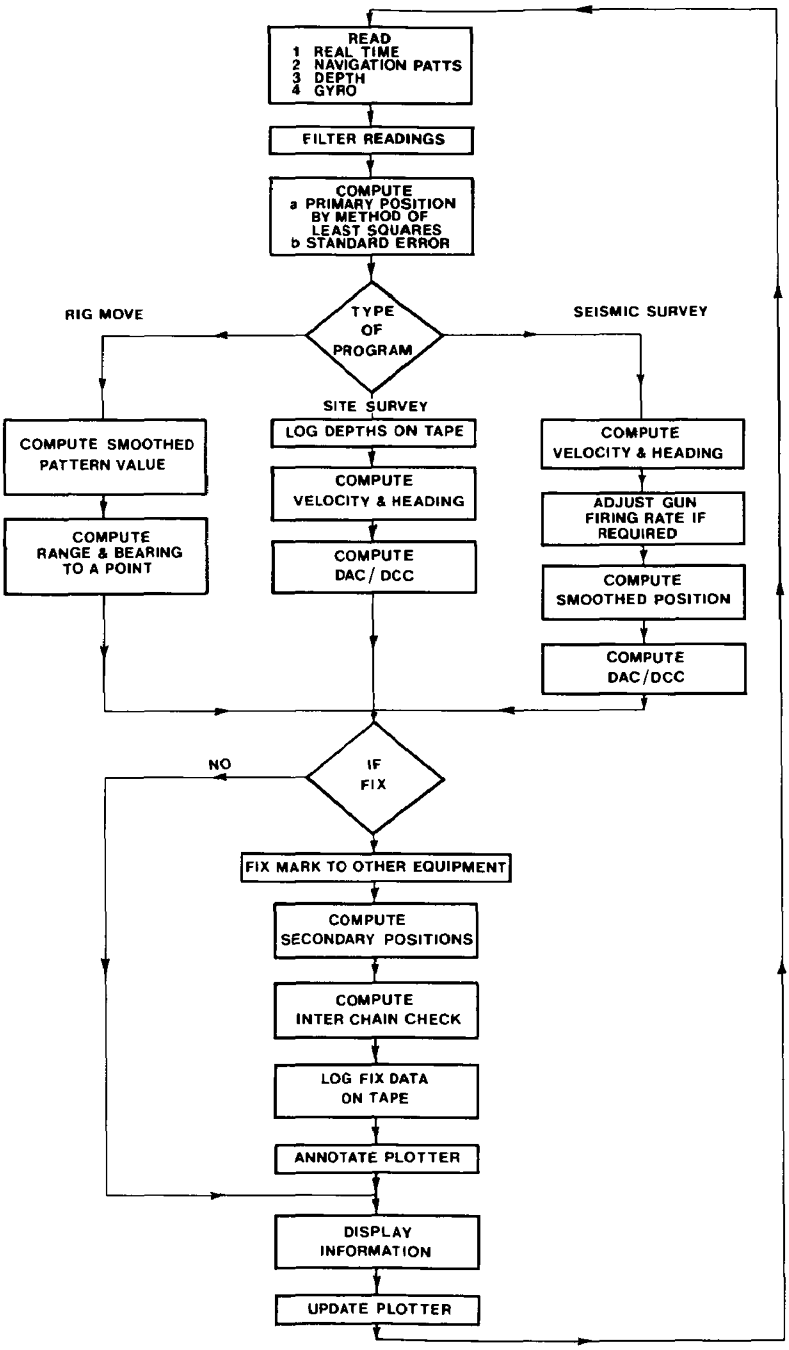

FIG. 5. — Computer cycle.

(Distance To Go), the perpendicular distance from the vessel to the survey line (Distance Cross Course), range to the aiming point and bearing to the aiming point. The aiming point is a point that lies on the extension of the said line before the starting point.

Filtering, smoothing and prediction techniques can be used for problems in which the parameters being estimated by the least squares process are varying with time. The process of computing the ship's position at any instant in order to plot the real time position on a chart would be filtering. The computation of the time at which the ship is expected to be at the correct position for a fix would be prediction, and the subsequent post-processing estimation of the actual location of the ship at a fix would be smoothing. It is the surveyor who validates the position information and should have control of the filtering, smoothing and prediction techniques. The object of filtering is to enable rejection in software of spurious ranges from the navigation systems and to continue with dead reckoning should range information fail temporarily. The most common technique used at present is the Kalman filter.

The data should be stored in digital form on magnetic tape or floppy disc by the navigation computer at a rate determined by the surveyor. This data should then be reprocessed on board using an independent processing subsystem to produce fair charts. In this way the surveyor will benefit from the immediate feedback.

The surveyor should be able to make full use of the VDU display, track plotter and keyboard facility to continuously monitor and apply changes to the system. (See Figures 6-11). The surveyor should be able to enter comments, e.g., swell, its direction and height, from the keyboard. The comments could either be printed out or stored on magnetic tape as an additional record of the survey.

3.5. Off-line post-processing and geophysical interpretation suite

There are four major components of computer-assisted charting : data acquisition and digitizing, data processing, editing and charting. Variations in the production path exist because each chart is unique. It is, therefore, important that the surveyor and geophysicist determine what they wish the charts to depict.

Data acquisition and digitizing

The post-process program should combine data collected by the on-line program and data obtained by digitizing analogue records. For instance, data relating to pipelines, pockmarks, rock outcrops and wellheads can be obtained from a side-sonar record. Accuracy is important to the digitizing process. It is essential that the surveyor is familiar with digitizing procedures and continually checks for input errors.

Digital data processing

Digital data processing refers to those intermediate steps in the computer-assisted chart production process, such as recomputation of position using a new combination of position lines and/or revised C − O errors, applying tidal correc-

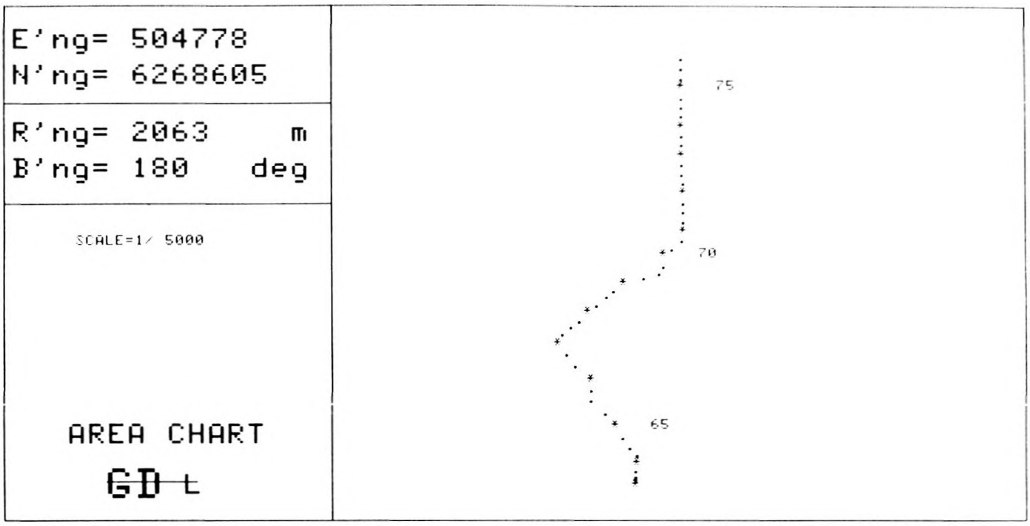

FIG. 6. — VDU area chart.

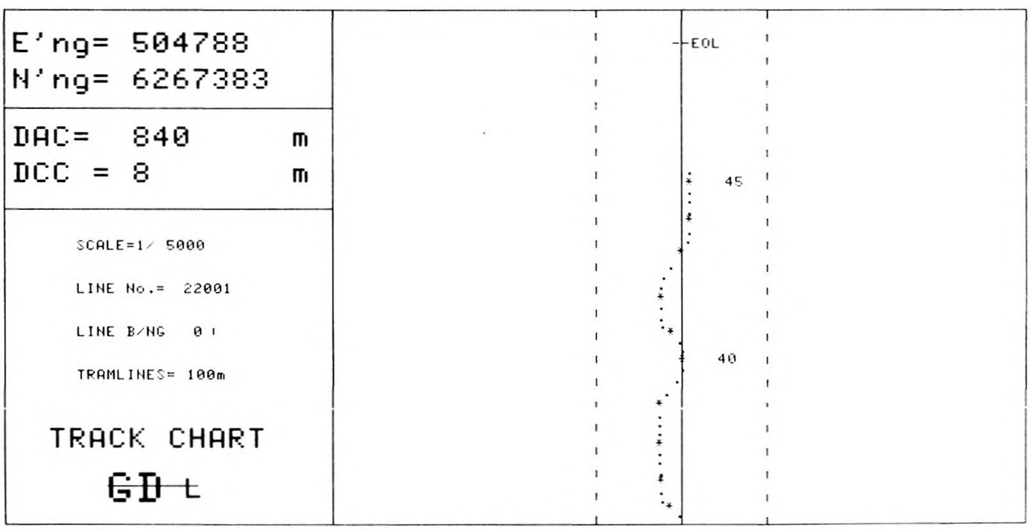

FIG. 7. — VDU track chart.

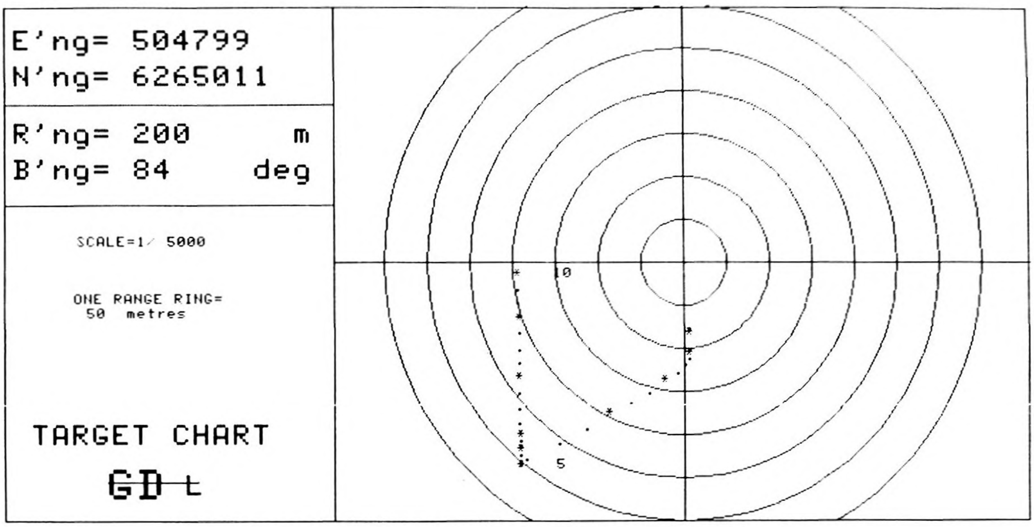

FIG. 8. — VDU target chart.

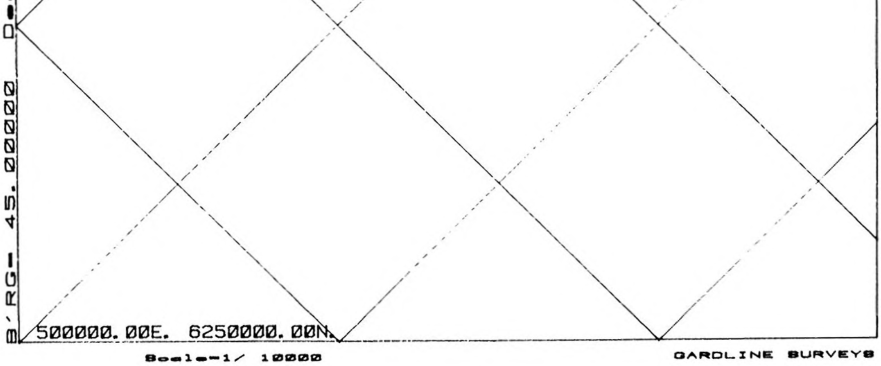

FIG. 9. — Plotter area chart.

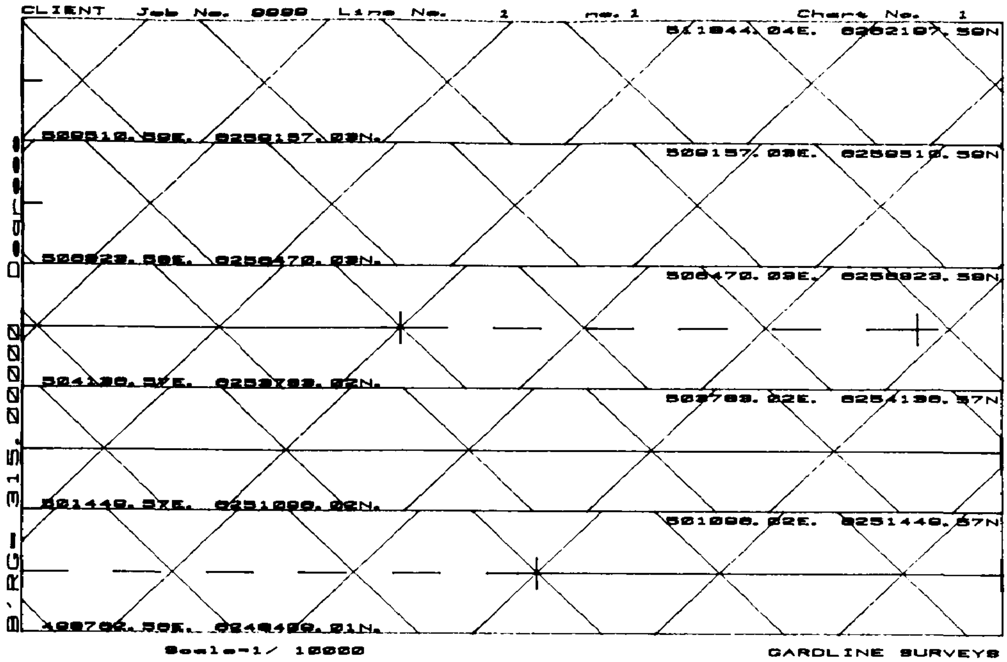

FIG. 10. — Plotter strip chart.

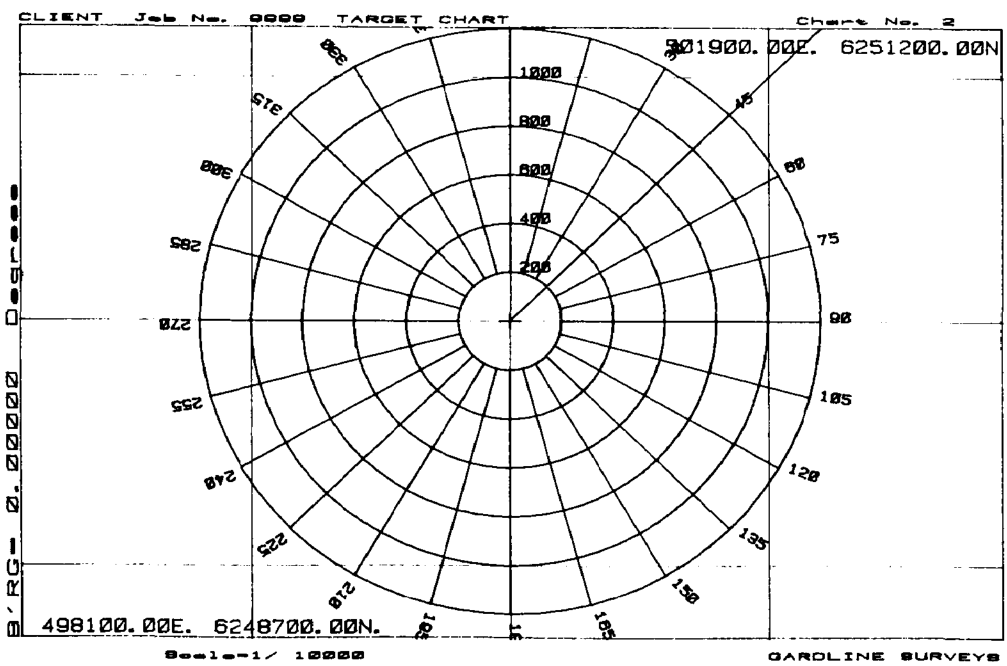

FIG. 11. — Plotter target chart.

tions to raw depths. The program should also be used to manipulate digital data for projection and datum change or sounding units change. The data at all stages should be checked for errors and potential problems. Other programs should be available to extract useful statistical information from the data.

Editing

The purpose of editing is to remove unwanted data collected by the on-line system and correct mistakes and omissions originating with digitizing. Line, point, numerical and name data should be able to be added, deleted, changed or moved. At no stage in either the reprocessing or editing stages should the original field data tapes be altered as they are the definitive record of the survey. All work should be carried out on backup copies.

Plotting

Several different plots can be produced through the computer-assisted cartographic process. The type of plot output depends on the steps in the production flow. The program should be able to produce :

a) a navigation plot depicting the ship's track (Figure 12);
b) a bathymetric plot showing depth below mean sea level (Figure 13);
c) a profile plot showing a series of geophysical cross sections below the seabed from digitized profile records (Figure 14);
d) an isopach plot which shows either the thickness of a particular layer or the depths from the seabed level to a specified horizon (Figure 15);
e) a seabed feature plot showing the position of pipelines, telephone cables, anchor scars, wrecks and other features (Figure 16).

3.6. General utility programs

In addition to the previous programs, the surveyor should have programs to perform any miscellaneous functions, including an off-line computation program to perform all standard survey computations and a diagnostic program to check out the entire system if there appears to be a hardware fault.

CONCLUSION

Most survey companies have developed calculator/plotter systems and many can perform most of the functions outlined in section 3.4. Development of these systems has always been dependent on the introduction of new desktop calculators and their associated peripherals. Whilst most calculator/plotter systems are adequate for navigating the survey vessel, desktop calculators' processing time is slow compared to a minicomputer using an assembler language, such as FORTRAN or PASCAL. Little time has been spent on increasing processing speed and developing new uses. An offshore digital computer system could improve the computation cycle time and logging rate, also the use of an additional sensor for

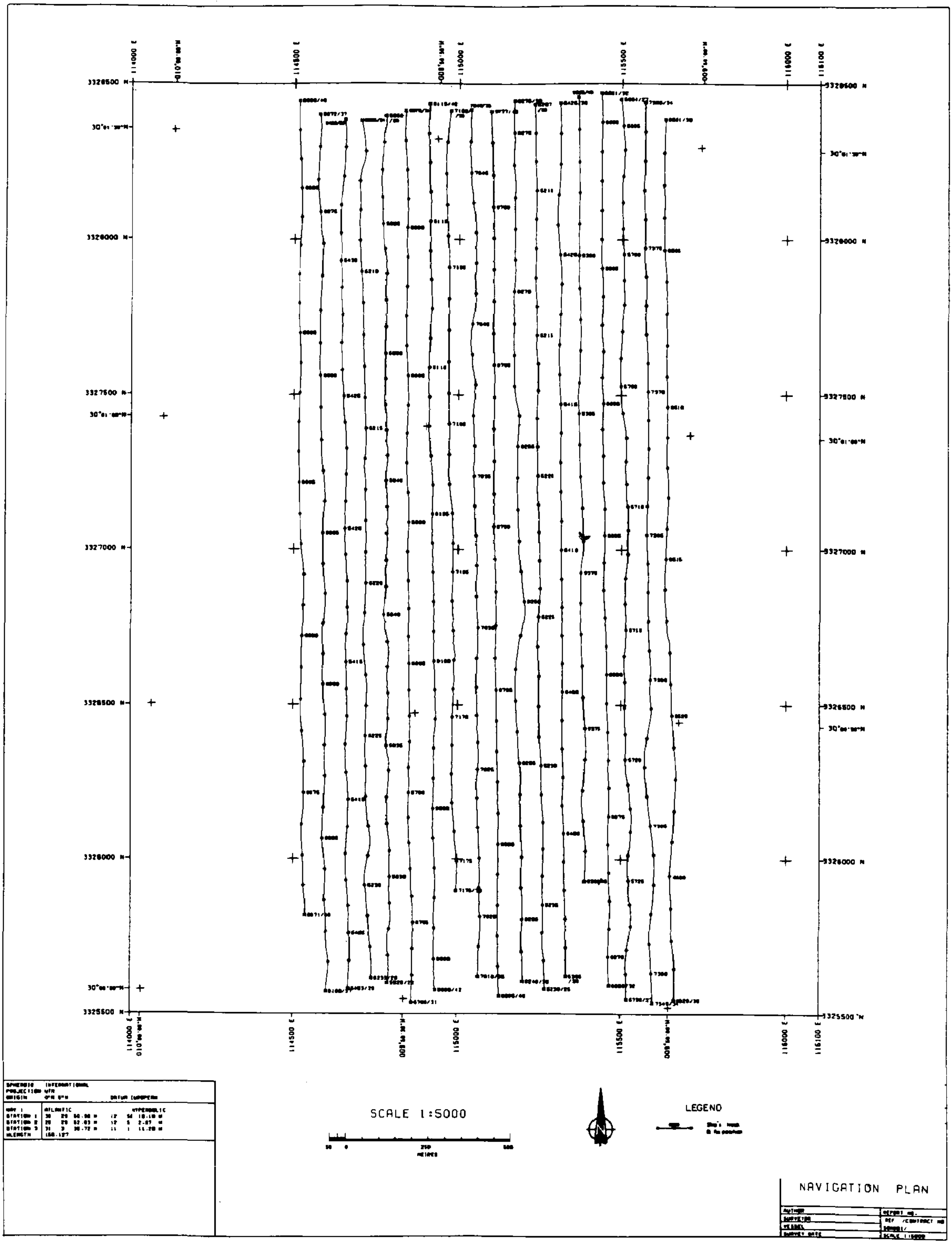

FIG. 12. — Navigation track chart.

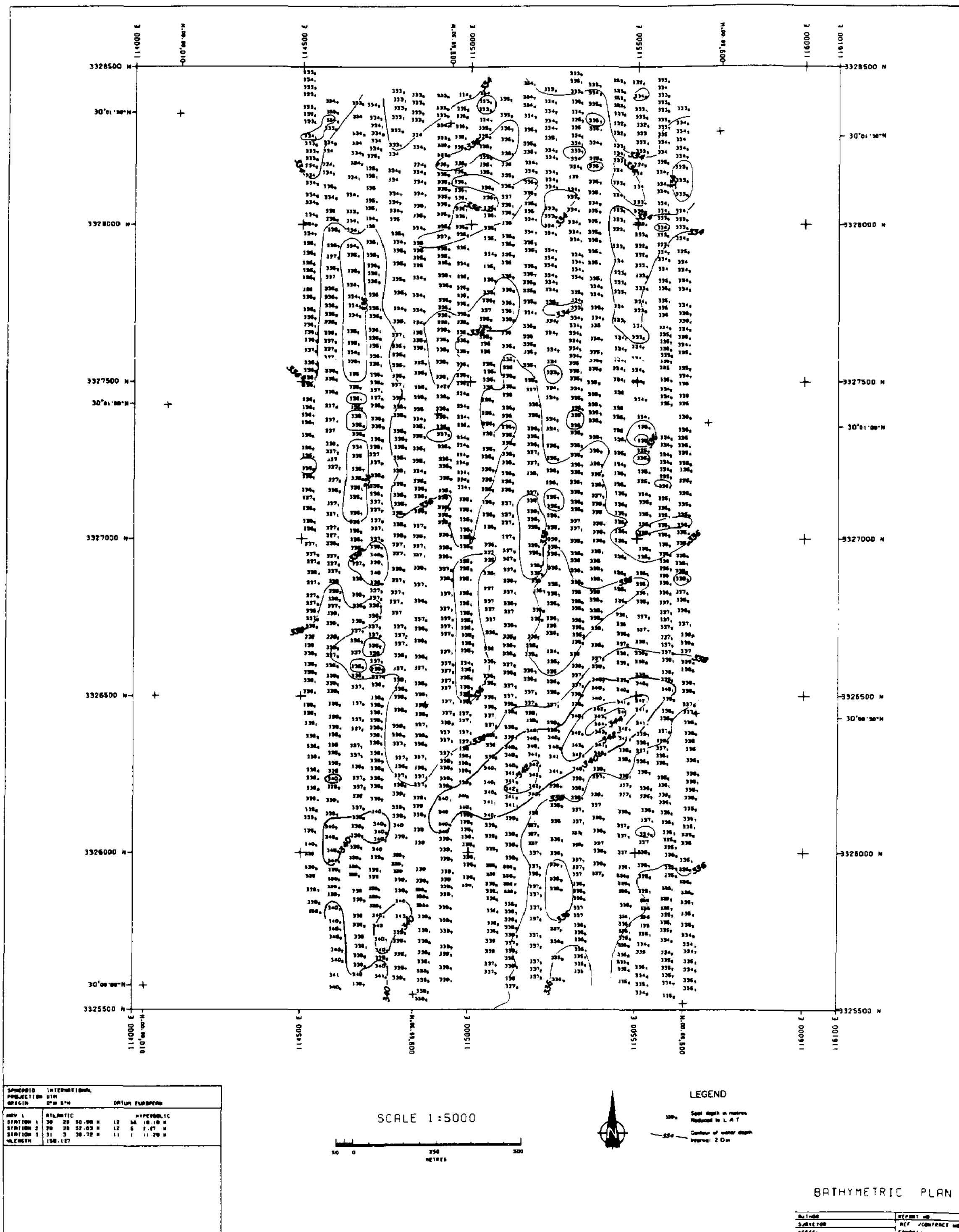

FIG. 13. — Bathymetric chart.

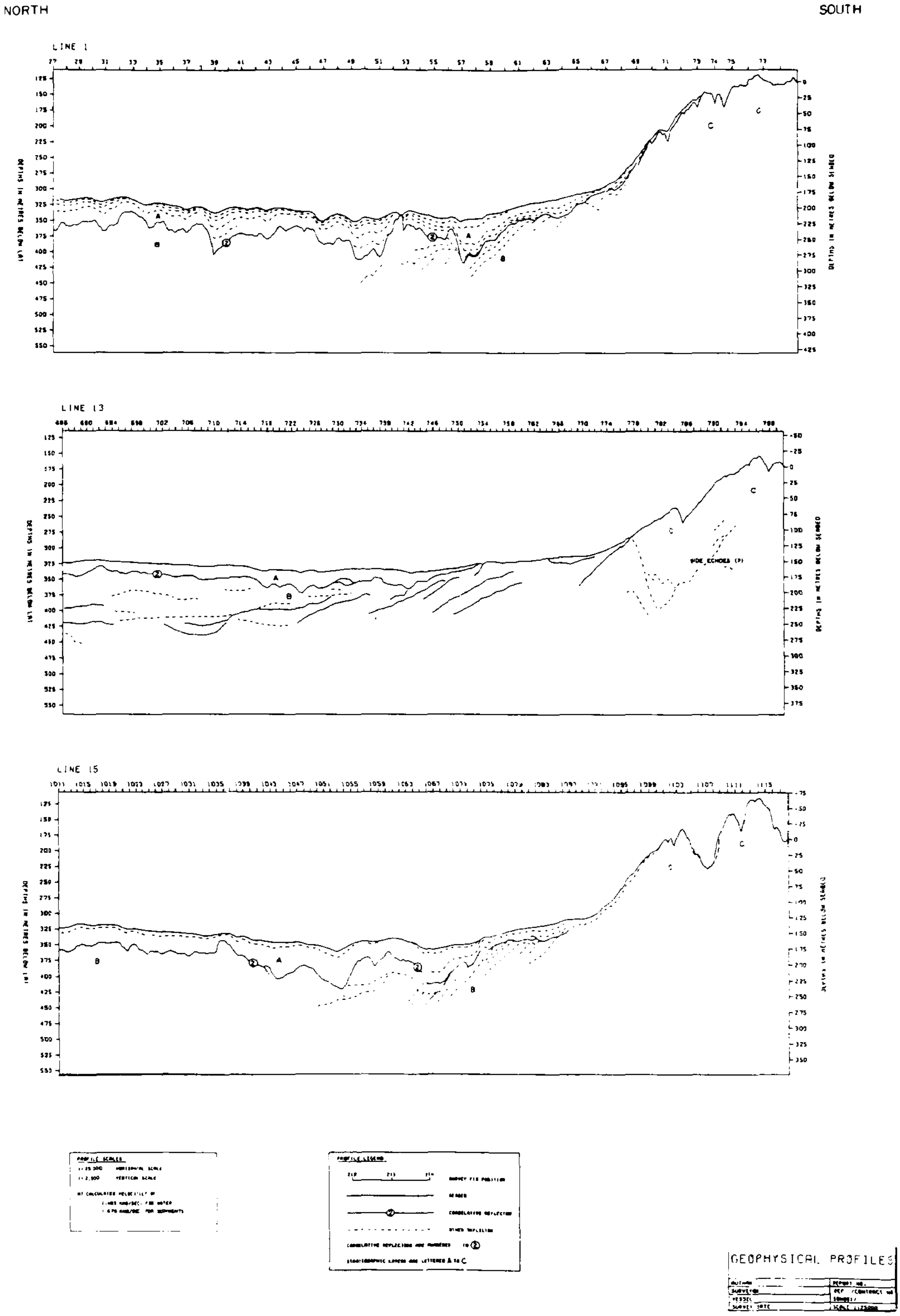

FIG. 14. — Geophysical profiles.

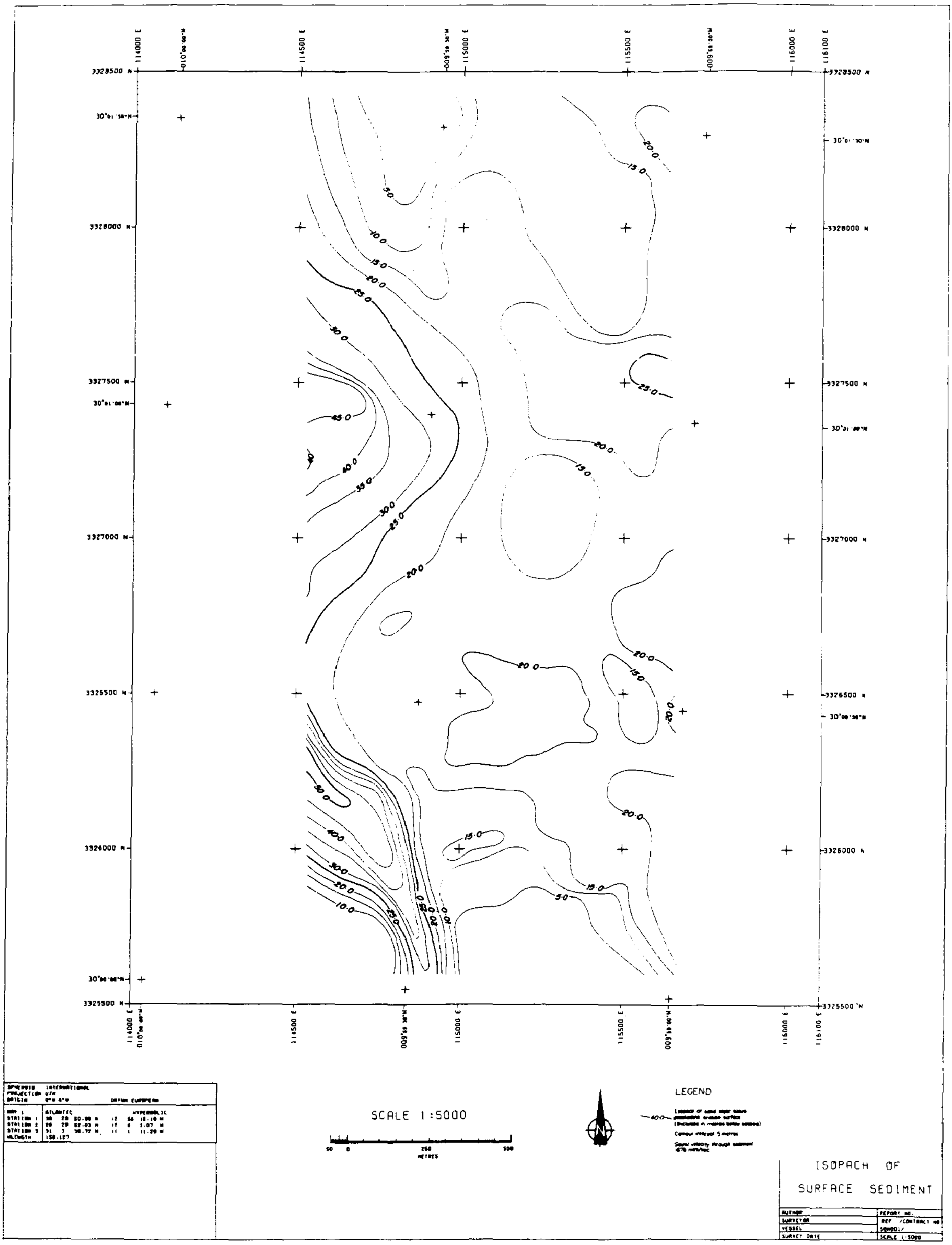

FIG. 15. — Isopach chart.

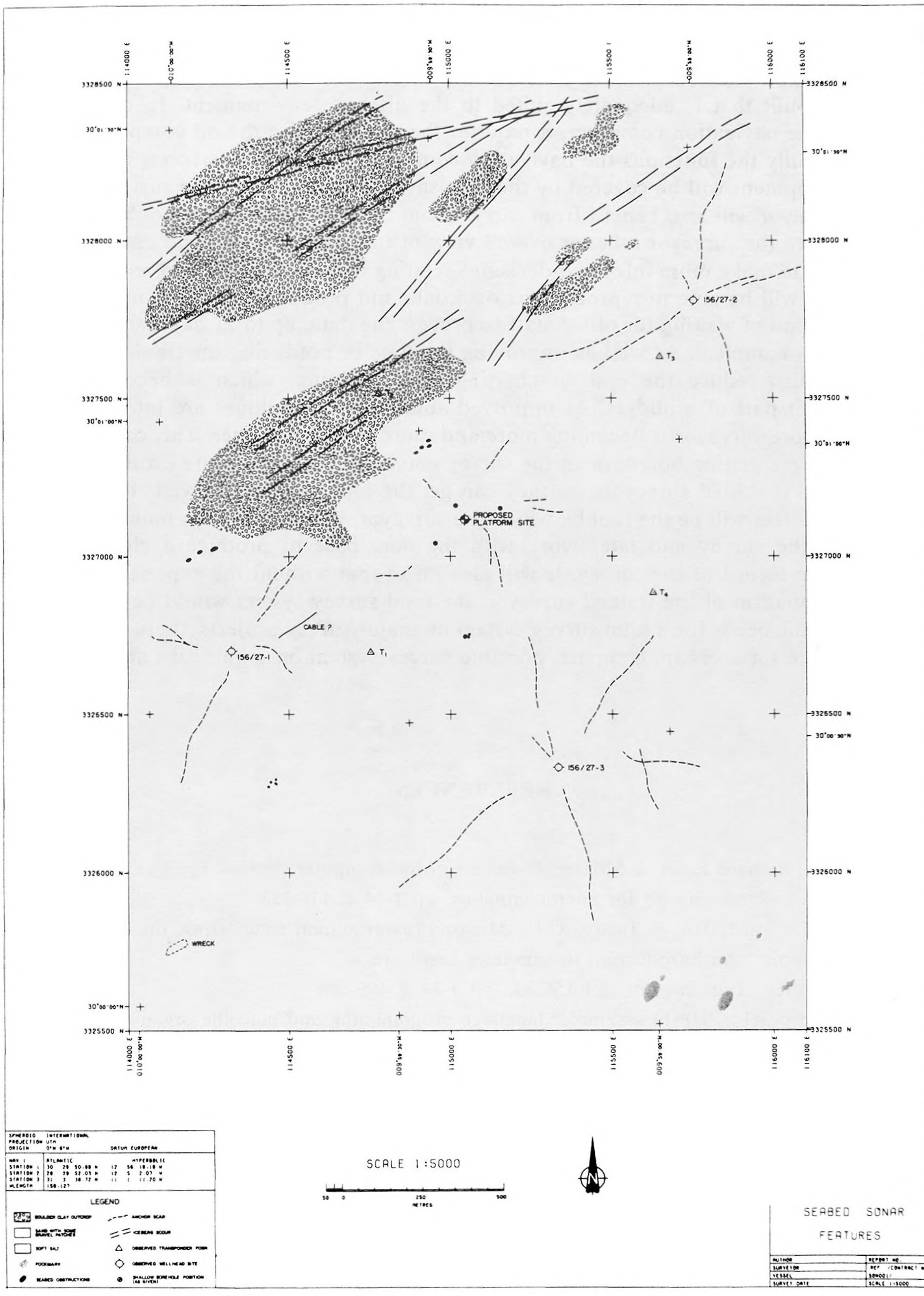

FIG. 16. — Seabed sonar features chart.

positioning the towed fish or computing real time speed of sound in water. The survey programmer should make himself/herself familiar with the additional capabilities of a minicomputer compared to a desktop calculator. Today there are many computer components available from which a powerful minicomputer system can be built that is adequately suited to the offshore environment. In order to design the navigation computer, it requires the surveyor and the oil companies to outline fully the functions the navigation computer system will perform. The cost of development will be covered by the time saved in reprocessing the survey data. The surveyor will also benefit from carrying out the reprocessing work onboard as it will give the surveyor a better overall view of the job's progress and enable the surveyor to make more informed decisions relating to the programme of work. The surveyor will be able to reprocess his own data and produce fair charts immediately, instead of waiting for office staff to process the data, up to 21 days later when the job is complete. As well as improving the time in producing the final chart, it should also reduce the cost of charting and reporting, which is becoming a significant part of a budget. As improved automation techniques are introduced, the offshore surveyor is becoming more and more a button pusher. This can result in surveyors getting bored, or in the survey company finding it more economic to employ less skilled surveyors, as they can get the job done just as well. The total survey system will be the tool by which the surveyor, in real time, can monitor and control the survey and later work with the data base to produce a clean and definitive record of the survey. It will also mean that without the experience and professionalism of the trained surveyor, the total survey system would be useless. Despite the needs for a total survey system on major survey projects, there will still be a place for a cheap, compact, portable survey system on minor jobs and small vessels.

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