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AUTOMATED DATA HANDLING ONBOARD H.Nl.M.S. « TYDEMAN »

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The oceanographic research vessel, H.Nl.M.S. *Tydeman* (fig. 1), of the Royal Netherlands Navy, is equipped with a rather comprehensive automated data handling system. After a description of the installed system, conclusions are drawn at a time – a good 4 years after commissioning – when one expects that growing pains have been eliminated and a good deal of practical experience has been gained.

The ship is equipped with two systems:

a) the HYDRAUT system for her hydrographic task;

b) the OCEAN system for her oceanographic task.

The HYDRAUT system – which is installed aboard the ship and one of her fast 10-metre launches – is identical to the HYDRAUT systems onboard the two hydrographic survey ships: H.Nl.M.S. *Buyskes* and H.Nl.M.S. *Blommendal*. As these systems have previously been described in the *Hydrographic Newsletter*, Vol. 2, No. 6, and in the *International Hydrographic Review*, LII (2), July 1975, only the OCEAN system will be dealt with in this paper.

The OCEAN system consists of two subsystems, each with its own specifc function:

I. The data logging system (named "Ocean logging system");

II. The data processing system (named "Ocean processing system").

Both systems are built around an identical base system (printed in bold letters in their respective diagrams).

During the system design phase, two relatively small computer systems were intentionally chosen instead of one big system. The principal argument was that, in case of an unforeseen breakdown of a component of the logging base system, this component could be replaced by the corresponding component of the processing base system, so that automatic data collecting could be continued.

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FIG. 1. – The oceanographic research vessel H.NI.M.S. *Tydeman*.

The two mentioned base systems, HP 9640A systems with two additional magnetic tape drives, each consist of the following components :

a) an HP 21M20 mini-computer (memory : 32 K words of 16 bits);
b) an HP 7900A disk-drive unit with a fixed and a removable disk (capacity 5 Mbytes, random access time 30 msec);
c) an HP 12926A paper tape punch unit (75 char/sec);
d) an HP 12925A paper tape photoreader unit (500 char/sec);
e) two magnetic tape drives HP 12970 (9 tracks/800 bpi);
f) a system terminal, an LA-36 DEC-writer (30 char/sec matrix printer).

Both systems operate under the control of an operating system, indicated as Real Time Executive (RTE) by the computer manufacturer.

This operating system makes it possible :

– to let programs run apparently at the same time;
– to operate the system from more than one terminal;
– to run programs : a) at fixed intervals
  b) under program control
  c) under operator's control
  d) event driven.

The base systems have been installed in what is termed the Central Computer Room (fig. 2). The other peripherals have been installed where they are needed, e.g. meteo-office, bridge and laboratories.

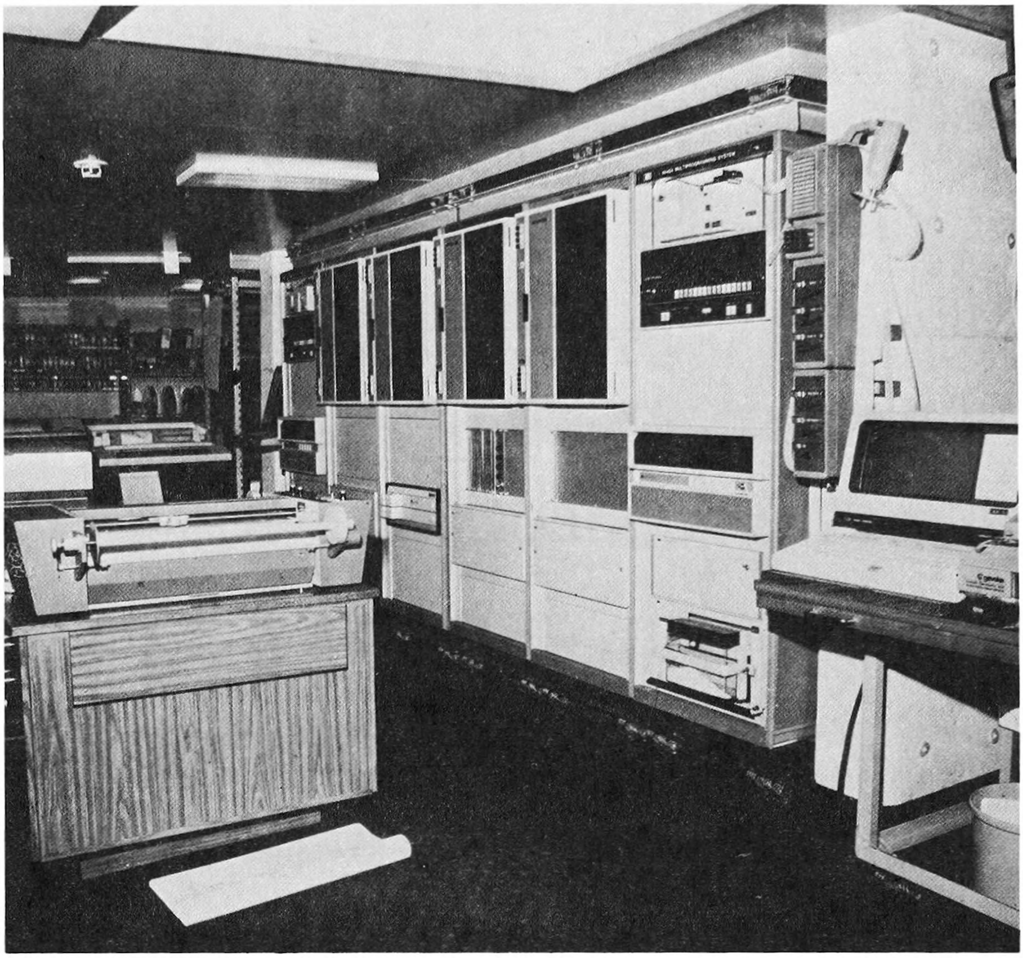

FIG. 2. – The computer room.

THE OCEAN LOGGING SYSTEM
(see figure 3)

One base system is expanded to the data logging system by connecting the following sensors and computer peripherals.

Sensors for positioning :

- Satellite Navigation System (Magnavox 702 A (SATNAV) with its own HP 2100 computer). To upgrade the accuracy of both the dead-reckoning and the satellite fix positions, the electromagnetic speedlog and the gyro-compass have been connected to this navigation system.
- Omega receiver (Sercel).
- Decca Mk 21 main chain receiver. When it is necessary to use interchain fixing, an extra Decca receiver (e.g. from the launch) is connected.

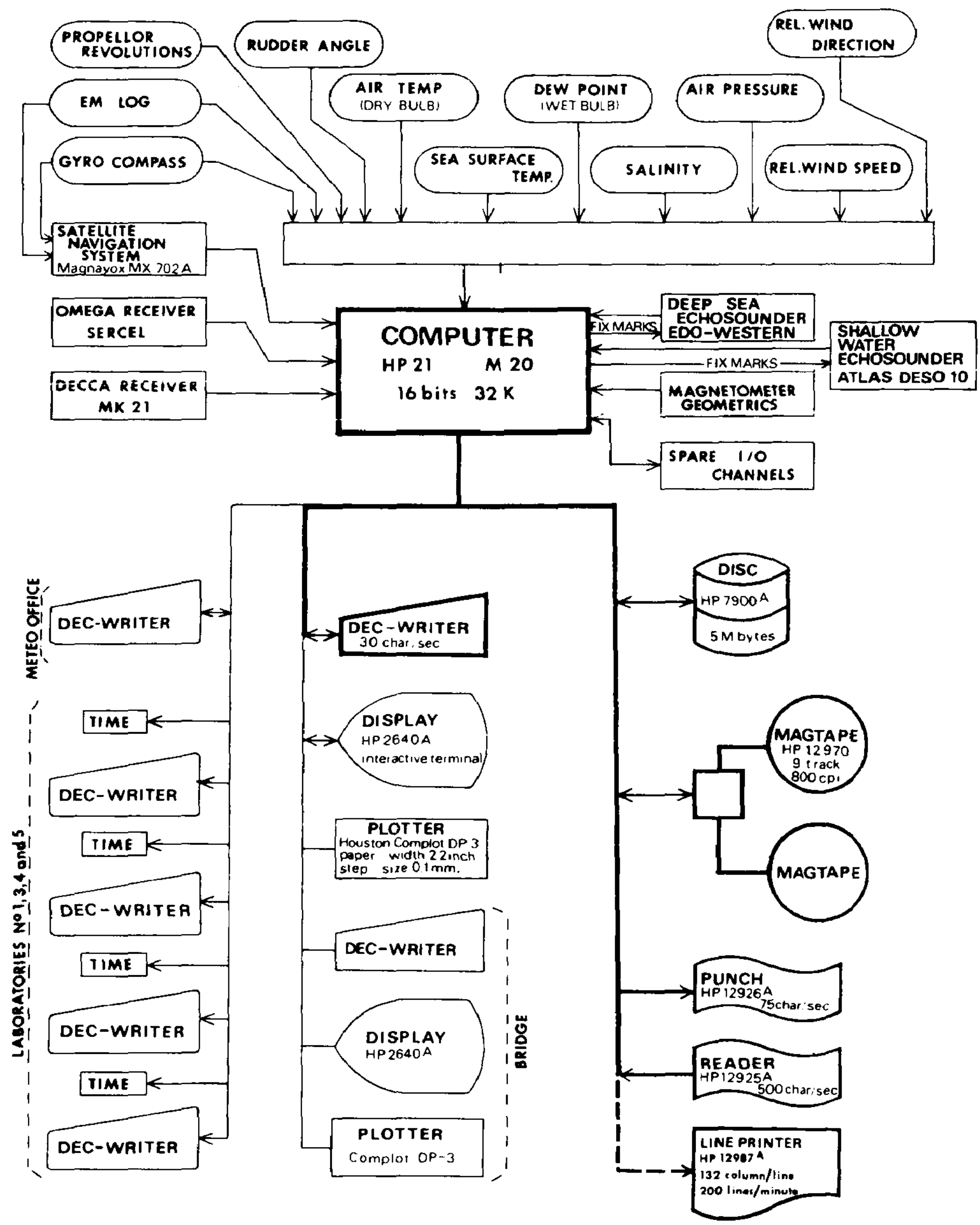

FIG. 3. – Data logging system.

- Electro-magnetic (Plath).
- Gyrocompass (Anschutz).
- Propellor revolution counter.
- Rudder angle indicator.

Sensors for oceanographical/meteorological observations :

- Deep-sea echo-sounder (EDO Western with Digitrak).
- Shallow-water echo-sounder (Atlas Deso-10 with EDIG-10).

- Magnetometer (Geometrics).
- Dry bulb thermometer.
- Wet bulb thermometer.
- Barometer.
- Sea surface temperature thermometer.
- Sea surface salinity meter.
- Wind speed meter.
- Wind direction meter.

Peripherals for system operation and output :

- Two display terminals (HP 2640A), one installed on the bridge and one in the computer room.
- Six LA-36 DEC-writers (30 char/sec matrix printer) installed on the bridge, the meteo-office and in four of the laboratories.
- Five time displays, which are installed in the computer room and in four of the laboratories.
- Two incremental plotters (Houston DP-3, step size 0.1 mm) installed on the bridge and in the computer room.
- One lineprinter HP 2607A (132 columns, 200 lines/minute). By means of a switch this lineprinter can be connected either to the logging system or to the processing system.

The programs performing the various tasks run under the control of the operating system. All operator's communication with the programs is on a user's base : a.o. yes/no answers. Where numerical input is required (e.g. parameters of a chart to be drawn) an example of input data is given. Programs verify, as much as possible, the correct data input by the operator. With the input and output of the system as a guide, a description of the present program package is given below (see also fig. 4). Thanks to the use of an operating system, tasks can be modified or added in an easy way, even while the logging of data continues.

Input

When starting the system, the system clock can be set automatically to the day and time of the SATNAV or to the day and time as put in by the operator. The connected positioning systems (Satnav, Omega, Decca) or any combination of these systems can all be read at the same time.

The SATNAV system is interrogated every 5 seconds and responds with either a DR-position or a position according to a passing satellite (Satfix position). The SATNAV system also gives additional information to the logging system, such as : time, water heading/speed (this is the vector sum of : current, wind drift, compass error, inaccuracy of Satfix positions, etc.) and track made good over the ground computed from log, gyro and mentioned water heading/speed.

The Omega receiver is interrogated every 20 seconds for its two hyperbolic lanes, after which a check on maximum possible position change takes place to detect lane slips. After application of the propagation corrections – interpolated from the corrections of the well-known correction tables – the hyperbolic coordinates are converted into geographic coordinates. Thus far, the corrections have to be put in manually for the appropriate period and area as stated in the tables. The position according to the Omega system is stored at the time of closest approach of a satellite. The difference between this stored Omega position and the resulting Satfix position at time of closest approach is applied to the next Omega positions, until a new difference is known. To avoid an incorrect Satfix position influencing the Omega position, the operator has the possibility of intervening in the described automatic process. The Omega readings are filtered to overcome the typical Omega noise problems. It should be clear that the Omega position is used for DR purposes only.

The Decca Mk-21 receiver is read every 5 seconds. Besides applying fixed and variable corrections, the software can compute the water heading and speed from the difference between the position derived from the log and gyro and the Decca position.

The water depth can be obtained from the EDO-Western deep-sea echo-sounder and/or from the Atlas Deso-10 shallow-water echo-sounder (0-280 m). In the data logging format, space has been reserved for two depths per second.

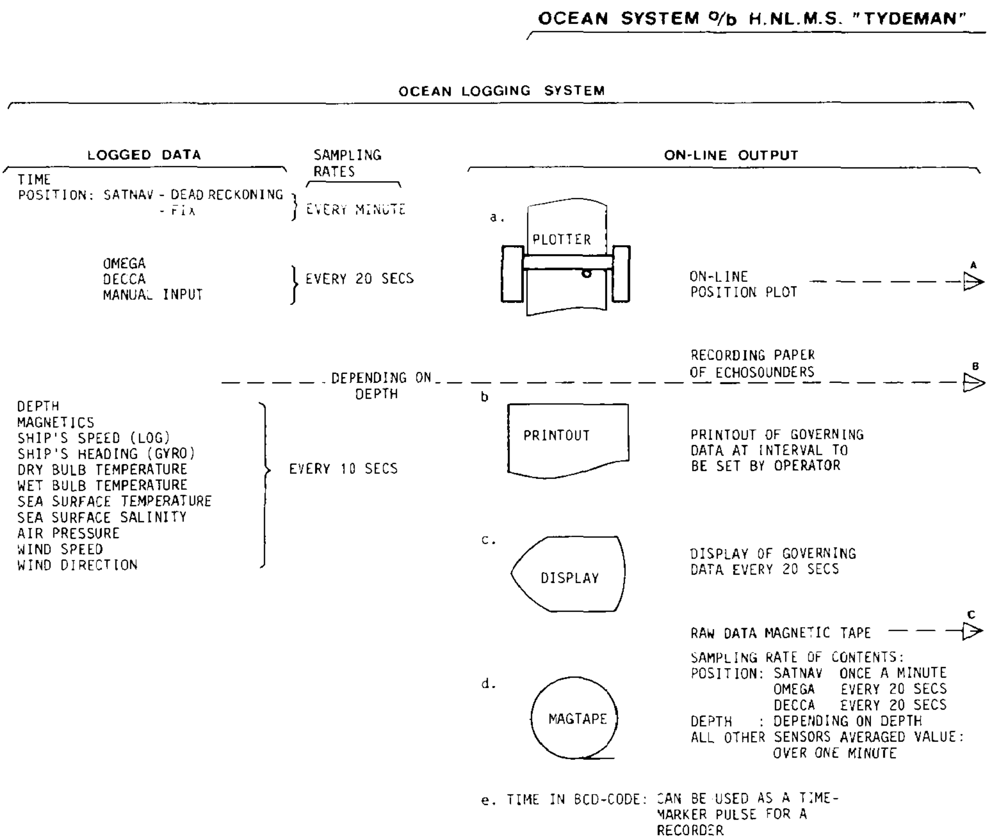

FIG. 4A. – Ocean logging system onboard *Tydeman*.

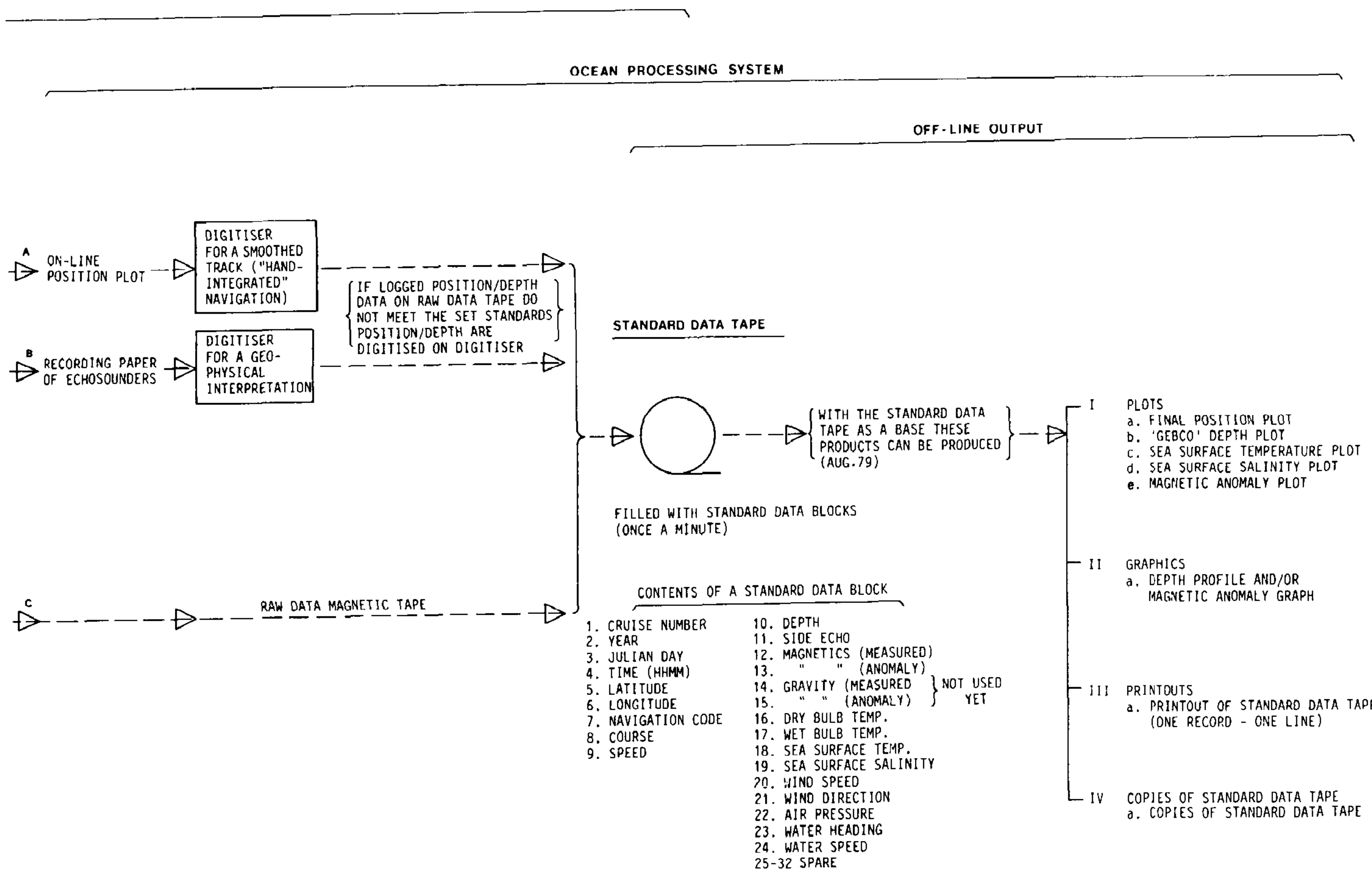

FIG. 4B. – Ocean processing system onboard *Tydeman*.

The field strength of the earth magnetic field is measured by a towed proton magnetometer, which is read every 10 seconds. After passing a quality control the value is taken into account when determining the averaged value over a minute, which is logged on magnetic tape.

All other connected sensors are treated in the same way by the system : reading every 10 seconds and after quality control logging of the average value on magnetic tape every minute. The above-mentioned other sensors are : log, gyro, propellor revolution counter, rudder angle meter, dry and wet bulb thermometers, barometer, sea surface thermometer, sea surface salinity meter, wind speed and direction meter.

Output

The governing data in the system, supplemented by some computed values like dewpoint and relative humidity, are displayed on the two display terminals (bridge and computer room) every 20 seconds. The display terminals are also used to display the results of the quality controls; e.g., in the case of a lane slip, the affected pattern is displayed blinking and an audio alarm is activated. The information on the display terminals can be copied on all or on a choice of the LA-36 DEC-writers. These copies can be generated at fixed intervals or at the operator's request.

The ship's position according to the connected positioning systems can be plotted on the two plotters (bridge and computer room) at an operator-adjustable interval. In practice, only the plotter on the bridge is used for this purpose (during a hydrographic survey the plotter from the computer-room is installed in the boat called the HYDRO-launch).

The plot charts – in Mercator projection – which can be drawn while the logging of data continues, have maximum dimensions of 160 × 50 centimetres but, through skewing the north direction, these dimensions can hardly be called a limitation. Also position input by hand, either in geographic or in hyperbolic coordinates, can be plotted.

The system time is shown on time displays in the computer room and in 4 laboratories. The time, in BCD code, is also available as an output from these time displays. These outputs are used rather frequently for time marking pulses on recorders not connected to the system. In this way the graphic information from the recorders can be incorporated – after being digitised in the "Ocean" processing system – in the automated collected data. Once a minute, all collected data is logged in a fixed format on a magnetic tape, known as the raw data tape. Apart from the mentioned print-out of the governing data, the output of the meteo-office consists of max. and min. measured wind speed during the past hour for usage in the synoptical observation. On request, the system prints an FM21E synoptical observation form, completed as far as possible. The missing data, e.g. cloud codes, are made known to the system in a conversational way, after which the system prints a fully completed code form – address heading included – ready for delivery to the radio room. For astronomical navigation, a program which substitutes the nautical almanac, tables and construction is incorporated in the system.

THE OCEAN PROCESSING SYSTEM

(see figure 5)

The second base system is expanded into the processing system with the under-mentioned extra peripherals :

- two interactive graphic display terminals, for interactive manipulating of data files :
  i) a Tektronix 4014/1 display terminal;
  ii) an HP 2648A display terminal with cassette in/output;
- two plotters :
  i) a Calcomp 502 flat-bed plotter (plot dimensions 70 × 80 cm, step size 0.1 mm);
  ii) a Houston DP-7 drum plotter (width 90 cm, step size 0.05 mm);
- a Tridata Cartrifile-4096 cartridge recorder for reading the magnetic tape cassettes of the HYDRAUT data logging system;
- a Ferranti Freescan digitiser (digitising area 90 × 120 cm, resolution 0.1 mm) for digitising graphic information (recorder rolls, etc.);
- a lineprinter (HP 2607A) - this is the lineprinter which can be connected either to the logging or to the processing system, by means of a switch.

An insight into the function and the capabilities of the processing system is given in describing the present working method.

The first step in the process is to create what is termed a standard data tape from the raw data tape of the logging system. A standard data tape contains in a fixed format from minute to minute the finally accepted values of the data below :

1. Cruise number
2. Year
3. Day of year
4. Time
5. Position (latitude)
6. Position (longitude)
7. Navigation code
8. Course
9. Speed
10. Depth
11. Side echo
12. Magnetic field strength (measured)
13. Magnetic field strength (anomaly)
14. Gravity (measured)
15. Gravity (anomaly)
16. Dry bulb temperature
17. Wet bulb temperature
18. Sea surface temperature
19. Sea surface salinity
20. True wind speed (m/sec)
21. True wind direction
22. Air pressure
23. Water heading
24. Water speed

25-32. Spare locations for possible future implements

The first version of a standard data tape is created after a quality control and data reduction process. In this process it is possible to enter the periods during which the data cannot be copied from the raw data tape. This is necessary as, for various reasons, some data needs human interpretation before it can be accepted as the final data.

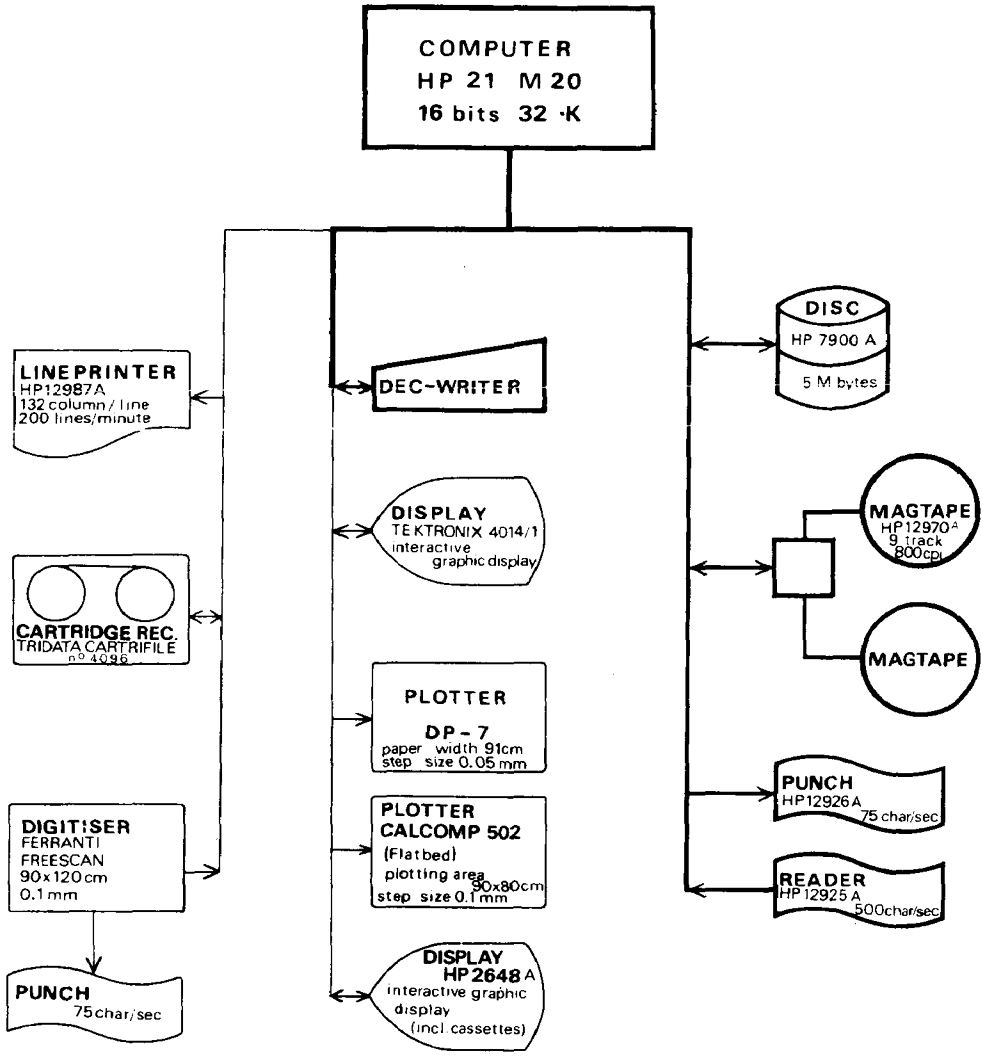

FIG. 5. – Data processing system.

Apart from the Decca positioning system, with some exceptions, none of the other positioning systems integrated in the logging system is suitable for automatic transferring of the logged position onto the standard data tape. Especially during drift stations, or on stations with many course/speed alterations, the DR-position according to the SATNAV system is far from acceptable. The most probable positions are determined and marked by hand on the on-line position plot at regular intervals (e.g. at the times of Satfix positions). The following information is used to determine these positions :

– the on-line position plot;
– the print-out of the SATNAV, which contains a.o. information about the accuracy of the Satfix positions;

- the recorder chart of the Omega receiver, to have an insight into the stability of the signals received;
- the print-out of an LA-36 DEC-writer containing the governing data of the Ocean logging system at fixed intervals.

These most probable positions are digitised with the digitiser and written into the time-corresponding standard data blocks.

The intermediate positions are interpolated with the log/gyro information and also written into the time-corresponding standard data blocks. This method, which can be described as hand-integrated navigation, has the advantage that it keeps the personnel involved and gives them job satisfaction which is getting scarce once the computer takes over many of the tasks. Of course, the time it takes to mark and digitise the positions, which is actually not too long, can be seen as a drawback.

Also, direct copying of deep-sea echo-sounder depths from the raw data tape to the standard data tape is an exception. Notwithstanding a quality control system, which sees to it that an echo signal is inside a window and above a threshold before it is being digitised, there is so much dropout, that depths of this on-line digitiser are too unreliable to be copied directly. In practice, only digitised soundings from a flat bottom during calm sea conditions can be copied.

Due to a beam width of 35 degrees of the deep-sea echo-sounder, the first echo signal is quite often the echo of a nearby sea hill instead of the seafloor echo directly beneath the ship. Thus, the requirement not to chart the first incoming echo, but to chart a more geophysical interpretation, makes the depths from the on-line digitiser also unsuitable for direct copying to the standard data tape. However, as all echo signals received are registered on the recorder paper, together with the fix marks generated by the logging system, the echograph can be hand digitised on the Ferranti digitiser. The standard data tape is filled with two kinds of depths resulting from this geophysical hand interpretation ('depth' is depth beneath the ship – a 'side echo' is the registered depth of a nearby sea hill).

The field strength of the earth magnetic reference field, which is both time and position dependent, can be computed when the final position is on the standard data tape. Next, the difference with the measured value is computed and written into the standard data block as magnetic anomaly. In practice, all other data can be copied directly from the raw data tape.

Due to the nature of the expeditions, no practice has been gained so far in processing gravity data.

Once the standard data tape is made up, the following products can be made :

I. Plots in Mercator projection :

a) Final position plot;
b) 'Gebco' depth plot;
c) Sea surface temperature plot;
d) Sea surface salinity plot;
e) Magnetic anomaly plot.

II. Graphs :

a) Depth profile and/or magnetic anomaly graph.

III. Print-outs :

a) Print-out of standard data tape (one record-one line).

IV. Magnetic tapes :

a) Copies of standard data tape.

If made known in advance, requests for new forms of presentation can be realised.

In the processing system there is also software for :

- The processing of Hydraut data into a fairsheet. Not only the ship, but one of her launches is also equipped with a HYDRAUT system.
- The automated processing of radio-sonde data. The radio-sondes used by H.Nl.M.S. *Tydeman* transmit, apart from the usual temperature, humidity and air pressure information, the phase-difference of a small built-in Omega receiver (termed the LOCATE system). The temperature, humidity and air pressure data are processed into a temperature and humidity diagram, while the altitude winds are computed from the Omega data.
- Geodetic computations which have to be performed frequently.
- Plotting of a sound ray path diagram after input of temperature/depth data.
- Plotting of charts, with hyperbolic lattices, in either Mercator or UTM projection.

Documentation

The software packages of both the logging and the processing system are continuously subject to changes and expansions both as originated by the wishes of scientific institutes participating, and in the strive to utilize the possibilities of the systems to a maximum. All program documentation is stored in files on disk. In this way, changes in the documentation can be made rather easily and a complete updated documentation print-out can be made by just one command. A similar procedure is available for the flow-charts, where the changes to the file are made by an interactive drawing system, which is owned by the firm who installed both systems. The changes in the software are mostly initiated and performed by the ship; however, the Hydrographer of the Navy takes the final responsibility. All programs are documented in the English language both for software exchange purposes and for facility, when embarking foreign personnel.

Operation

With an operator's manual, newly posted officers can handle the operating system and the program packages of the logging and the processing system after a 10-hour introduction. The logging system can be operated from each terminal except from those installed in the labs. The lab terminals were deliberately kept separate (hardware) from control in order to eliminate possible unauthorized commands to the system. However, on request, a selectable lab-terminal can be connected to control the system again. In practice, the officer on duty controls/operates the system from the bridge terminals. By giving all commands to the system on the LA-36 writer on the bridge, a kind of system logbook is created on this printer. The Met-personnel operate their application programs either from the met-office terminal or from the terminal in Lab-V (where the XBT-recorder has been installed).

Hardware

The choice of the hardware has been made after an extensive investigation of the market. Experiences of foreign oceanographic institutes weighed heavily in this process. The hardware, which did not necessarily need to meet military specifications, consists of off the shelf instruments. The firm van Rietschoten & Houwens, (Applied Dynamics Europe) arranged the components into a system. They were also responsible for the first version of the logging software package. After the warranty period, a maintenance contract was granted to this same firm. This contract also includes components added to the system configuration (such as plotter and digitiser) by the Royal Netherlands Navy.

Experience

There are plenty of beautiful system descriptions but what about the working of these systems in practice ? The answer to this important question is, in short : 'it works – extremely well'. The hardware performance is most satisfactory ; however, as the system consists of many components, there do happen to be defects, though at sea the system has always been serviceable (until now!). The really important components : computer, disk and magnetic tape drives, have had no major breakdowns and, in the case of a printer or puncher breakdown, the exchange of components, changes to the software, or priority setting, have made the inconvenience bearable. Onboard repairs consist of exchanging printing circuit boards (pcb) only (in principle).

Apart from a spare computer and disk drive, the onboard spare parts package consists of a space interface pcb for the most commonly used interfaces, some switches, and fuses, etc. Not only the hardware, but also the software, satisfies in practice. It will be clear that direct contact with the user (programmer/user stationed onboard), the ease of modifiying tasks – thanks to the operating system – and the use of a high level language (FORTRAN IV) have had their direct influence on this.

Administrative use of the system

The capacity of both the hardware and the operating system permits the systems to be used also for purposes not included in their specific task.

The EDITOR program is a system program, supplied by the computer manufacturer, which creates disk files from text typed in and gives the operator the possibility of altering these texts and manipulating text blocks. The program is used to store lists and rolls which are liable to frequent changes (e.g. crew lists) on disk. After correcting the files for mutations, an up-to-date printout of a roll/list can easily be made. In a similar way the EDITOR program is used for internal reports, daily orders, etc. Another example of administrative use : the ship's periodic maintenance scheme has been fed into the system. A dedicated program lists – for a chosen day or period – the apparatus that needs maintenance, together with particulars such as the number of personnel, the time and the special test equipment involved .

Is automation cost effective ?

This is a question which arises when one sees the cost of acquiring the system and the yearly maintenance costs.

Let us deal with this question step by step.

a) Logging :

Position : The system gives a good position from minute to minute without too many man-hours. An alternative hand plotting of positions read from the instruments would take lots of man-hours and would not give such accurate results at such frequent intervals. Besides that : who would draw all the plotting sheets, especially the sheets with the hyperbolic lattices on them ?

Magnetic data : The time it takes the computer to compute the value of the magnetic reference field is negligible. The alternative to compute the magnetic reference field value from the tables would be very time-consuming.

Depth data : As prescribed above, depths are not automatically digitised, but hand digitised. Using the digitiser to read and store, the echo-graph gives in general more depth information which is also more accurate than depths retrieved from the echo-graph when using a recorder scale template.

Meteorological data : The meteorological data is logged at about the same frequency and accuracy it is recorded on a normal multichannel recorder. However, the use of the partially filled FM21E synoptical observation codeform saves 10-15 minutes per observation, compared with the old fashioned way. Synoptical observations are taken at hourly intervals. The system is also used to process the radio-sonde data. Hand input of data, computing and printing of the processed altitude wind, temperature, pressure and humidity data takes altogether 15 minutes per radio-sonde observation. To determine the altitude winds from the Omega readings of the radio-sonde by hand would be very time-consuming, while drawing the temperature and humidity diagrams in the conventional way takes a skilled person about one hour.

On-line output : The time mark pulses provide an easy time reference between recorder data and (e.g.) position data.

The display and the printout of the governing data on the bridge and in the labs save a lot of time otherwise spent on informative communication and administration.

The on-line position plot provides an easy way of keeping an eye on the position accuracy and has proved to be very handy for retracing drift buoys, etc.

b) Processing :

Although it takes time and administration to create the standard data tape, once this tape is ready, (graphic) products can be made with very little effort on any scale. This capability is really time-saving and the more plots/products are to be made, the greater the saving.

c) Exchange :

Magnetic tape is a good data carrier. It not only saves a lot of storage space, but it is the most economic way of supplying the collected data to data banks and institutes, as they have the great advantage of easy access to the data.

d) Personnel involved with automation onboard :

The officer in charge of automation spends about 50-75% of his time on automation (the rest of his time is spent on normal ship work like bridge duty). Routine work like controlling/operating the systems is carried out by deck officers. Beyond the 10 hours' on-the-job introduction, this does not require any knowledge of automation. A chief petty officer takes care of the preventive and corrective maintenance of the hardware. He spends about 50% of his time on the system's hardware (including the connected sensors). As H.Nl.M.S. *Tydeman*, which introduced a new kind of expedition to the Royal Netherlands Navy, had never sailed without automation, it is difficult to have exact figures on man-hour savings (if any). However, we estimate that we save 8 man-hours a day with respect to the making of the conventional product such as final position plot, GEBCO sheet, bottom profiles, etc. In addition to this, 5 man-hours are saved by the meteorological personnel.

e) Exploitation costs of the Ocean system :

Our rule of thumb for exploitation costs (write-off and maintenance costs) is :

- write off in 10 years;
- maintenance contracts of 10% of hardware price per year.

Whether the above mentioned items : more information, more accurate information, more easily accessible information, and the small man-hour saving, are worth this money is a decision one has to evaluate for each application. With respect to our Ocean system, we think they are.

Modifications to peripherals

a) The Houston DP-3 plotter :

1) As the Rotring pens which are obtainable from our Navy stores do not fit into the standard pen-holders, we use home-made pen-holders in both the DP-3 and DP-7 plotters.
2) To improve the view on the plot paper the metal bar was replaced by a perspex one.
3) The bridge DP-3 plotter is equipped with a roll-chart adapter to facilitate plotting on mylar rolls.

b) The HP-2690A display terminal on the bridge:

1. As the brightness of the display proved to be an inconvenience during the periods of darkness, an adjustable control for brightness was built in.

c) The Atlas Deso-10 echo-sounder and the EDIG-10 digitiser:

1. To overcome false echoes of air bubbles at short range, a special suppressor, adjustable up to a range of 5 metres below the keel, has been installed, similar to the sea clutter control in a radar set.
2) During the periods of darkness the brightness of the digitiser front panel proved to be an inconvenience, so an adjustable control for brightness was built in.

d) The EDO Western deep-sea echo-sounder:

1) The recorder-unit is rather noisy and has a lot of controls. A perspex screen has been installed to bring down this noise level and to guard against accidental operation of knobs and switches. Incidentally, we decided to mark the fix-mark lines on the echo-gram with a specially designed stamp in order to have the necessary administration in a fixed format and to minimize the chances of the operator forgetting to annotate the echogram with essential information.

Electrical, mechanical and climatological provisions

As mentioned before, the installed equipment did not need to meet military specifications, but to make the environment more acceptable for the off-the-shelf systems, we made some provisions:

Electrical:

All equipment needs 115 volts/60 cps voltage power supply. To prevent malfunctions due to possible fluctuations of the ship's power supply, a rotating converter (Piller) with a big fly-wheel has been installed. This converter, consisting of a three-phase asynchronous motor (25 kW, cos at 0.78, 1,800 rpm) and a three-phase synchronous bruhless generator (20 KVA, cos at 0.8) keeps the voltage constant within ± 2 %.

The fly-wheel guarantees at least 1,770 rpm if, at maximum power demand, the ship's power supply is shut off for about 0.5 sec. To prevent disk damage during a power failure, the disk drives have a 24 V battery pack to withdraw the read/write disk heads under these circumstances. The ship's 24 V DC is connected to the disk drives in the event of a power failure lasting longer than 2 hours.

Mechanical

All computer peripherals – except the plotter, the Ferranti digitiser and the time displays – have shock absorbers installed to prevent possible problems due to vibrations (e.g. due to slamming or engine vibrations).

Climatological

Besides the ship's air conditioning, two extra cooling units have been installed in the computer room to compensate for the heat dissipated by the systems. The 19-inch cabinets are installed on top of a casing with forced ventilation. The carrying off of the air is via the top of the cabinets.

Time schedule

In a review of the progression from nothing at all to a fully operational system, the following dates ought to be remembered :

- September 1974 - March 1975 : Orientation and writing of specifications.
- March - July 1975 : Discussions and negotiations with various firms. This resulted in the order being placed with van Rietschoten & Houwens (Applied Dynamics Europe) in July 1975.
- July - October 1975 : Design of the system.
- December 1975 : Installation of the two base systems at Applied Dynamics Europe in Rotterdam.
- December 1975 - July 1976 : Familiarization with the operating systems and development of logging software.
- July - September 1976 : Installation of the systems onboard H.Nl.M.S. *Tydeman*.
- September - November 1976 : Installation of last peripherals such as digitiser and plotter.
- September 1976 - May 1977 : Development, debugging of software and modification of software to operational requirements.
- September 1976 - February 1977 : Hardware trouble shooting.
- July 1977 : Both hardware and logging software fully operational.
- November 1977 : Documentation of both hardware and software completed.

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NAVIGATION

The practice of marine navigation, i.e., the determination of one's geographic position on the water, in the Arctic regions is impaired by several factors. Because of the remoteness and limited marine activity in these regions the waters are relatively poorly charted and coverage by either traditional or modern electronic aids to navigation is limited. The low relief and featureless terrain characteristic of much of the Arctic coastline hinders navigation by traditional radar and visual means. Moreover, application of visual piloting methods as well as celestial navigation is limited by the inhospitable Arctic weather. High latitudes also place restrictions on use of magnetic and gyrocompasses and on celestial navigation. Navigational light and buoy systems, the heart of navigation systems in restricted waters in temperate regions, are precluded, or at least limited, by the ice and environment of the Arctic. In short, the utility of traditional navigational methods in both restricted and open waters is significantly diminished in the Arctic.

To overcome these limitations on conventional methods, current Arctic marine traffic relies upon satellite navigation, Omega, and installed shore aid systems, such as the system of Racons along the Alaskan North Slope, to supplement traditional navigational methods. Only satellite navigation provides coverage throughout the Arctic. As Arctic marine commerce expands, accurate and reliable marine navigation over larger portions of the Arctic will become critical. Consequently, the limited navigational capability in the Arctic will require upgrading to assure safe navigation. Existing systems (e.g., the Alaskan Racon System) may require expansion. Increased use of satellite navigation and possible expansion of LORAN-C coverage will likely provide adequate navigation coverage to open water areas. The continued movement of tug and barge traffic along near-shore open water passages and the future emergence of deep draft surface or submarine Arctic carriers will place a premium on accurate and comprehensive bottom sounding information. Most of the existing hydrography in Alaskan waters north of the Aleutian Islands does not meet National Ocean Survey spacing criteria. Similarly, the quality of bottom profiling in the Canadian Arctic is generally far below that in temperate regions. The known presence of significant and relatively abrupt rises in the bottom of normally deep Arctic channels further emphasizes the need for good sounding information.

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