AUTOMATION OF HYDROGRAPHIC SURVEYING [1][2]

by Commander J. M. MACKAY, R. N.
Hydrographic Department, British Admiralty

This paper was first presented at the Conference of Commonwealth Survey Officers held in Cambridge, in August 1971, and is here reproduced by kind permission of the Directorate of Overseas Surveys, Overseas Development Administration, in the United Kingdom.

INTRODUCTION

1. The purpose of this paper is to consider the gains which may be achieved by the automation of hydrographic surveying; to describe two British systems in general terms, chiefly related to the instrumentation and field trials, together with the difficulties overcome by ourselves and the contractors in their development; and to have a brief speculative look at the future of automated sonar surveying.

2. Computers are very much in fashion. The achievements which they make possible have been dreamt of by many surveyors for many years as they laboured over their calculations, but they also have very basic limitations. As so often happens the facilities we seek are not entirely vouchsafed to us, but at the same time the new capabilities which result offer some unexpected benefits.

3. The advantages of computers are that they are wonderful work horses which can handle a large volume of data with accuracy and incredible speed. Since the modern tendency is towards the gathering of far more information this is most valuable, and indeed the older manual methods could not meet the requirements of physical oceanography and marine geophysics. This speed and work capacity also mean that calculations and analysis can be far more thorough. Whereas before it was absolutely necessary for the hydrographic surveyor at sea to leave out some of the less important terms in formulae, and to restrict accuracy to the lowest acceptable for the task in hand, it is now possible to aim at the very best results. Computers are also excellent time keepers and can read many sensors simultaneously which is a distinct gain in accuracy of itself, but also means that deductions such as a ship's or a craft's speed can be far more precise. They can control

very accurate automatic plotters so that theoretically a survey can be drawn without any human agency apart from the input of the necessary data. They can also control the movement of a ship or craft along predetermined lines of sounding, with the crew merely choosing the next line and watching. In theory they save manpower, and certainly they can remove much of the drudgery from the task of the hydrographic surveyor (at the possible price of involving him in a change in the professional abilities he has to master).

4. On the other hand computers are of course completely mindless. Modern wonder at them tends to gloss over this and much emphasis is given to the chess playing types of activity which they can be programmed to perform. This may stem from the fears from staff, or the hopes of management, that people can be ' replaced by a computer '. In fact the smallest child has a greater capacity for judgement than one of these machines, despite the fact that a chair in ' Machine Intelligence ' has now been established at Edinburgh University. A computer fitted with the peripheral capability of ' optical character recognition ' can recognize hand written numbers singly, but if presented with a shape such as a cup, it takes several minutes to establish its identity. It would find the greatest difficulty in assessing all the factors which lead to correct decisions in surveying, and when one tries to guide it, which can be successfully achieved, it is surprising how many tedious instructions are required for activities which an ordinary operator takes naturally in his stride. The human eye backed by normal intelligence and commonsense is at present irreplaceable.

5. It should also be stated that computers are expensive, although prices are being reduced, and that there are few known cases of manpower saving at sea resulting from their installation. A great advantage is that, for a given manning complement, they give the surveyor new capabilities.

6. I would like to introduce the idea that the chief benefits which a user should seek from computers should be that surveyors are thereby enabled to perform wider tasks, to produce better quality work and to present it in a form compatible with further computer processing. Any thought of prestige, or joy in change for change's sake, can lead to great, and expensive, difficulties.

7. All survey organizations are worked to a budget. Those in charge need to decide whether their purposes are best served by expenditure on computer systems giving an improved capacity to handle the information produced by existing equipment, or by purchasing better basic equipment giving more accurate results which can be handled in the old way. It may be possible, of course, for some officers to revolutionize both their basic instrumentation and data handling methods simultaneously, but the expense would be considerable.

MARCONI ELLIOTT HYDROPLOT SYSTEM [3] [4] [5]

8. In the R. N. Hydrographic Surveying Service a data logging and computer system became necessary for handling the information produced by the Ocean Survey Ships since the accuracies required and the volume of work could not be dealt with by manual methods. It was thought in the early days that a small desk type computer would suit the requirement but it was found eventually that a fairly large system was necessary. The chief problems requiring solution were that the results from the gravity analysis were inaccurate due to inability to apply the corrections properly, because the ship's speed could not be deduced sufficiently accurately using weak navigation systems. The readings were not accurately synchronized and any fluctuating errors in the system could not be eliminated. The volume of data acquired by an ocean survey ship continuously recording gravity, magnetics and bathymetry for 24 hours per day could not be recorded to the high standards which had formerly been expected.

9. Figure 1 shows the system designed by Messrs. Elliotts (now Marconi Space and Defence Systems). On the left are listed the instruments which the computer reads at precise time intervals of which the most important are the navigation systems and the gravimeter ouputs. It will be seen that several navigation systems can be used. It is here that one of the first unexpected benefits becomes apparent in that it is almost as simple for a computer to read two navsystems as one, to a high degree of accuracy, and thus one can be used to continuously check the other, which would have meant the continuous employment of an extra watchkeeper if manual methods were used. These outputs are called NAV 1 and NAV 2. If the

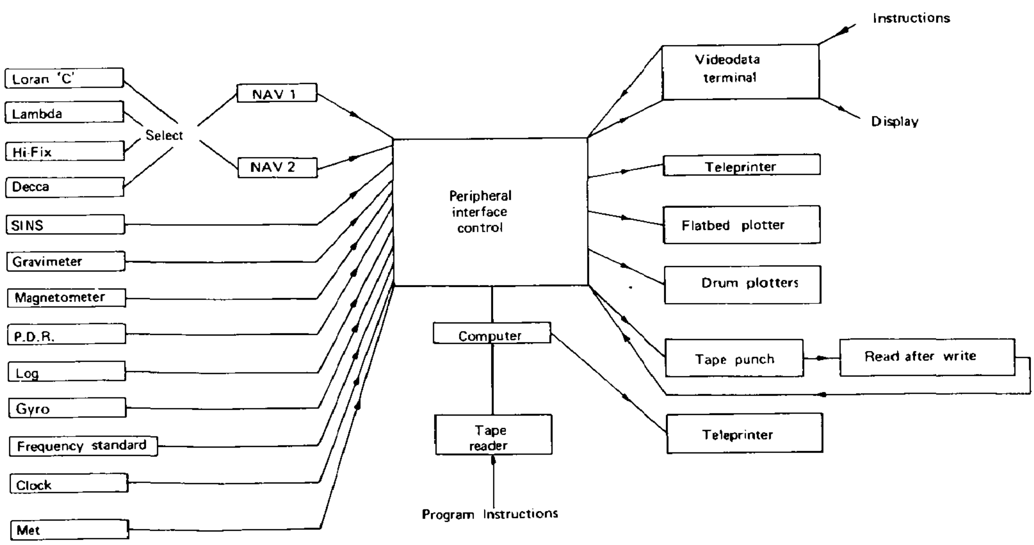

FIG. 1. — Hydroplot System.

readings become suspect for any reason, or if the divergence between them exceeds a specified limit, then an alarm is indicated for the benefit of the surveyor. The computer calculates the grid and geographical coordinates of each fix, and the ship's speed since the last fix for calculation of the gravity corrections. The results are output by several means including a visual (television type) display, a teleprinter, punch tape and a drum plotter. The latter is valuable for monitoring the performance of the navsystems since any errors are immediately apparent.

10. The gravimeter and magnetometer readings are also taken and the corrections are applied to the former. This corrected reading is output five minutes after the observation (due to the electrical damping in the gravimeter electronics) and is very much faster, and more accurate, than was possible by hand.

11. The depth from the Precision Depth Recorder is digitised at each fix and the single deepest and shoalest soundings between are recorded. The method chosen was less refined than the best solution and the results at first were correspondingly disappointing. The factors involved in digitising echo soundings are discussed further below.

12. The occasion of installing a data logging and computing system was used to record meteorological information and to calculate true wind speed and direction at fixed time intervals. The Hydrographic Department is not a research organization and, in retrospect, the inclusion of sensors which were not essential to the task might be considered as an unnecessary diversion. This is not to say that more scientifically orientated operators might not find this capability valuable.

13. The Ocean Survey Ships also carry a satellite navigation system and will be fitted with a Ships Inertial Navigation System (SINS) in due course. These require additional independent computers which are not within the scope of this paper but consideration of data links between computers might well be worthwhile for some users.

14. The taped outputs of the system are forwarded ashore to form a computer compatible record of the survey from which charts can be automatically drawn at the Hydrographic Office, either immediately on receipt, or for 'banking' until later when further information becomes available.

15. Generally speaking the system is well adaptable to the very precise requirements of the Hydrographic Surveyor, after the difficulties described below are overcome.

SURVEY HOVERCRAFT SYSTEM [6]

16. This system is essentially for use in Coastal rather than Ocean Surveys. It was devised by the initiative of Messrs. Decca and Hovermarine to take advantage of the recent advances in the technologies of high speed craft and data logging. A block diagram of the system is shown in figure 2.

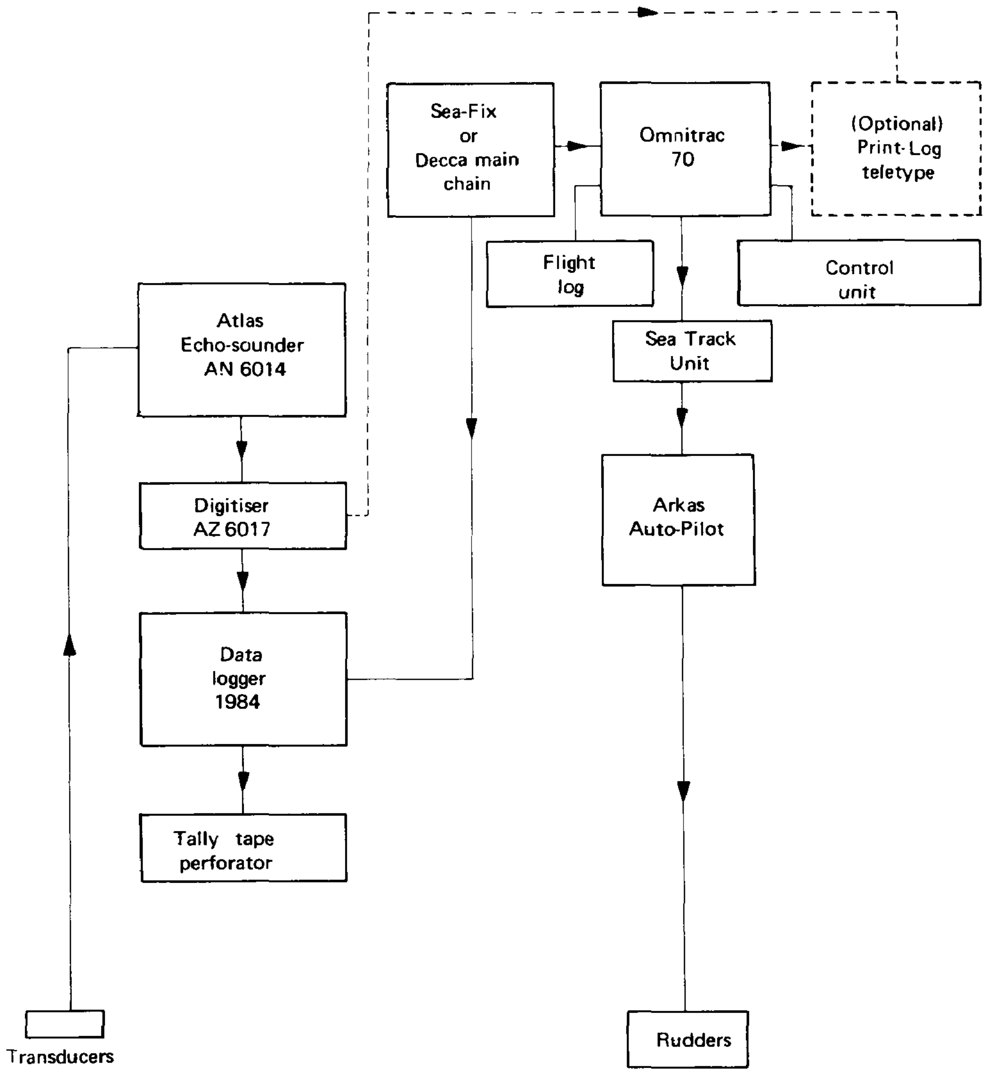

FIG. 2. — Decca Surveymarine System.

17. The sensors logged are, for navigation, Hi-Fix and Sea-Fix, and for sounding either a Kelvin Hughes or an Atlas echo sounder. For actual survey purposes the readings are simply logged and stored on paper tape,

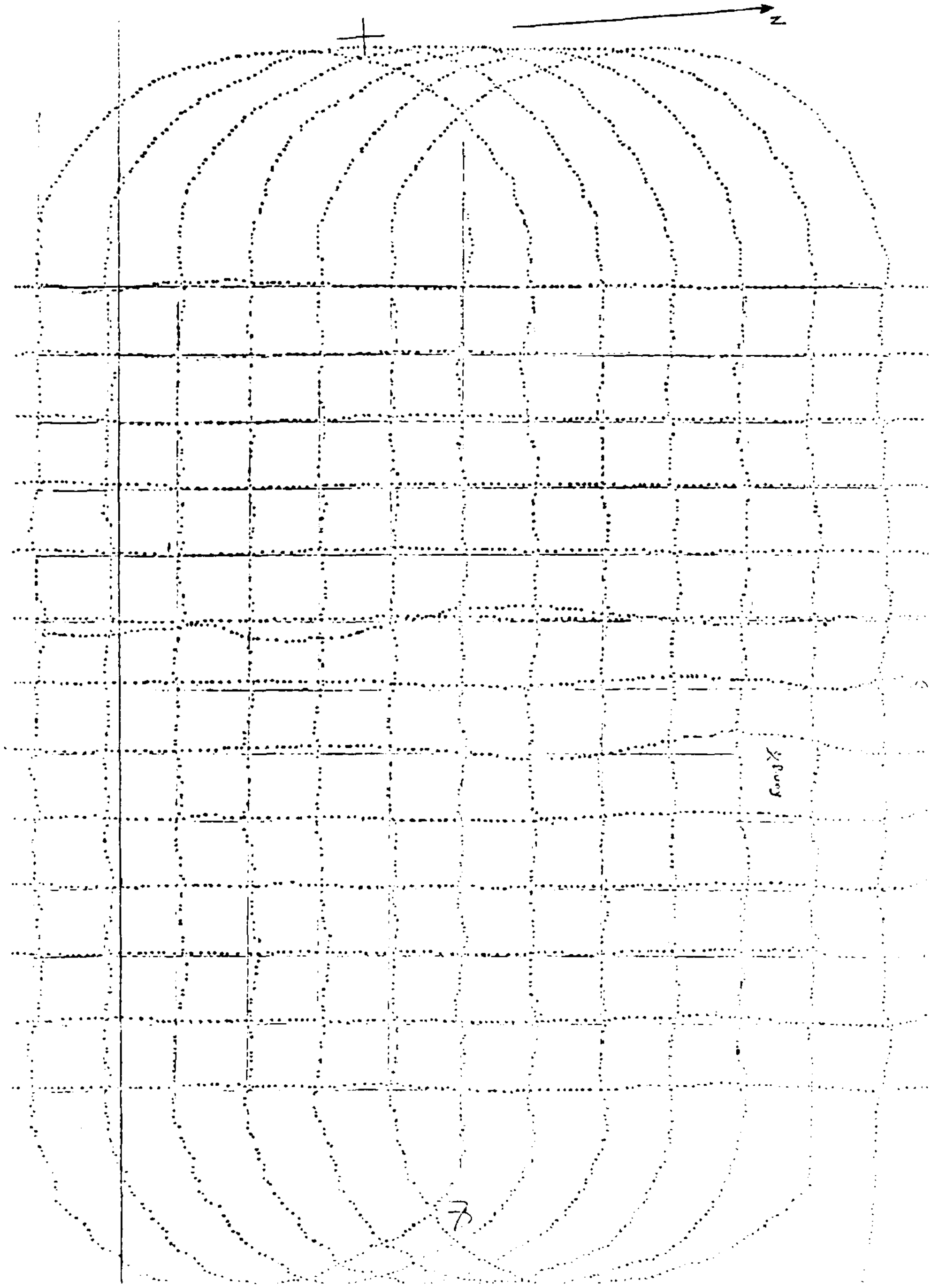

FIG. 3. — Automatic control of sounding.

but for the control of the craft there is a separate control computer which guides the craft along selected lines of sounding with great accuracy. An example of the type of work which can be done is shown in figure 3 where the dots mark position at approximately one second intervals. This useful advance in surveying is achieved by choosing the orientation of the lines of sounding and setting up a skewed ' flat earth ' grid using the bearing as an axis. One coordinate thus corresponds to the craft's deviation from the track and the other its distance along it. Depending on the size of the displacement from the track so a larger or smaller amount of corrective helm is applied. As can be seen the maintenance of the track is very good. The craft is turned when the other coordinate reaches a predetermined value. The operator has by this time selected the next line from which a radius of curvature of the turn from the mid point can be deduced. Depending on whether the craft is inside or outside this curve so the helm is either eased or more firmly applied. This control system is most efficient particularly when it is borne in mind that the craft is travelling at 30 knots. It has the advantage that the incidence of abortive lines is practically nil and that manpower is released.

18. The method of providing the basic survey information to the system is logical and precise; the inputs and corrections can be monitored; the high rate of data logging every fifth of a second is very valuable for high speed surveying and research work, and much experience has been gained in the complex system of shore analysis.

19. The above brief descriptions, which can be followed up in the references, are given to provide background information for a discussion of the special requirements and difficulties involved in the automation of hydrographic surveying.

SPECIAL REQUIREMENT FOR AUTOMATED SURVEYING NAVIGATION SYSTEMS

20. Before a surveyor starts work he naturally goes to great lengths to ensure that the data supplied by his instruments are correct. If a data logging system is ' interfaced ', or connected, to a navigation fixing system it has no means of knowing whether the readings are correct or not, and erroneous figures may appear on the punched tape to the confusion of staff ashore. To indicate the state of the navsystems we use four notations :

- U Unvalid. The equipment is operating correctly (therefore not ' invalid ') but is not lined up to its correct lane number or zone;
- V Valid. The equipment is lined up and in a reliable state for use;
- F Failed. The manufacturer's alarm signal has been activated (due to weak signal strength or some other specified cause) and the set cannot be used;
- S Suspect. The comparison between NAV 1 and NAV 2 indicates that there is an error.

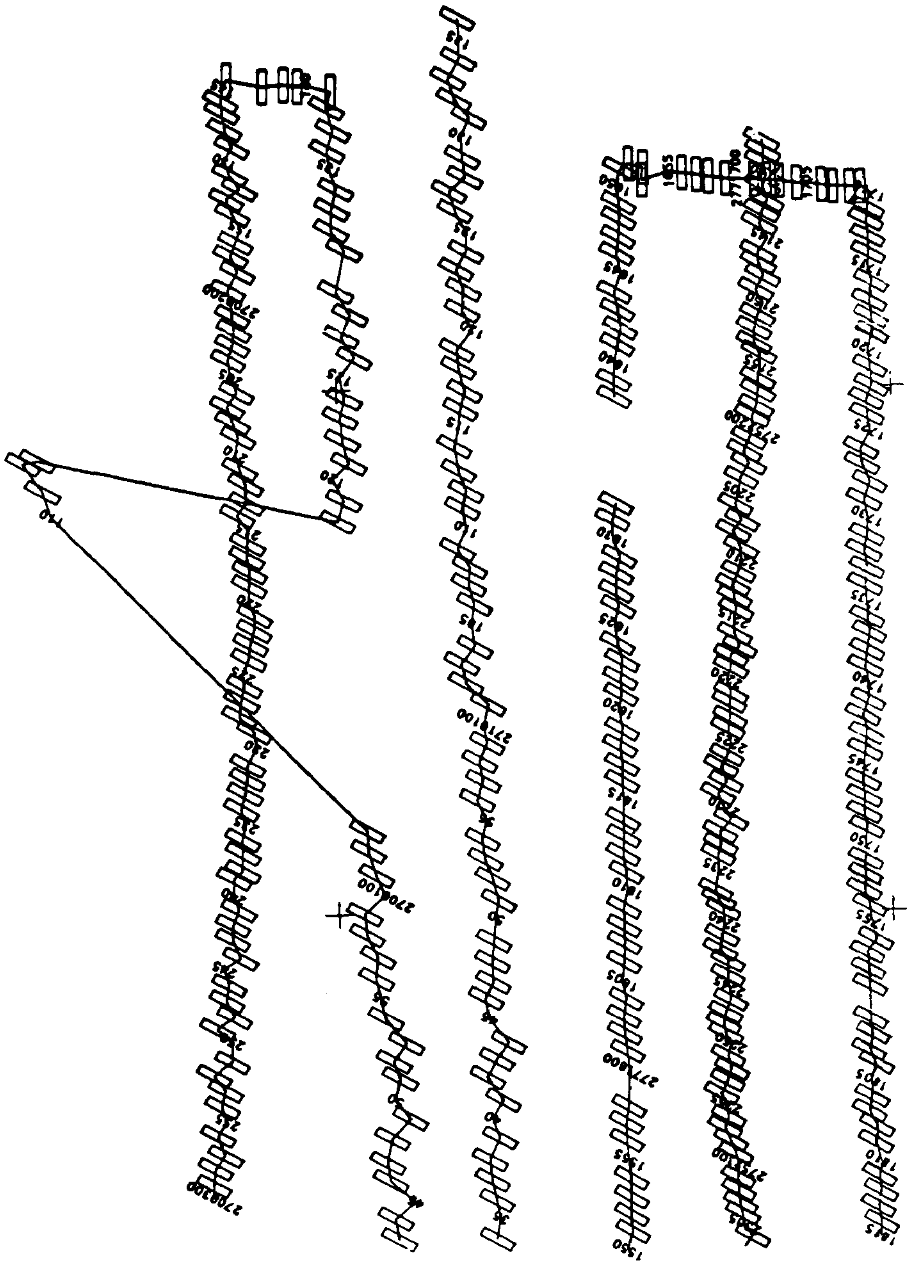

FIG. 4. — Hydroplot. Automatic track and parameter plot showing variation between day and night fixing and a line slip.

The use to which the navsystem can be appropriately put depends on the notation. Calculations are not based on ' Unvalid ' or ' Failed ' navsystems. If the operator decides that NAV 1 is ' Unvalid ', perhaps from multiple lane slips, and changes the notation, or if the alarm sounds to indicate ' Failed ' then the calculations are transferred to NAV 2. If this in turn fails then there is a facility to continue logging by DR.

21. Having guided the computer to this extent it is essential to ensure that it takes the correct readings at its set time intervals. The dial indicators on many navsystems do not always revolve with uniform regularity and the human operator will always ensure that readings are not taken while a dial is flickering. The computer can make no such judgement and it is therefore necessary to employ a system of ' smoothing ' to eliminate these effects by either averaging a short series of readings or else establishing a pattern within a short series from which random ' spikes ' can be eliminated. This has been called short term or ' initial smoothing '. In addition to the random ' spikes ', there are systematic pattern shifts which fluctuate at a time frequency usually measurable in minutes. These have to be eliminated either by mathematical filters or by some other means [7]. Hydrographer has recently commissioned a special study of this difficult problem by the Navy's Director of Weapons (Navigation), assisted by a consultant hydrographic surveyor, and their report is expected shortly. If the long term and short term smoothing operate correctly then the ship's speed can be calculated and the corrections to the gravity readings will be valid.

22. To provide basic information for this research the ADL (automatic data logging) and computer system was programmed to take a rapid (1 second) series of navsystem readings. When plotted out over a short period these show the spikes and fluctuations of the readings very clearly. Over a longer period they indicate that a survey ship's track may not always coincide with the points joined by a straight line, which is assumed under manual methods to be the case (see figure 4). The hovercraft survey system with its automatic controls is also of interest because continuous alterations of course at such small intervals lead to a curved track rather than a series of ' dog legs ' at intervals corresponding to the frequency of the fix. The new advances help to solve problems and also provide some insight into the basic assumptions made in the past.

ECHO SOUNDING

23. The problems involved in the use of computers to read echo soundings are more complex because the behaviour of acoustic waves in water is more erratic than that of radio waves in the atmosphere and, whereas a ship's movement may be assumed to conform to steady patterns of a sort, the irregularities of the seabed are completely haphazard. It is not permissible to average out a series of deep and shallow readings for recording on a chart,

because some ship will find the shallow one. Nor is it acceptable to deduce the pattern of seabed characteristics from which ' spikes ' may be eliminated, because it is precisely these ' spikes ' which the hydrographic surveyor is commissioned to find, measure and fix.

24. To make a correct representation of the seabed on paper it is not adequate to simply record the soundings at fixed time intervals since many peaks and troughs would thereby be missed which would falsify the contours. The human eye can, with experience, decide which sounding should occupy each position on paper even though the spacing may not be mathematically correct. It would be a complex computer program which could resolve the three considerations of time, depth and position to the accuracy required. A possible solution is the use of line following equipment whereby the soundings on the echo sounding trace can be selected for digitisation by a trained operator. One then, however, becomes dependent on the accuracy of the line following equipment. The pursuit of accuracy can indeed go further and it may be the case that an echo sounding depth based on electronic time measurements is more accurate than one based on the rotating stylus arm of conventional echo sounders.

25. One of the difficulties of trusting digitising echo sounders is that they can make errors of varying magnitude. If the error is very large it can be eliminated; if it is very small it is insignificant, but if it is of medium size there is no way of finding out whether it is a real feature or not without referring to the E/S trace. A valuable feature on the traces of digitised echo sounders is a notation either by a tick mark or a white line which indicates that a sounding has been digitised and transferred to the tape record. Unfortunately these marks can themselves be false, leading one to believe that the records are correct when in fact they are not.

26. In this uncertain situation the present Departmental policy is to carry out trials but in the meantime to continue using the trusted method of reading from the E/S trace. It is felt that the importance of correct soundings is so great that time spent on them is not wasted.

27. For some users this may not be a satisfactory solution since they are working in areas which are surveyed regularly so that the risk of unexpected dangers is statistically remote. Users concerned with conservancy of natural resources will not have to worry about the risks involved with large ships manoeuvring with small under keel clearances, and may likewise find the digitising of soundings an attractive proposition. Very often, too, the necessity to save manpower may be a vital consideration.

TRIALS [8]

28. For those who have to work to strict margins of accuracy, manpower or finance it is possible to devise suitable trials for comparing automated with manual surveys. Although not too well provided with manpower or finance the aims of the trials carried out were firstly to establish accuracy.

29. Starting with the basic instrumentation it is necessary to establish whether the attachment of extra electronic equipment to them in any way detracts from their accuracy. It is possible to imagine that electrical circuits could be upset by the additional wiring but neither with the Hydroplot nor Decca systems has this occurred. This has been called a 'compatibility' trial. This has usually been followed by an 'accuracy' trial to ensure that, not only are readings correct at a single spot but also throughout the full scale deflection of each instrument. In the case of navsystems, readings were taken every tenth of a 'lane'. These never showed any systematic deviation over the full cycle. To establish greater confidence a 'running' test is necessary since this should show that the system works under action conditions. At first, in the case of the hovercraft/Decca system, it was thought that a comparison could be carried out on a surveyed sounding 'range' on the line of a transit. The transit line and a space to left and right were sounded by the well trusted conventional means and the hovercraft was run along the same line. This produced an anomalous result because there were two different factors namely the different E/S frequency and the variability of the hovercraft transducer depth with speed. The trials were therefore shifted to the largest dry dock in U.K. at Southampton where a cinecamera was set up on a levelled line of sight over the dock sill where depths could be measured on a tide-gauge. By erecting a levelling staff on the craft it was possible to calculate the change of depth of the transducer under various hovering conditions. Unfortunately the echo sounder was not working that day which would have provided a valuable check since the variation in depth reading over the sill would have given the same information by an independent method. Valuable information would also have been obtained on the difference between the physical and apparent acoustic/electronic origin of echo sounding transmissions. It was found from these trials that, with an HM2 Hovercraft, the variations in depth for a set 'lift' r.p.m. were never more than about 10 inches, and that they could be forecast to an accuracy of about 2 inches. By comparison it has since been found that the variation of squat of a Coastal Survey Vessel (1 000 tons displacement) over its speed range is about ½ metre. This is a case of the suspicions aroused in the acceptance of new systems revealing that formerly accepted concepts were less accurate than was supposed.

30. Having devised a correction table for hoverheight it was still difficult to carry out effective trials. It was decided to run two patterns of parallel lines of soundings at right angles to each other (see figure 3) since a 'cross

line ' is a well tried method of checking soundings. The results were somewhat disappointing because the computer was not programmed to detect the exact crossing points and there were doubts concerning the tidal corrections over the two periods. A better system would have been to run the same lines in opposite directions when the fathom contours would have been a more reliable indication of accuracy. The best tests have been devised by the Port of London Authority and were made possible by the use of a slower craft. The automated logging equipment was attached to the echo sounding and position fixing instruments but at the same time the former manual methods were continued. In this way an exact comparison was made. The results were quite encouraging and the orders of difference were small. Out of curiosity the Port of London Authority decided to carry out a further comparison by analysing the data a second time by manual methods. It was found that the differences between the two manual results were greater than between the first manual analysis and the automated survey. This shows up again that the previous assumptions of accuracy do not always stand up to a thorough trial. Statistical comparisons have limitations when analysing hydrographic surveys. One can establish that the standard deviation of sounding differences is a certain, probably small, and acceptable figure. It is however not so important to know that 66 % or 95 % of the soundings are different by insignificant amounts, as that there are no dangers amongst the remainder. Again a difference of 4 feet may not be very significant when it is in a single sounding occupying an area between say the 6 and 10 fathom contour, if they are about 0.1″ apart on paper, but it would be of serious consequence in the centre of a deep draught tanker route. Thus the significance of difference between manual and automated surveys varies both with the geographical position and the slope of the seabed where they occur. It is rather difficult to present this in statistical terms.

EXPERIENCE GAINED WITH THE SYSTEMS [9] [10]

31. The following remarks are based on the experience gained in computer projects at sea during the past three years.

32. *Digitising.* A computer needs to be presented with information in a digitised form because it is designed to accept figures, and to make ' either ' ' or ' decisions. This calls for the process called ' digitisation ' which has been referred to above, or the reduction of such records as the echo sounding trace to figures. In many cases the technique has been imposed on instruments designed before the days of data logging. Although this does not necessarily introduce errors it is usually found to be more satisfactory if the manufacturer of the basic equipment can arrange its digitised outputs because he understands the design more fully which leads to greater reliability.

33. *Keeping Control.* A system is as good as the people who write and operate the programs. There are at present few surveyors who can write a program and it is more probable that a trained programmer will read himself into surveying in order to carry out this task. The program is derived from basic survey theory and it is most important that the surveyor should satisfy himself that it is correct. The program writer should provide a detailed listing of his work and the tape should be most thoroughly checked and approved before use at sea since basic program failures seriously undermine the user's confidence. In the same manner the validity of the daily varying input data must be established beyond question. We have found that surveys have been carried out with the wrong figure of the earth for the projection in use and that one ship on passage, steaming south across the equator, appeared, according to the computer system, to turn north and go home. These errors are easily made when one realizes that the basic information is buried on punched paper tape which it is difficult for the eye to interpret or verify. These preliminary difficulties can be eliminated by the application of the particular care which characterises surveyors when dealing with such matters as triangulation data, and by the use of a sensible, self evident input medium such as a videodata (airport ticket checking type) ' TV ' display. This can be programmed to demand the necessary readings before the survey starts and to accept them in the logical and practical form to which the surveyor is accustomed.

34. Difficulties may also arise with the output of data. The officer in charge of a survey has no hesitation in signing his approval at the bottom of a chart or on well laid out triangulation data, but he may pause and wonder what he is doing when faced with volumes of punched or magnetic tape. There have been cases where tape punching errors, indistinguishable to the eye, have caused valuable work to be lost. To overcome this it has been decided to change from a paper to a magnetic tape system which enables a ' read after write ' checking routine to be introduced. After the survey records have been committed to tape they are immediately read back to the computer which registers an alarm if there are any errors. This should be an important advance in establishing the validity of survey records and in gaining the confidence of officers in charge of surveys. To reinforce the point the hydrographic office ashore will automatically plot samples of the taped records to send back to the ships for comparison with their manually produced fair sheets.

35. It is also important under the heading of ' Keeping Control ' to bear administrative and financial considerations in mind. It is vital to realise that when a ' system ' is started, all its components can have interactive effects on the whole. Haphazard or ill-informed developments can have far reaching consequences and it is necessary that all officers concerned should have a mutually agreed programme spanning several years ahead.

36. *Automatic Plotting and Drawing.* The work of surveying officers has increased, on the bridge and in the chartoom, by the introduction of more complex basic instruments and by the necessity to supervise the automatic logging systems employed. In the case of high speed surveys there is not

time to plot the ship's track, on a large scale, travelling at 30 knots, and even in Ocean Surveys it has become necessary to relieve him of this task. At present an automatic Calcomp drum plotter is used to plot the ship's position from the two selected navigation systems which immediately shows when one of them becomes inconsistent. The drum plotter has the disadvantages that much of the plotting sheet is obscured behind the drum, and in addition it is not possible to ensure the complete accuracy of the result because the sprocket arrangements for holding the paper are not sufficiently precise for the highest standards of work. It was therefore decided to purchase a flatbed plotter upon which the whole survey area would be shown and which could be used for top quality ' off-line ' work such as the plotting of lattices. With this facility the officer of the watch will be able to monitor the quality of the whole system's output, without being closely involved in one particular routine aspect.

37. Up to three drum plotters will be used for recording measured parameters on-line which will reduce the manpower required for chartroom analysis. It has been possible already to produce parts of a survey on-line, showing gravity and magnetics.

38. Plotters can show a ship's position far more frequently than would be feasible by manual methods and thus a ship's track can be accurately delineated over periods when close analysis is required such as on oceanographical stations or during detailed investigations.

39. The automatic plotting of soundings has, up to the present, been a time consuming task, and much important work has been carried out by Decca. The processes involved in the selection and tidal reduction are complex and it is thought that the delays experienced are mostly due to lack of facilities. It is possible to contour soundings automatically but the services of a large computer are required.

40. Many hydrographic surveyors are accustomed to ' inking in ' soundings on the same evening. This is impossible on automated surveys without direct access to a computer and, even if some longer delay is acceptable, it is necessary to book adequate computer time and to have very well qualified staff available.

41. *Terminology.* Professions take pride in the creation and maintenance of their own terminology, and many occasions for obscurity can arise when two meet on one project. It is essential that the surveyors' accustomed usage should be preserved and that self evident descriptions should be used. With some computer systems it is all too easy to drift into the use of obscure codes and notations which makes the new technology that much more difficult for the surveyor to comprehend.

PERSONNEL

42. The switch to automated surveying has a profound effect upon surveying practice and upon a ship's maintenance load. No efforts should be spared to ensure that the changes are made smoothly. As soon as a decision is made to automate some processes an officer should be appointed to liaise, whole time if possible, with the contracting firm. Ideally he should qualify as a programmer and acquire a basic knowledge of computers. By the time the system is introduced each ship should have at least one officer fully trained in its use and key figures onboard should have taken part in a short introductory course. Surveyors are by profession very meticulous and they will not accept a system until they are completely confident that it retains their accustomed standards of accuracy and reliability. As we have seen these may be lower than was formerly believed, but nevertheless it is of great importance that the user's confidence should be maintained. In the early stages he will want to compare the automated results with the trusted manual methods. Far from easing the work load onboard there will, at this stage, be far more for everyone to do.

43. To provide confidence a 'fire brigade' repair service must also be available to attend at short notice in case of defects or difficulties. Frequent meetings must be arranged to ensure close liaison between the various officers concerned. Once confidence has been established, Ships Officers will find that eventually their work is reduced.

44. *Noise*. This can be a nuisance both acoustically and electronically. Ships Officers have found that the proliferation of audible alarm signals and the clatter of the teleprinter have caused unacceptable noise levels on the bridge. Investigations are being carried out for the provision of more silent teleprinting equipment and alarms can be shown visually.

45. Modern survey ships are now most complex in their electronic instrumentation. Mutual interference can be a severe cause of difficulty and precautions should be taken against it.

46. In the brief look at one aspect of the future which follows there is not reference to the valuable work of other offices in such fields as the automation of boat sounding and formation sounding, or surveying from helicopters and the wireless transmission of survey data of which we have no first hand knowledge, but which are nevertheless most significant advances.

AUTOMATED SONAR SURVEYS [11]

47. It is believed that an important direction of future development is towards the greater use of sonar.

48. A research ship is already fitted with a type of ‘ sector scanning ’ sonar which can detect the presence of an object only three feet high and can measure its height to an accuracy of about 1 metre at 200 yards. This is achieved by a capacity to measure range and angles underwater, either in the horizontal or vertical planes to accuracies of the order of inches and decimals of a degree respectively. When used in the horizontal plane this definition allows the production of a ‘ picture ’ of the seabed (over a 30° sector) which is similar to that on a radar display. In this way all obstructions in the area under investigation can be detected. When used to measure depression angles in the vertical plane it can measure the height of the obstructions detected. If properly developed it would be possible to automatically measure depth between lines of sounding.

49. Figure 5 shows, on the right, how this sonar, if used for sideways scanning, could achieve an accuracy of depth measurement of about 1 foot out to 200 yards from the ship's track. The proposed display arrangements would consist essentially of a series of elevations of the seabed spaced at about 1 yard intervals, depending on the speed of the ship. What this amounts to is that the seabed of the continental shelf could be surveyed at a speed equivalent to the speed of sound in seawater, rather than that of a survey ship or boat, and the depths between lines of soundings could be measured rather

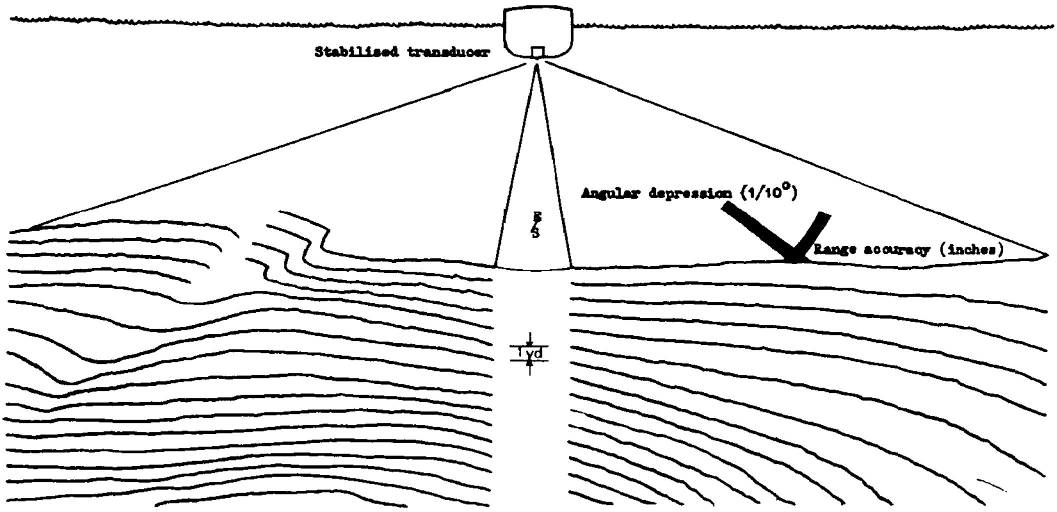

Fig. 5. — Sector Scanning Survey Sonar. Use for depth measurement. Display of measured profiles set at intervals of about one yard along the ship's track. A profile of a wreck is shown on the left.

than deduced. This development would be as historic an advance as that from the lead and line to the echo sounder in the 1930s.

50. The problems of converting this information to a chart are very formidable indeed. The volume of the data to be handled will certainly require computer analysis and the selection of soundings will be even more difficult than described above. However the challenge of being able to obtain this

vital information, which would permit the survey of the continental shelf to something approaching land mapping standards, should be taken up.

CONCLUSION

51. Most of this paper has been concerned with the difficulties of present projects and the measures successfully employed to overcome them, but it is necessary to look ahead as well and to find some means of accelerating the rate of technical development, even in times of peace.

52. The difficulties experienced have been greater than were anticipated at the outset but the fact that all concerned have shown persistance in surmounting them augurs well for the future and we would have no hesitation in recommending automation to those who have a real need for it. Our policy is to keep our feet on the ground and to advance in well planned evolutionary stages, where expenditure is justified, for the improvement of quality or to acquire a necessary new capability.

Acknowledgement

REFERENCES

[1] D. J. Hooper : Automation in Hydrography. Read at Liverpool Institute of Navigation, 28 January 1971.

[2] D. J.Hooper and J. K. V. Lee : Electronic eyes scan the depths. *The Consulting Engineer*, April/May 1971.

[3] D. J. Mabey : Automatic data logging and computing system for the Hydrographer of the Navy. Transactions of the Applications of Seagoing Computers Conference. Marine Technology Society, 1969. Pages 175-186.

[4] T. Dalzell : An automatic data logging system in survey ships. 63rd Annual Convention of the Canadian Institute of Surveying. Halifax. 15-17 April 1970.

[5] Naval Division, Elliott Brothers Ltd. (now Marconi Space and Defence Systems) : A data processing system for the Hydrographer of the Navy. Reference NWD (F) 56 of 8 June 1966.

[6] J. M. Thomson : The case for high speed hydrographic surveying. Decca Survey publication.

[7] R. D. S. Earnshaw (Dr.) and W. A. Huddy : Automatic handling of Loran C data to give best possible position and speed. Marine Sciences Symposium, New Orleans, 1969.

[8] Report of trials carried out by the Hydrographic Department, MOD(N), on the Hovercraft Survey System developed by Decca Survey Ltd

and Hovermarine Transport Ltd, 1968 and 1969. (Released with the firms' permission).

[9] R. W. SUDWEEKS (Instructor Lt. Cdr.) : An automatic data logging system at sea in H.M.S. *Hecla*. I.E.R.E. Conference, Swansea 1970.

[10] E. E. CLARK and B. MATTHEWS : Experience with shipborne computer systems for research and survey applications. I.E.R.E. Conference, Swansea 1970.

[11] J. C. COOK (Dr.) and J. M. MACKAY (Lt. Cdr.) : A precise sonar for hydrographic surveying. *National Electronics Review*, Vol. 7, No. 1, 1971.