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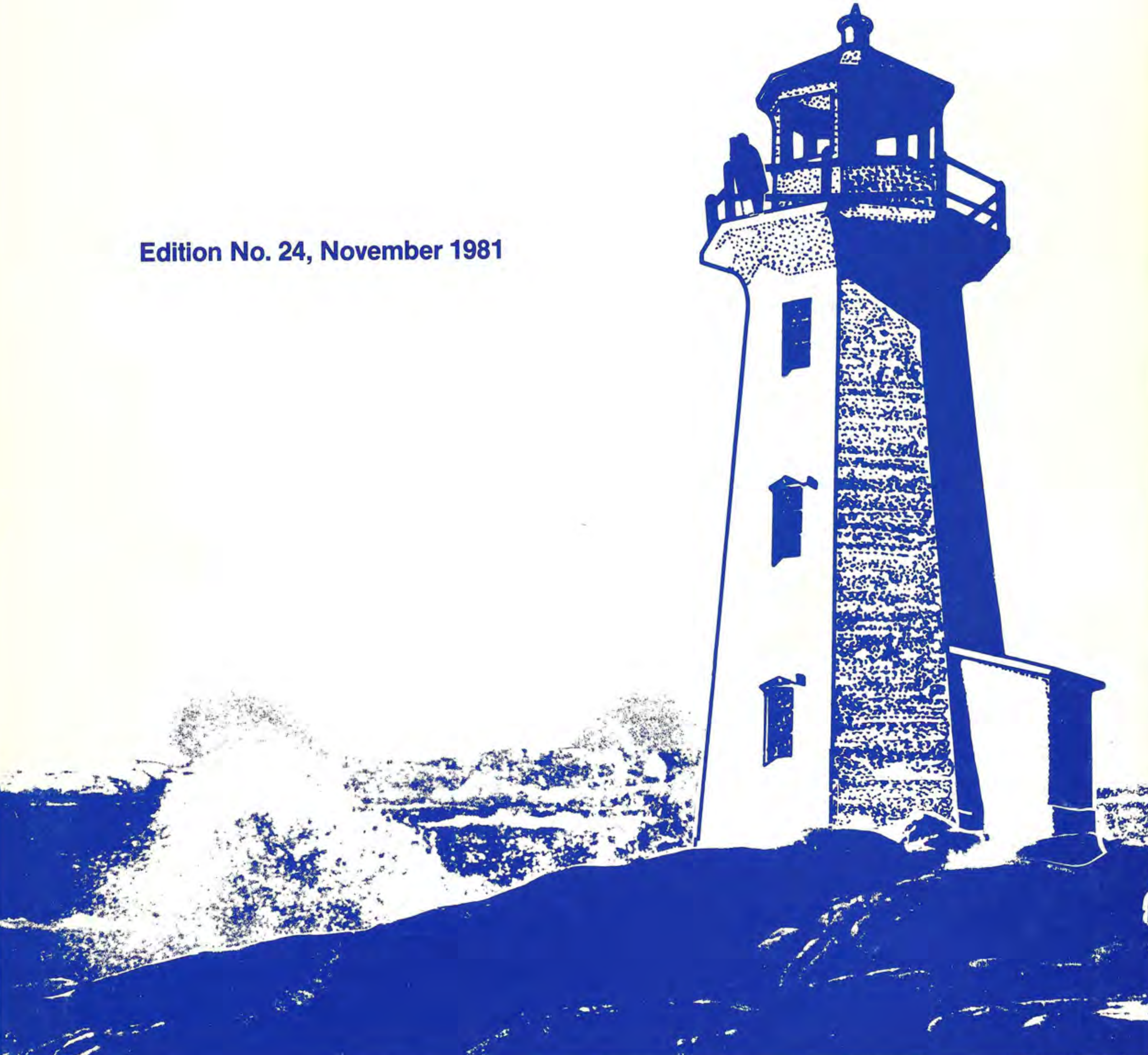

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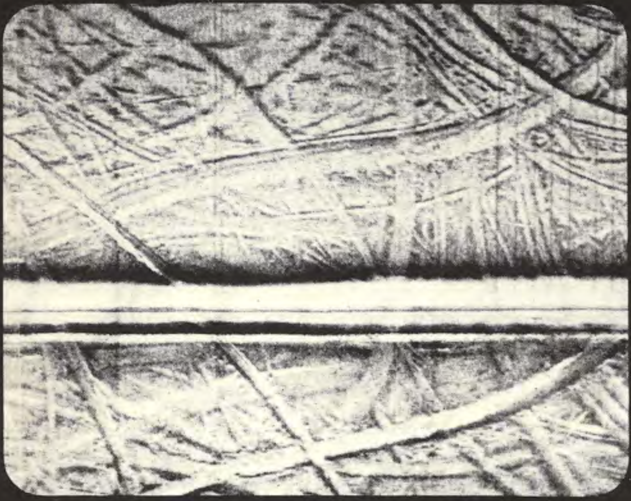

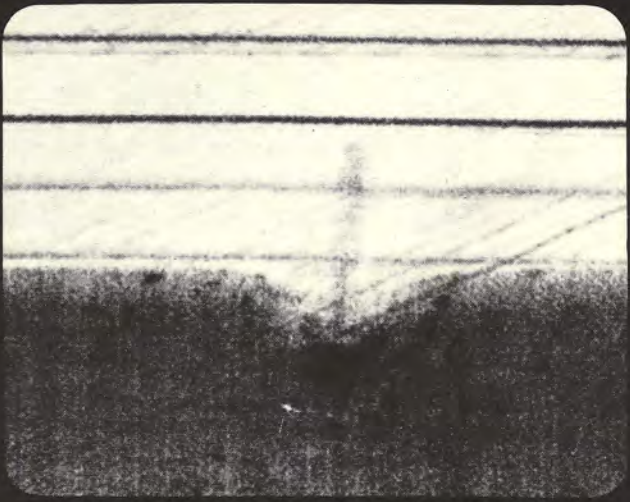

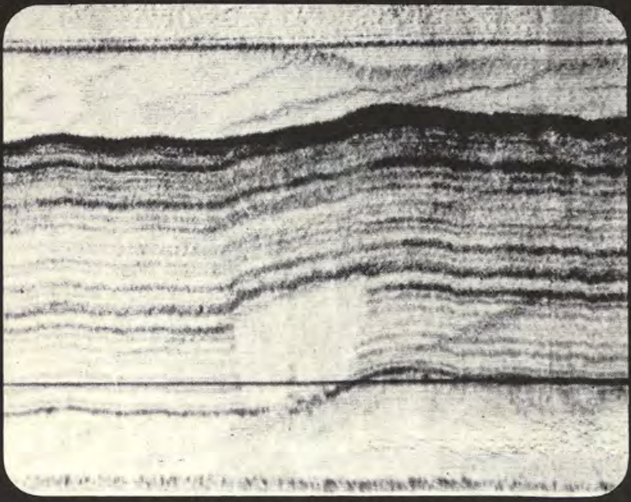

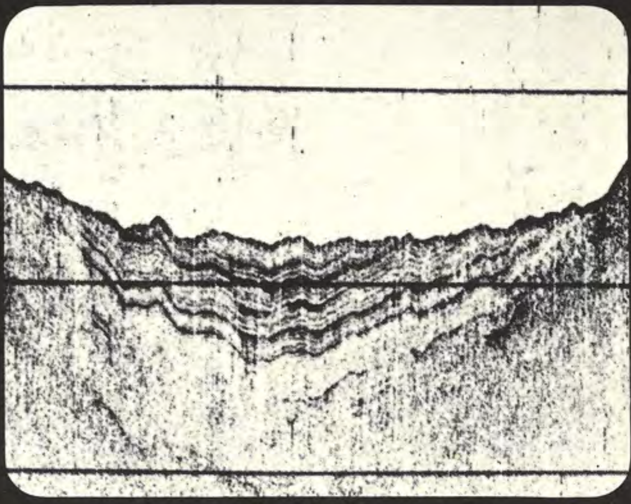

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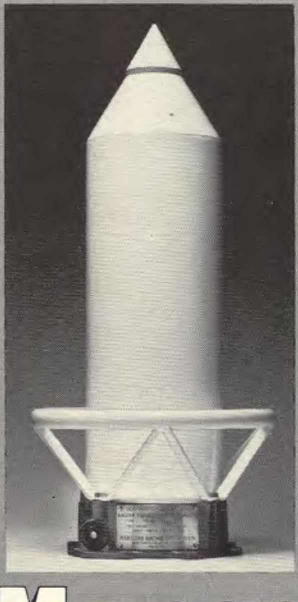

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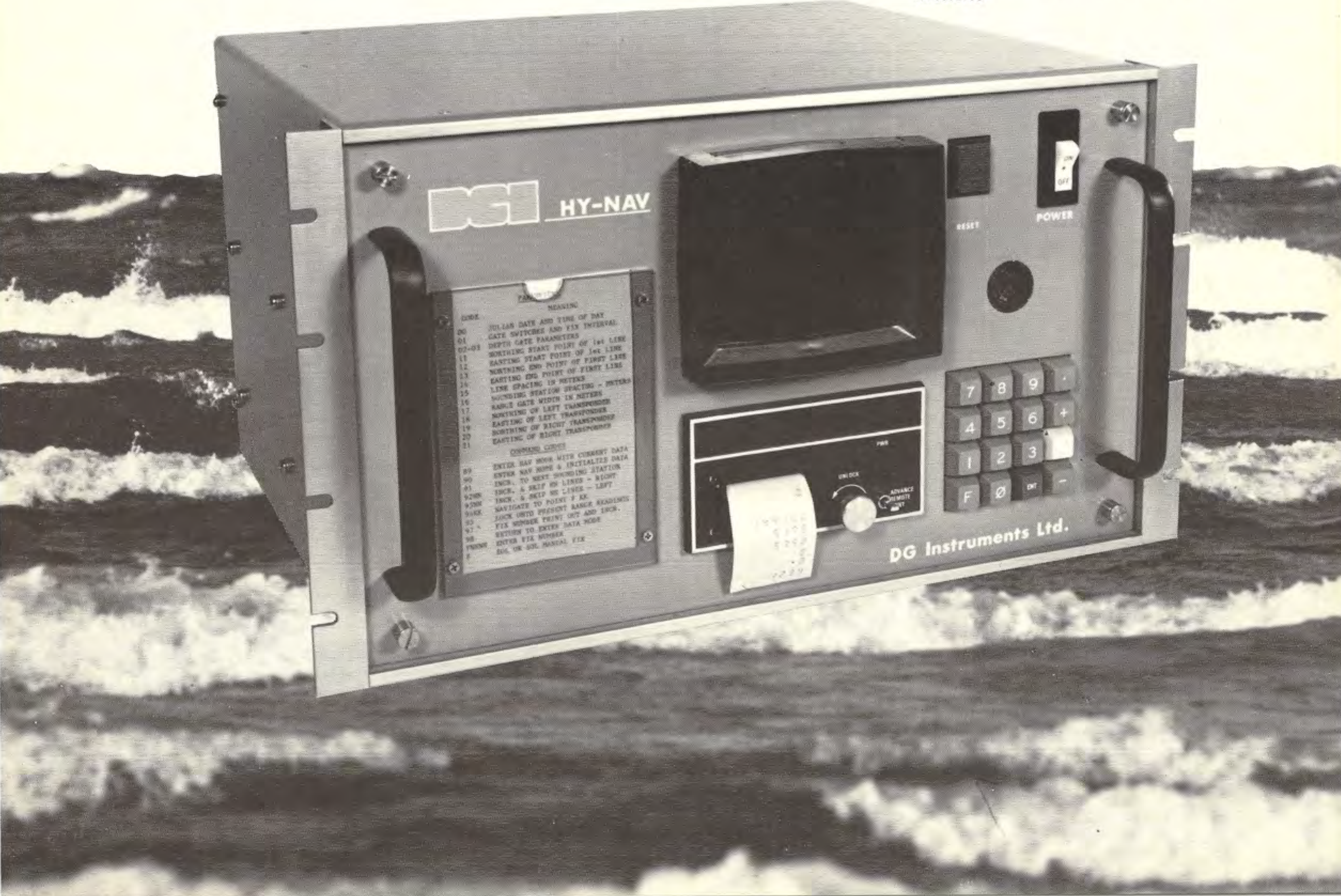
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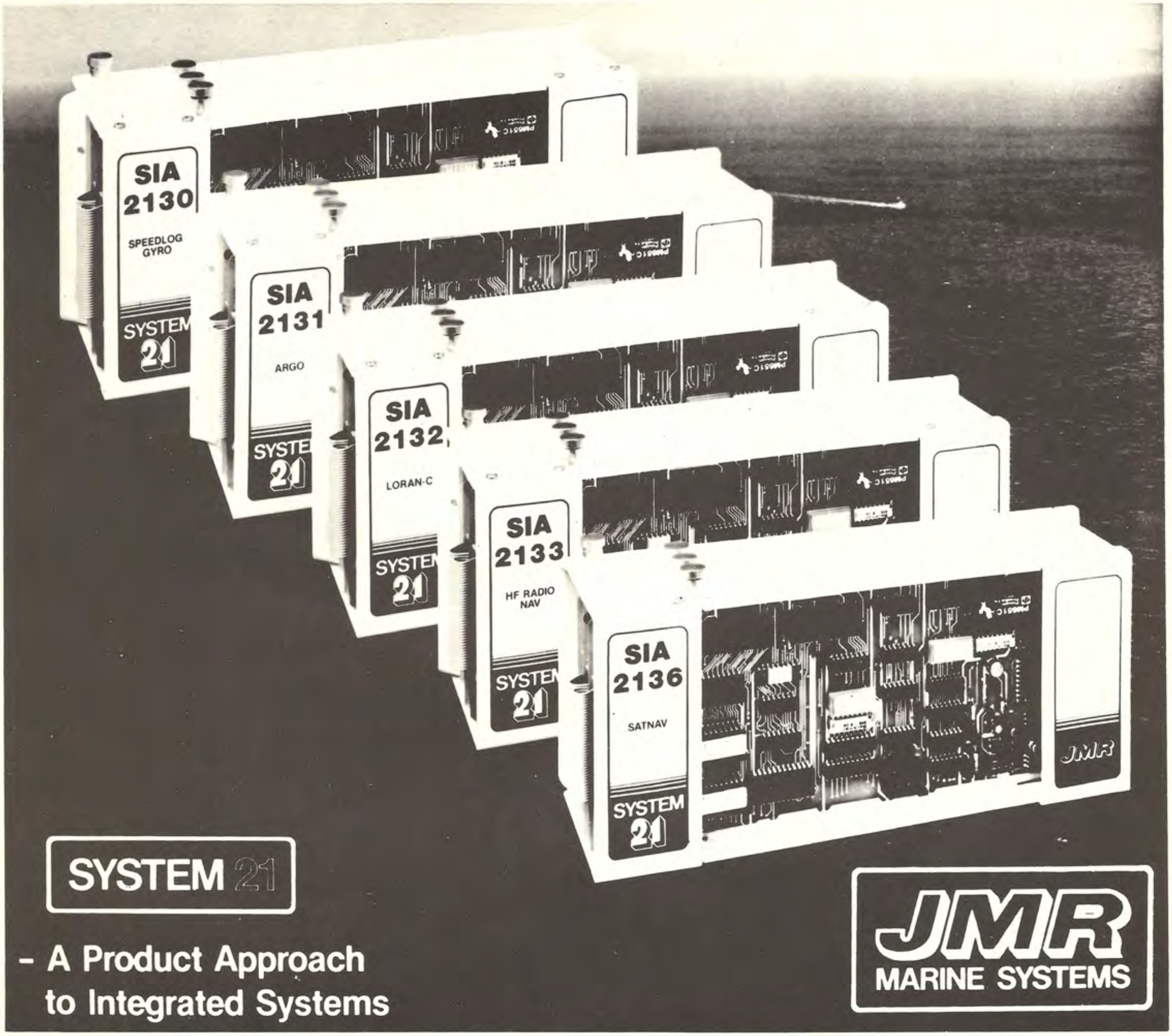
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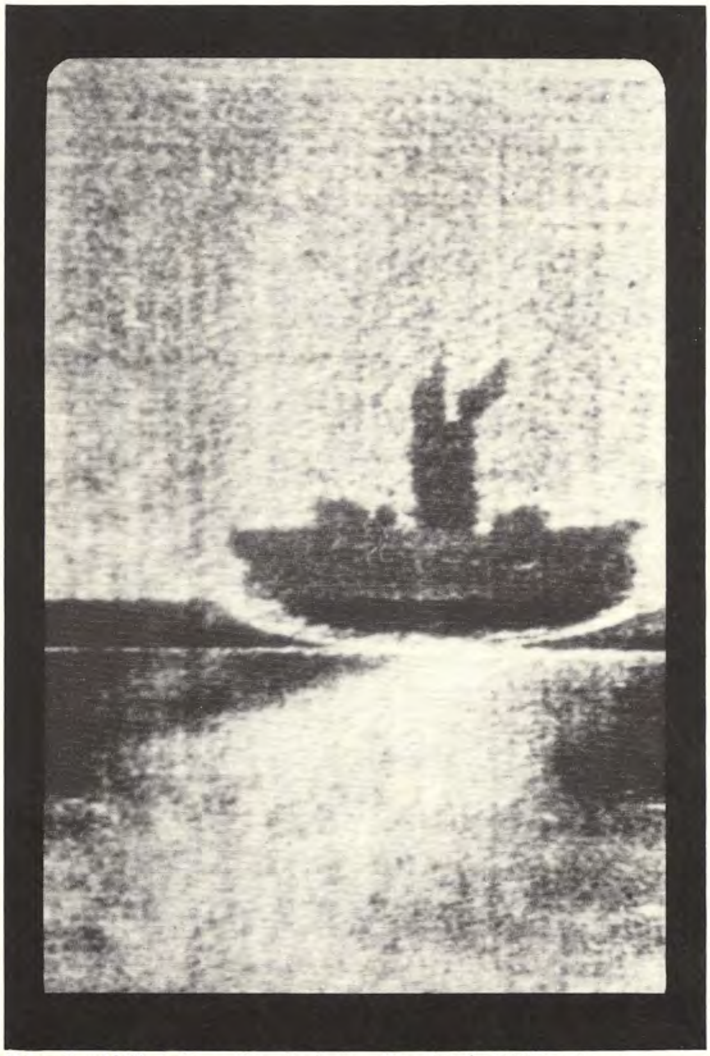

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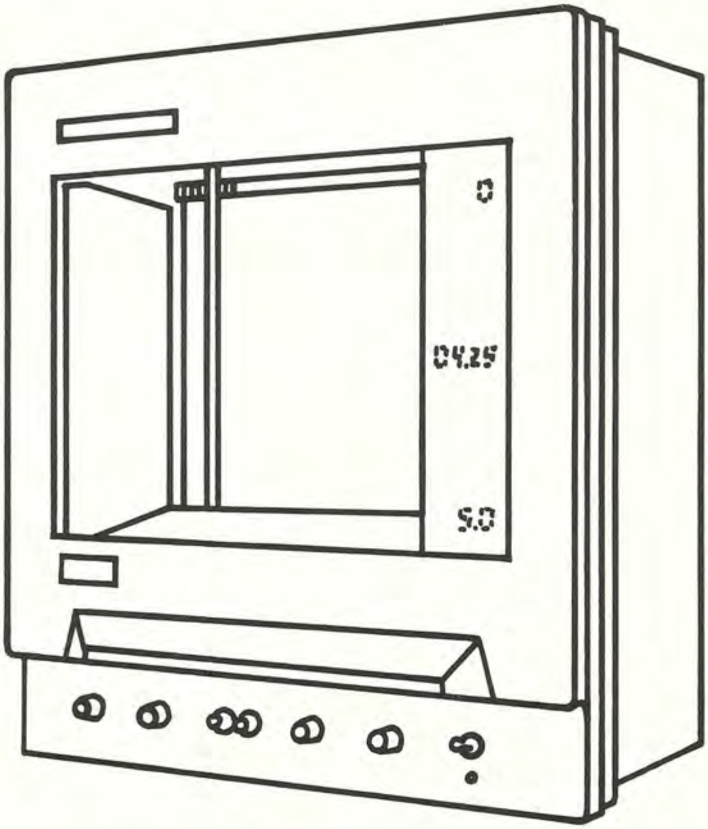
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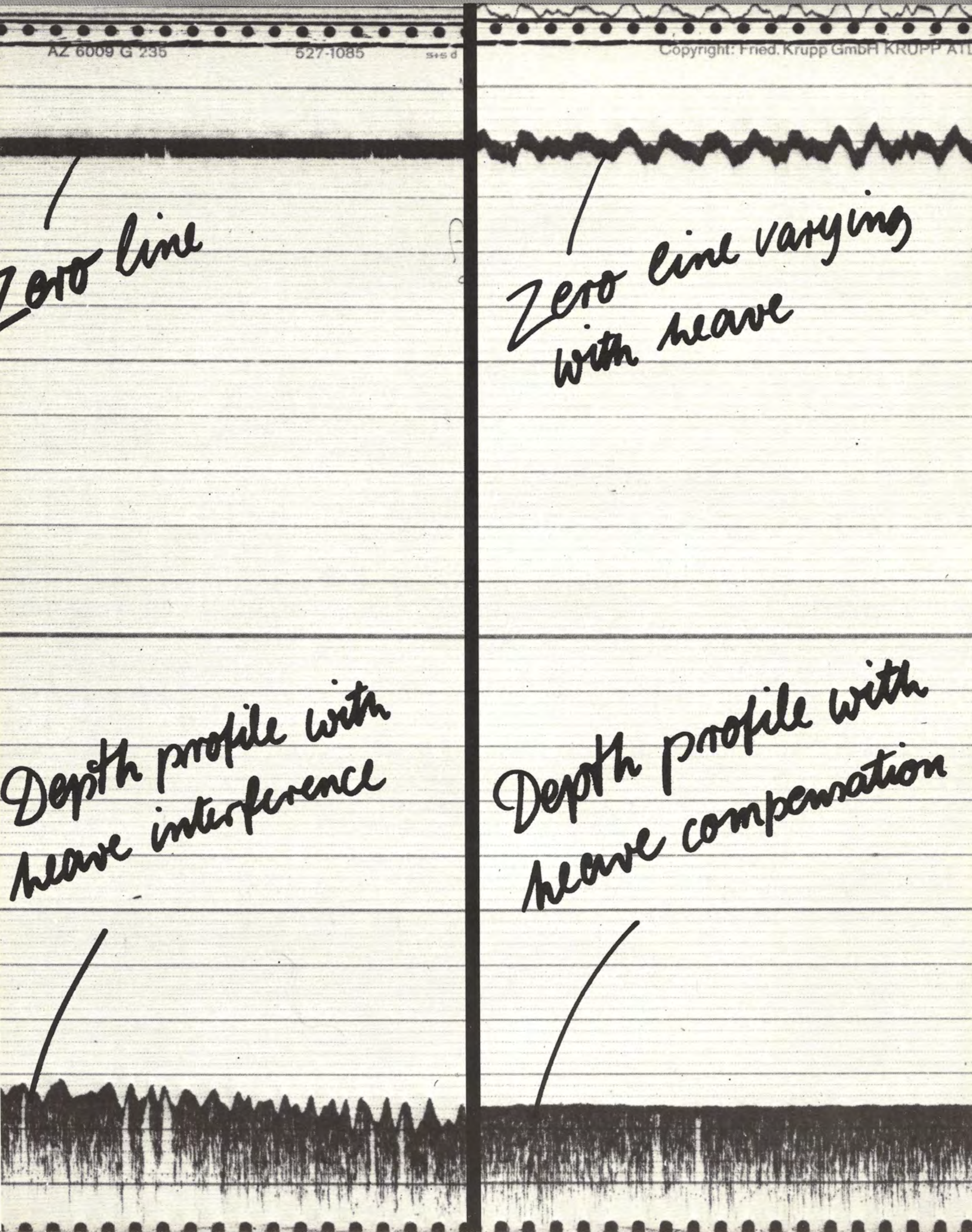
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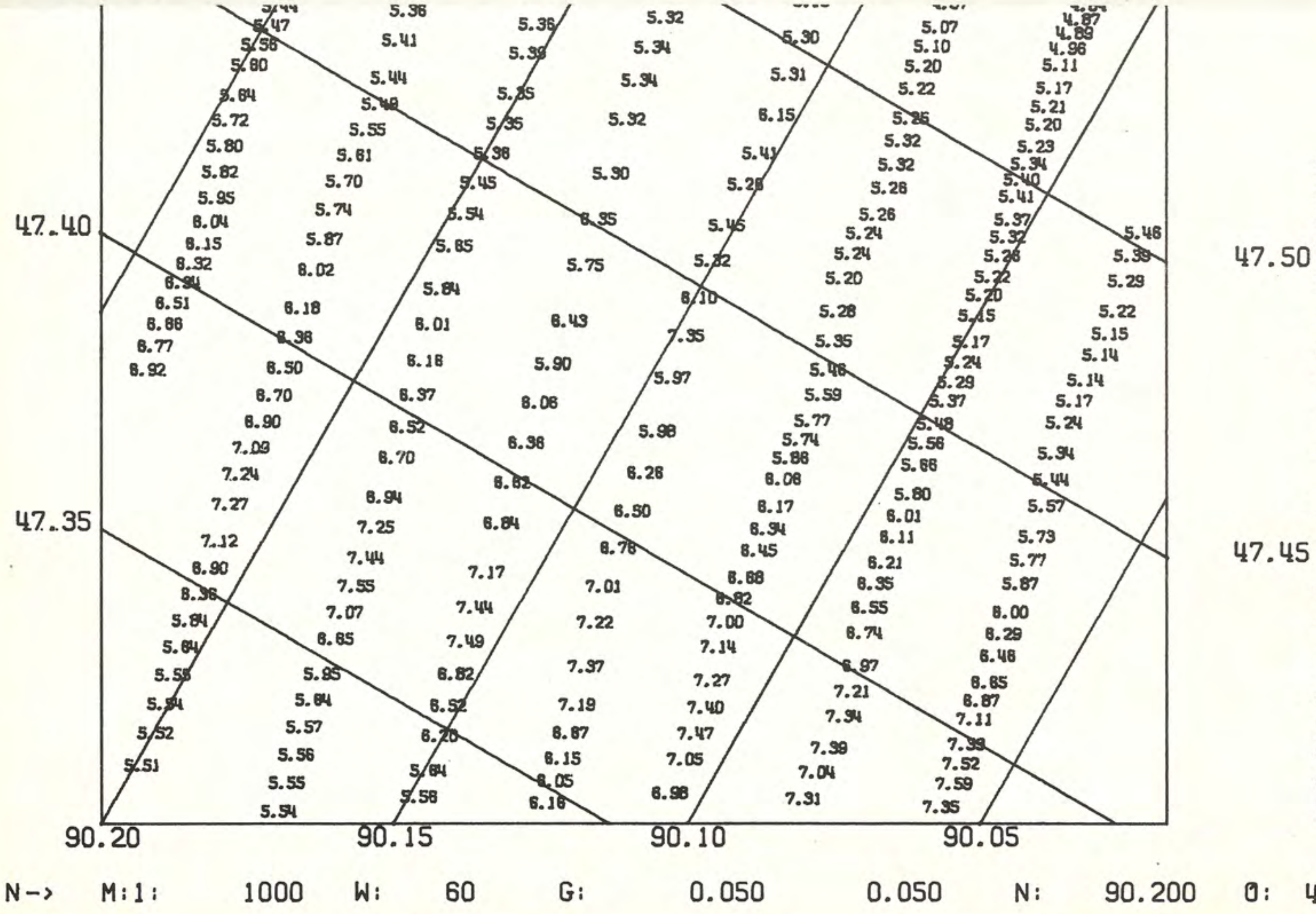

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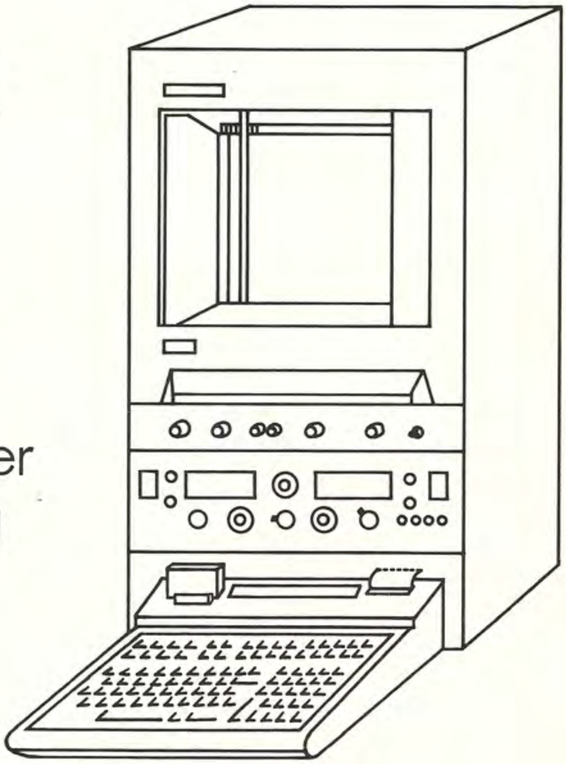

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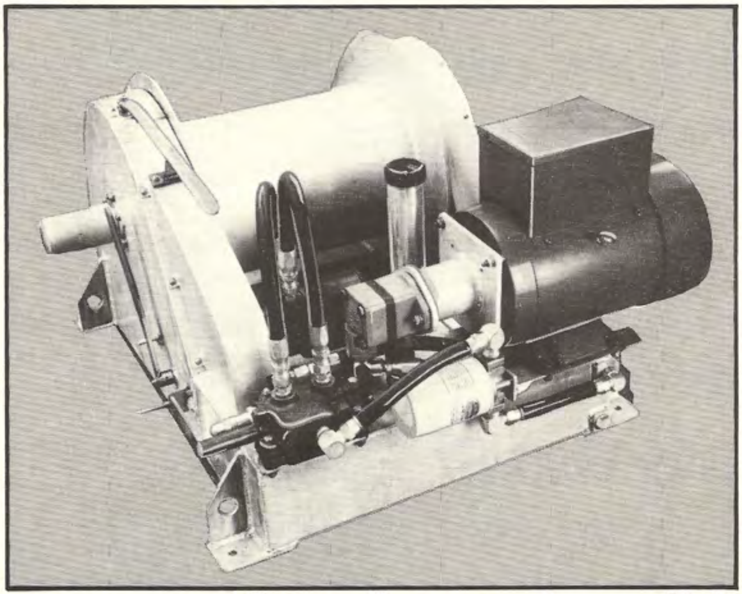

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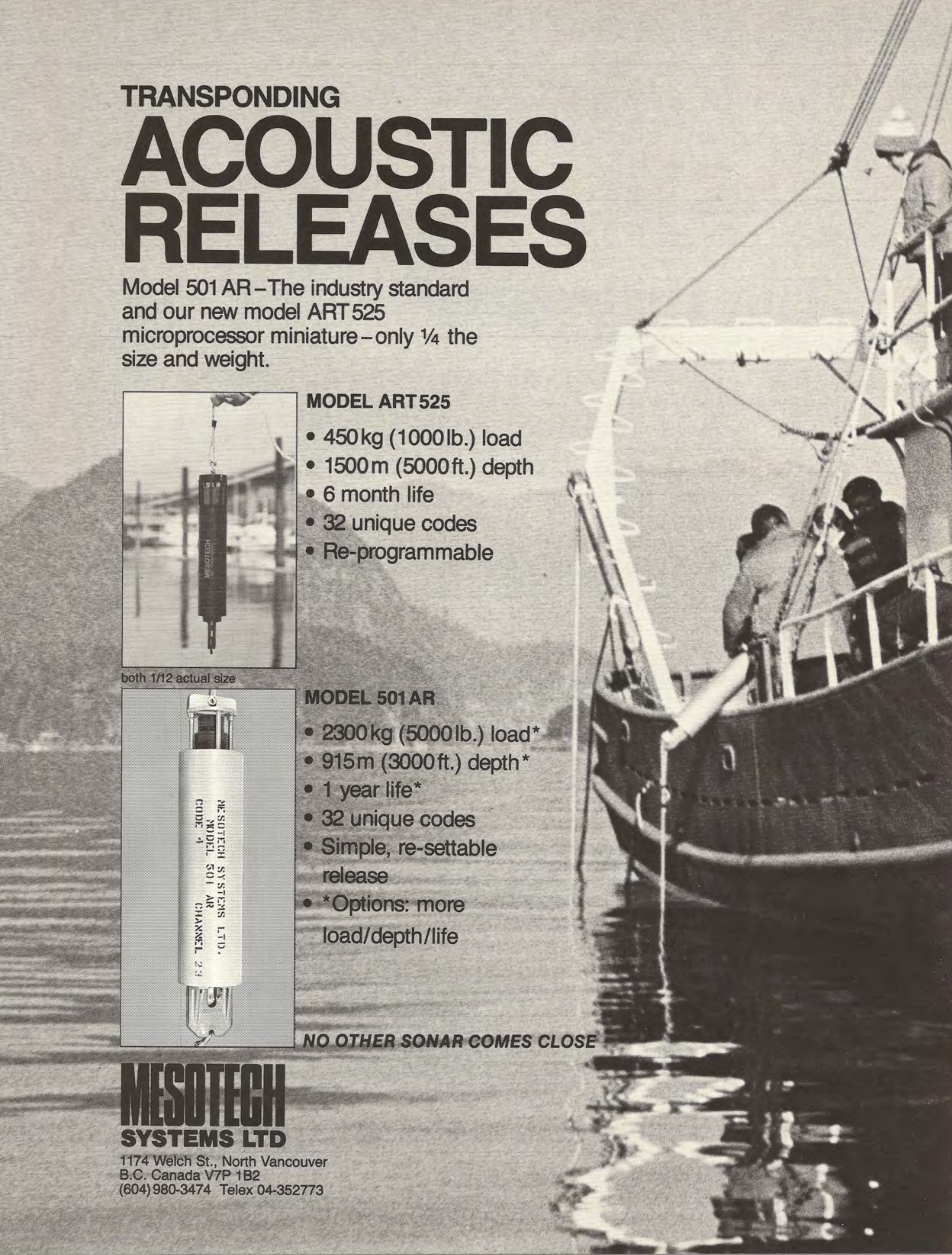

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Contents Page

Editorial 1

Pavlov's Hydrographers 2
A.D. O'Connor

Canadian Hydrographic Workshop, Quebec, 1982 4
R.S. Sanfaçon

Improving the Performance of the Motorola MRS 5
M.J. Casey

Charting the Beaufort Sea 10
R.W. Sandilands

The Marine Arctic Route Reconnaissance System 13
G. Macdonald and J. Medendorp

A Review of Digital Terrain Modelling Applied to Hydrographic Charting Activities 23
Dr. Pam Sallaway

"Smart" Digitizer Proven in Arctic 32
E.A. Meyer

Mathematics and Computing Syllabuses for Hydrographers in Canada 34
D.E. Wells

Book Review 38
J. Goodyear

CHA/CHS News 40

Notes 43

News from Industry 43

EDITORIAL

The historical origin of hydrographic surveyors as mariners on the one hand, and surveyors on the other hand, gives some difficulty when it comes to professional affiliation. In Canada the majority of hydrographic surveyors, at least those working for the Federal Government, tend to be more associated with the survey profession than the marine. This is not the norm, as in most countries hydrographic surveying is a specialization within the navy. Furthermore, even in the civilian domain of hydrography the majority of technical personnel are originally merchant officers. Returning to Canada, there is much talk these days of the future direction of the survey profession. The direction proposed by many writers is towards land information management and perhaps hydrographers should ask if this is really the way they see their branch of surveying going. In a recent published collection of papers on the modernization of the survey profession in Canada, hydrographic surveying seems to not have been mentioned. Interpreting between the lines, it may be that the era of the great topographic land mapping of our country is coming to a close and our dry-footed colleagues are now more concerned with boundaries and parcels of land. Although these last two matters are now as of great concern for the wet land as for the dry land, the fundamental task of defining the shape of the topography beneath the sea is still a long way from completion. While our dry land oriented colleagues may now be diverting their attention from measurement to management, the function of measurement remains predominant in sea surveying. True, that data management is as critical at sea as it is anywhere else but it is in hydrographic surveying that the real excitement exists in improving measurement techniques with respect to both speed and accuracy.

Pavlov's Hydrographers

A. D. O'Connor

Pacific Region
Canadian Hydrographic Service
Sidney, British Columbia

In 1976 a compact hydrographic data logging system was introduced into production surveys in Pacific Region. PHAS (Portable Hydrographic Acquisition System) is a microprocessor based data logging system designed to log hydrographic data in small survey launches, it also has the potential to provide navigation information from incoming positioning data. Parameters concerning the quality and acceptability of data to be logged can be input to PHAS via a front panel keyboard. PHAS uses these parameters to monitor the data incoming from different sensors, sounder, positioning system, magnetometer, and gravimeter, and activate an alarm if the data exceed the set parameters. PHAS will also provide event mark pulses as required to different recorders.

In 1977 PHAS was chosen as the data logging system for the multi-discipline cruise of *M. V. Pandora II* to the Western Arctic. Except for sounding digitizing problems, caused by aeriation, PHAS successfully logged all positioning, sounding, and magnetics data on that cruise. Figure 1 shows the data collection station on *Pandora II.* An underestimated side effect of this automated data monitoring and logging procedure was the extent to which the duties of the hydrographer on watch were reduced.

In 1978, PHAS with modifications suggested by 1977 operations was again chosen as the data logger for the Western Arctic multidisciplinary cruise. Students were employed as watchkeepers on this cruise to free hydrographers for more demanding assignments on other surveys. PHAS again handled all data monitoring and logging chores while the watchkeepers kept track of position and monitored PHAS. One point, first made in 1977 and reinforced in 1978, was that the survey parameters input to PHAS, such as acceptable rate of change of depth or position, or, allowable time without a depth or position, are decided upon after careful consideration of all factors pertaining to the survey. If these parameters are exceeded the decision on corrective action cannot be taken at the watchkeeper level and the senior hydrographer must be consulted. The watchkeepers duties are therefore reduced to annotating recorders and waiting for PHAS to provide an alarm at which time the hydrographer is called.

The idea of replacing the watchkeepers entirely with PHAS had been put forward in both 1977 and 1978, over those years PHAS had demonstrated its reliability as a data monitor/logger. An FM radio paging system was acquired (Fig. 2) this system consists of an encoder, a transceiver, and a number of pagers. When a survey parameter is exceeded, PHAS, in addition to activating an alarm, could trigger the paging system thereby alerting the hydrographer in possession of the pager. Ships officers on the bridge were to be given a lattice or boat board and assume responsibility for running the identified survey lines. The officers would also keep a 15 minute log of the positioning system coordinates. PHAS would provide event mark pulses to the echo sounder and magnetometer recorders, the echo sounder event mark was coded, 1 strike of the stylus at 5 minutes, 2 at 15 minutes, and 3 at 30 minutes. Annotation of the graph would be handled manually on a casual basis.

The 1980 cruise of *Pandora II* to the Western Arctic was planned as outlined above, no watchkeepers were employed. Four hydrographers including the Hydrographer-in-Charge, made up the

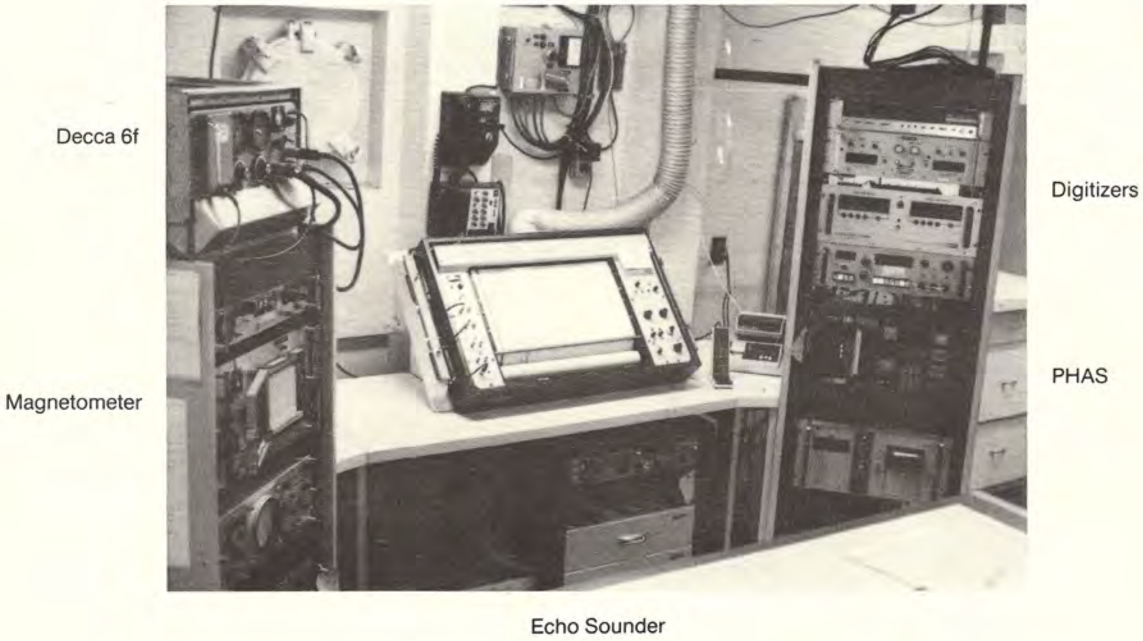

Figure 1 Data Collection Station, *Pandora II*

party. One hydrographer was employed daily in a survey launch while the other three were responsible for the management, planning, and control of the survey, the collection of survey data (24 hours per day), and the processing, verification and plotting of these data. During the day the lab was manned and PHAS was monitored normally. At meal times and during the evening the "duty" hydrographer carried the pager and was responsible for the data collection. The reaction of a "duty" hydrographer to a 3 a.m. page suggested the title for this piece. One problem that surfaced was that of the echo sounder paper tearing and leaving us with an unverifiable digital record of the depth. The seaman on watch was conscripted to keep a frequent eye on the recorder paper.

During the 1980 season, 7501 linear miles of sounding and 5906 linear miles of magnetic profiles were collected using this fully automated system. Torn sounding paper was responsible for the loss of 5 miles of sounding data. Most of the alarms concerned the loss of bottom lock by the digitizer, this problem is not new and hopefully will be solved by acquisition of the new generation of "smart" digitizers.

The system described above can release the hydrographer from the sometimes tedious task of watchkeeping on a shipborne survey for assignment to the more labour intensive launch surveys.

Acknowledgements
Thanks to hydrographers George Eaton, Ernie Sargent, Mike Ward, and to the officers and crew of *Pandora II* for their help in making this experiment successful.

Figure 2 Paging System and Pager

Atelier de travail sur l'Hydrographie canadienne Québec

2-4 février 1982

L'atelier de travail sur l'hydrographie canadienne, parrainé conjointement par le Service hydrographique du Canada et l'Association canadienne d'hydrographie, se tiendra à Québec, les 2, 3 et 4 février 1982.

Le but de l'atelier est d'informer et d'oncourager une discussion constructive parmi les différents groupes de travail du Service hydrographique du Canada.

M. Ronald Saucier a accepté la presidence de l'atelier et son comité est composé de Jean-Marie Gervais (finance), Jean-Paul Racette (programme technique), Denis Trudel (programme social et services spéciaux) et Richard Sanfaçon (information et publications). Nous leurs souhaitons la meilleure des chances.

L'atelier de travail est une nouvelle formule pour une convention du S.H.C. L'atelier ne sera pas une convention comme les précédentes. Seuls les employés du S.H.C. et les membres de l'A.C.H. y participeront. Il n'y aura pas d'étalage commercial. L'atelier de travail est différent d'une conférence en ce sense que la présentation du sujet à être discuté sera courte afin de consacrer le plus de temps possible à la discussion en groupe. Chaque session sera menée par un président qui verra à ce que la discussion ne s'éloigne pas du sujet. Il notera également les principaux points soulevés et contribuera à formuler des recommandations lorsque nécessaire.

Un aménagement particulier des salles a été proposé pour encourager la participation de toute l'assemblée. Grâce à la traduction simultanée, un sujet à la fois sera discuté. Il y aura des microphones installés sur les tables et les sessions d'atelier seront probablement enregistrées.

Déjà, des chambres on été reservées à l'hôtel La Concorde où nous aurons également la toujours si populaire suite hospitalité.

Le réputé Carnaval d'hiver de Québec débutera le 4 février et nous suggérons à ceux qui prévoient rester pour la fin de semaine d'en avertir R. Saucier, président de l'Atelier, le plus tôt possible afin qu'il prolonge les réservations des chambres. Les prix des chambres sont de $54. (occupation simple) et $59. (occupation double). Ce prix inclut le petit déjeuner. De plus, un programme spécial (incluant visites et sports d'hiver) sera préparé pour les épouses des participants.

Le programme des ateliers est présentement en préparation. Le succés d'un atelier du travail dépend directement de la qualité des sujets et le président et son comité vous remercient pour les nombreuses suggestions intéressantes qui ont été soumises.

Le vice-président de l'A.C.H., branche de Québec, Richard Sanfaçon, a proposé qu'un montant d'argent soitmis àpart pour la participation de l'A.C.H. à l'Atelier. Suite à cette première démarche de la jeune branche, un support financier particulier pour l'A.C.H. Québec a été discuté durant un appel-conférence avec le président national, M. Tony O'Connor, et les autres représentats des différentes branches. Chaque branche, de même que l'Exécutif national, contribuera financiérement a l'atelier.

Richard S. Sanfaçon
(information)

Canadian Hydrographic Workshop Québec

2-4 February 1982

The Canadian Hydrographic Workshop, jointly sponsored by the Canadian Hydrographic Service and the Canadian Hydrographers' Association, will be held at the Loews Le Concorde, Québec City, on February 2, 3 and 4, 1982.

The aim of the Workshop is to inform the participants by encouraging a constructive discussion among the various working groups of the Canadian Hydrographic Service.

Mr. Ronard Saucier has accepted chairmanship of the Workshop and the committee is composed of Jean-Marie Gervais (finance), Jean -Paul Racette (Technical Program), Denis Trudel (social program and special services) and Richard Sanfaçon (information and publications). We wish them the best of luck.

The 1982 Workshop is a departure from the usual format of the Hydrographic Conference in that there will only be C.H.A. and C.H.S. personnel attending and there will be no commercial exhibits. The format will consist of a short presentation of the subject matter to be discussed, allowing the major portion of the time for group discussion. The Chairman will ensure that the discussion stays on the subject matter. He will identify the main points brought out in the discussion and help formulate recommendations when necessary.

The particular layout of the room will encourage participation of the whole assembly. Since simultaneous translation will take place, there will be but one subject matter discussed at one time. There will be microphones set up on the tables and the workshop sessions will probably be recorded.

At this point, rooms have been reserved at the "Le Concorde" Hotel where we will also have the ever so popular hospitality suite.

The well-known Québec winter carnival commences on February 4 and I would suggest if people plan to stay over the weekend that they inform R. Saucier, Workshop Chairman, well in advance in order that he may extend the reservations on the rooms. Costs of the rooms have been established at $54. -single and $59. -double. This cost includes breakfast. Also, a special program including visits and winter sports) is going to be organized for spouses of the attendants.

The workshop program is presently being organized. The success of a workshop directly depends on the quality of the topics, and the chairman and his committee thank you for the numerous interesting suggestions.

The C.H.A. Vice President of the Quebec Branch, Richard Sanfaçon, proposed that an amount of money be set aside for the participation of the C.H.A in the Workshop. Following that first move from the youthful branch, a particular financial support for C.H.A. Québec Branch was discussed at a conference call with National President, Mr. Tony O'Connor, and the other C.H.A. Branch representatives. Each branch and the National Special Account will financially contribute to the Workshop.

Richard S. Sanfaçon
(information)

Improving the Performance of the Motorola MRS

M. J. Casey

Canadian Hydrographic Service
Central Region
Burlington, Ontario

The author has been an enthusiastic user of the Motorola Mini Ranger System (MRS) since 1972. He has used the system on a variety of vessels and surveys and under diverse conditions. He feels that small, portable easy to use systems such as the MRS have revolutionized hydrographic surveying of inshore areas. There are some idiosyncrasies to the system however that have remained largely unknown and which can lead to serious range error problems. During the 1980 Lake Erie Survey the author conducted a number of experiments designed to study some of these vagaries. A paper describing the experiment and its results was presented at the 20th Annual Canadian Hydrographic Conference in April, 1981. This article contains some of the more important aspects of that paper.

The style is unusual for a technical paper. The author's intention is to try to explain certain puzzling incidents which have occurred during sounding operations. Scenes are presented which outline a particular problem in a setting which should be familiar to hydrographers. These scenes serve as the motivation for some analysis which follows.

SCENE I

(Scene: The Canadian Survey Ship *Jubilee* is tied up alongside the quay in Ducks Harbour. The brilliant orange flag on the calibration station hangs loosely from its mast only metres away from the white hull of the ship. On board in the hydrographic plotting room Mickey Fenn, the ship's hydrographer, is seated in front of a large rack of equipment. His eyes are fixed on the flashing red display numbers of one of the instruments — a Mini Ranger III.)

(Aside) **Mickey:** Well here we go again. The bloody thing is out! Fifteen metres too long — both channels!
(He begins to write something in his note book. Moments later the First Mate appears at the door)

Mate: What's up Mickey — everything ok?

Mickey: Not quite. She's out again — fifteen metres too long. I don't understand it since we just checked it last night and it was right on.

Mate: Yes, well last night was clear as a bell and today's right misty — that must have an effect on it — it certainly affects any radar.

Mickey: I'm sure it affects the maximum range alright but I'm not so sure that it would cause a range error.

(after a slight pause)
Mickey: I'm not sure what I should do — should I correct the ranges now so that they'll read correctly or leave them as they are? It could be a legitimate range error caused by some timing shift in the machine — in which case I should dial it out.

Don't touch that dial Mickey — you'll only make matters worse!

Mickey does have cause for dismay however. After all he had just invested time and energy into calibrating the system the night before and now he finds he has a significant ranging error. It would be a simple thing to just shrug it off and dial in the correction. Unfortunately, that will lead to a seemingly never ending series of adjustments up and down which serve only to exasperate our friend.

The alternative is equally unattractive. By not correcting the machine Mickey is, in effect, ignoring a significant source of error — so he's not happy.

What Mickey lacks is another piece of information to go along with his range readings. One that will give him an idea of the *quality* of the range measurement and hence tell him when he should calibrate and, most importantly, *when he should not.* A built-in signal strength indicator is ideal for this task. The signal strength data will give him an explicit measurement of the pulse shape quality and we will see later why this is important.

Before examining the details of the relationship between range quality and signal strength we should first consider some characteristics of the signal strength data alone.

From the well established Radar Equation (Laurila, 1976)

$$P'_t = \frac{P_t G_t}{4\pi R^2}$$

where P'_t the intensity of the radiated power
P_t the peak power
G_t the gain of the antenna
R the distance from the transmitter to the receiver

we see that the intensity of radiated energy varies inversely as the square of the distance from the source. Therefore, we should expect that signal strength should drop off with increasing distance from the transponder. Our test data confirmed this. Figure 1 shows a graph of the observed signal strength readings recorded as our launch steamed directly away from the transponders.

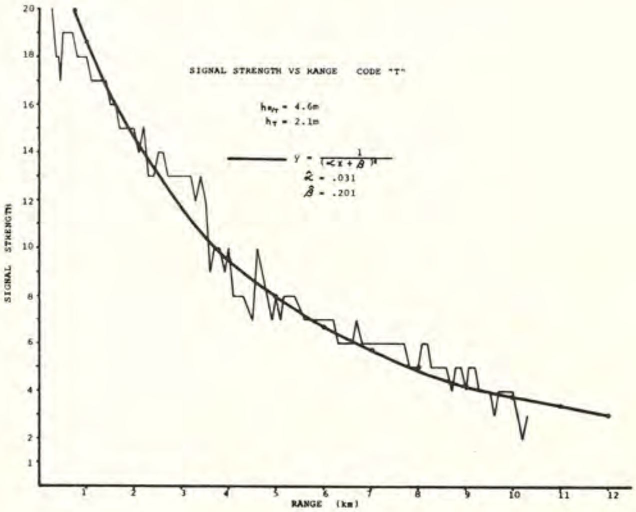

Figure 1

The fitted curve is of the form

$$y = \frac{1}{(\alpha\chi + \beta)^2}$$

where y is the signal strength
χ is the distance in kilometres

So here we have very strong evidence that signal strength data indeed also varies inversely with the square of the distance.

Signal strength is also affected by other factors as well, such as the horizontal and vertical beam widths of the transponder and R/T units and destructive interference of signals due to multi-path effects. Another factor which strongly affects signal strength is the atmospheric condition. Signal attenuation occurs when the signal path crosses areas of high particle density such as mist, fog or smog. Although the other factors such as distance, pointing and cancellation have a greater effect, this factor is the most devious since it is uncontrollable and difficult to quantify. This is likely the factor giving Mickey his problem.

Signal strength information alone of course does not help us unless we know what to do with it. Fortunately a very strong functional relationship exists between signal strength and range error. Figure 2 shows a graph of signal strength vs. range error for a subset of the data we collected.

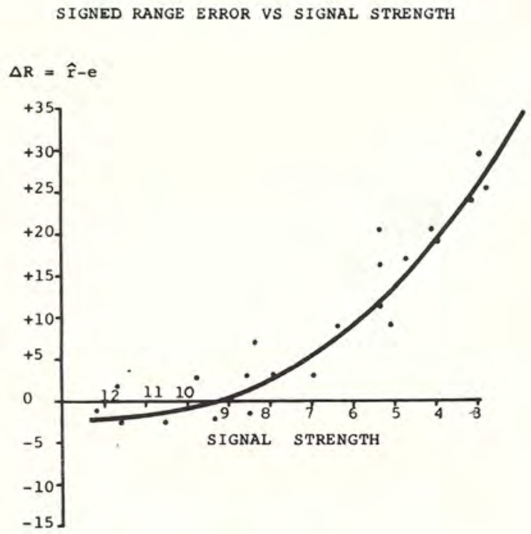

Figure 2

This graph shows a strong exponential increase in the range error due to decreased signal strength. Note that the graph shows that the range errors are equally distributed in sign for signal strength values greater than some value — about 9 in this case. Below this value the range error increases exponentially and is positive in sign.

Figure 3 shows the frequency distribution of the range error. Large errors here are exclusively positive. The reason for this is that signal strength is in a way a quantitative measure of the pulse shape quality. The machine has difficulty in discriminating the leading edge of the pulse when signal strength is low. Consequently the timing tends to be long in marginal situations and this manifests itself in ranges which are too long.

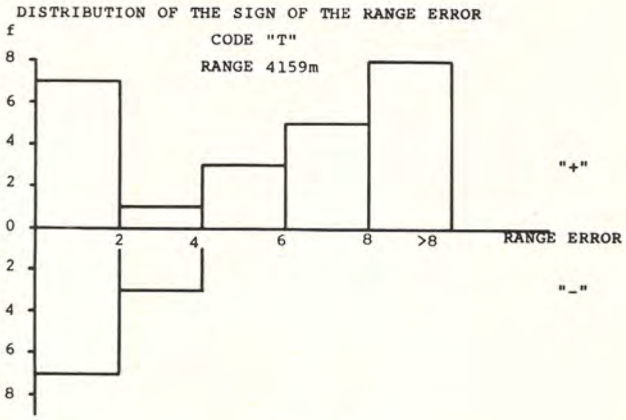

Figure 3

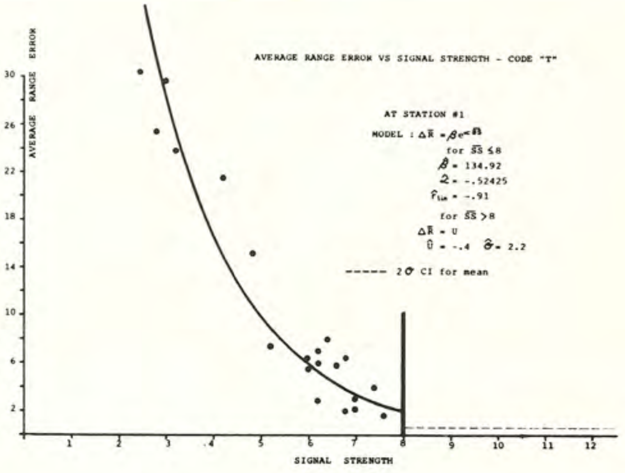

Figure 4

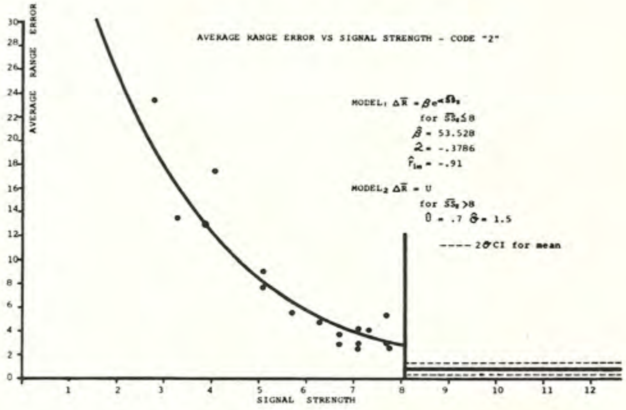

Figure 5

Figures 4 and 5 show the range error vs. signal strength for Codes "2" and "T".* The error function is shown as discontinuous. At a particular signal strength level (8 in this case), which I call the Critical Strength Threshold (CST), the function changes abruptly. Above the CST the system behaves well with the errors being normally distributed about some constant value. Below the CST the error function is a negative exponential. Figures 6 and 7 show the linear relation after a log transformation. The 95% confidence limits for the mean value of $\overline{Z}_i = \rceil n\,(\triangle R_i)$ are also shown.

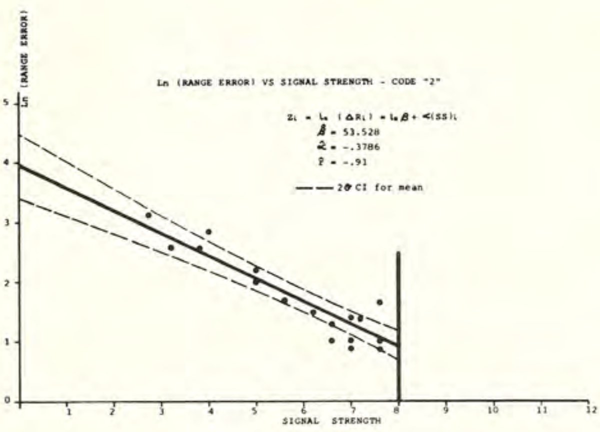

Figure 6

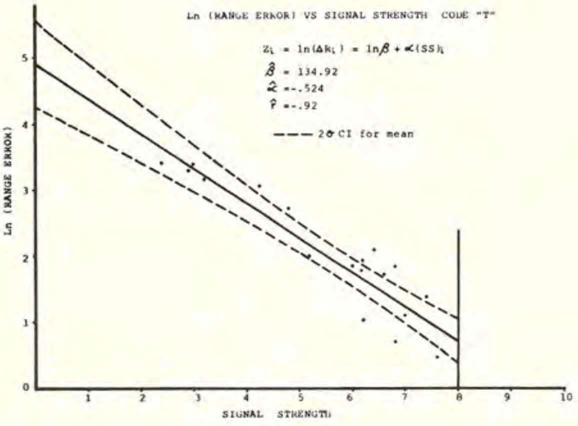

Figure 7

We can formally define the range error distribution as follows:

let ε_i be the range error
$(SS)_i$ be the signal strength
δ be the CST

then

$$\varepsilon_i \sim \begin{cases} N(\mu, \sigma^2) \text{ for } (SS)_i > \delta \\ N(\beta e^{\alpha (SS)_i}, \mathrm{Var}(\varepsilon_i)) \text{ for } (SS)_i < \underline{\delta} \end{cases}$$

that is, above the CST the errors are normally distributed with mean μ and variance σ^2 and below the CST the errors have a Log Normal distribution.

Mickey's problem then boils down to this. He is trying to re-calibrate the system under poor conditions. If his MRS was equipped with a signal strength indicator he would see that explicitly. This is the likely cause of the 15 m range shift he is seeing and if he leaves everything as it is then chances are, if the weather improves, the range readings will return to where they belong. Furthermore, if he had signal strength readings recorded along with his ranges and had confidence in his error function estimates ($\hat{\alpha}$, $\hat{\beta}$) then he could correct his range readings. Since, however, the variance of the range errors also increases with a decreasing signal strength Mickey could not have the same degree of confidence in these corrected readings unless he had some form of real time smoothing of the range data. The range averaging option is one solution — albeit a not very sophisticated one.

There is another way in which signal strength can be adversely affected and which has nothing to do with the prevailing atmospheric conditions. This concerns the effect low battery power has on the transponder efficiency.

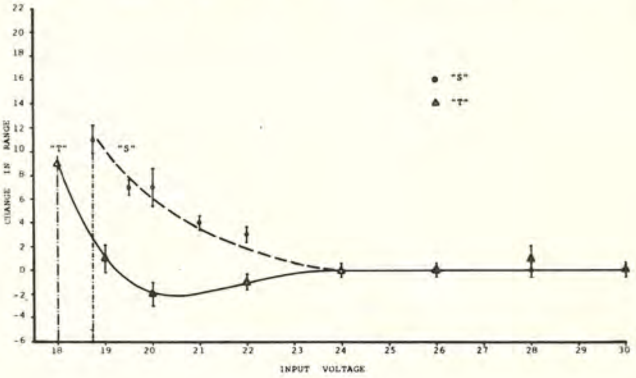

Figure 8

Figure 8 shows the change in range readings vs. transponder input voltage for codes S and T. It shows no significant (95% level) change until a value of 24 volts is reached. Below this voltage significant range changes occurred until threshold levels were reached at which point the transponder ceased to transmit. So it appears that there is high level voltage protection or regulation but either inadequate or non-existent protection at low levels.

This result is important since, for logistic reasons, it is common practice to leave power supplies out unattended until the batteries are exhausted. Our tests show that the transponders continue to transmit down to their threshold levels but at the cost of an increasing systematic error. There are several ways to avoid this. One solution adopted by the Canadian Hydrographic Service is to add extra circuitry to shut down the transponder when the voltage falls below some reasonable threshold (say 22 volts). A clock is also included so that a program of on/off times can be set up to extend the useful battery life. Various other devices such as photo-cell switches, solar panels or portable windmill generators can be used for this same purpose.

SCENE II

(Scene: late at night in the hydrographic plotting room aboard the survey vessel *CSS Jubilee*. The hydrographer on watch, Mickey Fenn, has just recorded and plotted a fix on his plotting board. His eyes scan the racks of instruments before him and catch the fluttering light on the Mini Ranger. Moments later a voice booms over the intercom.)

Mate: Hey Mickey are you there? We're losing that damn range again.

Mickey: Roger. Let's hold our course for a few minutes to see if we lose it for good.

(Five minutes later).
Mickey: OK Mate, I don't think its coming back. Can we alter to 270 and head over to the next line?

Mate: Roger 270 Mickey, but the last time we were out here she started booming in just after we altered course — perhaps if we had gone on just a bit farther . . .

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* Our range consoles were modified in-house to allow two new codes, "S" and "T", to be defined. These codes correspond to exclusive pulse spacings of 161 and 174 micro seconds respectively. This ensured interference free operation in an area occupied by other MRS users. More details can be found in (Casey, 1981).

(Mickey felt the slight roll of the vessel as *Jubilee* swung into her new course. His eyes were locked onto the status light of the Mini Ranger which had been off for some time now. Sure enough moments later the light fluttered once or twice and then burned continuously).

Mate: Damn! There it is again! We should have held our course Mickey, then we could have taken another fix or two on that line instead of having to come back later sometime to finish it off.

Mickey: There's definitely something odd here.
(aside) It's as though the machine works better when we're steaming at 90° to the signal path. But that's impossible since we're using an omni directional antenna — very strange.

Strange perhaps but quite explainable. The problem as Mickey suspects is with the "omni" antenna, but the real problem is with his interpretation of that term. An omni antenna will receive signals from all directions — that fact qualifies it for the name. The catch however is that it does not *receive* equally well from all directions and this is precisely the root cause of the frustration our two heroes are suffering. The omni-directional antenna has a *preferred direction* and this fact can be exploited by well prepared hydrographers to maximize their coverage.

Figure 9 shows a plot of signal strength vs. R/T elevation angle for one of the codes. Two things are apparent from this diagram. For one, the signal strength decreases as the elevation angle increases and for another, the directions 0°, 180° are much more sensitive to the elevation changes than are the 90° and 270° directions. This suggests a preferred direction to the "omni" antenna.

The following diagrams should make this clearer. Figure 10 shows frequency plots of observed signal strength and rotation angle. Note that these values were recorded over a series of elevation angles and rotational settings* and are not meant to represent the distribution of signal strength readings for each of the settings. What is important is the proportion of high (>8) readings. The 90-270 pair had 71% in this range whereas the 0-180 had only 21%. This is clearly a substantial gain and it shows that there is definitely a preferred direction to the omni antenna. Evidence of this effect can be seen in Figure 11 (Mortimer 1972). This is the polar radiation pattern for a Trisponder system's omni directional antenna and it clearly shows this same bias.

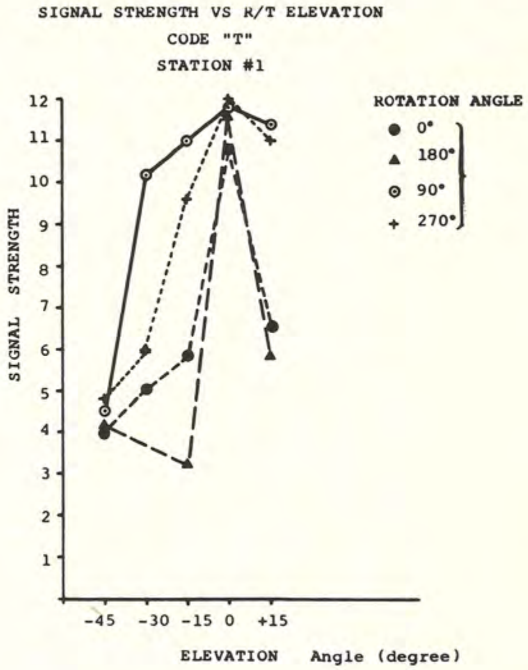

Figure 9

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* The R/T unit was rotated about its vertical axis and readings recorded at 0°, 90°, 180° and 270°. At each of these settings the unit was elevated from 0° to ±45° in 15° increments.

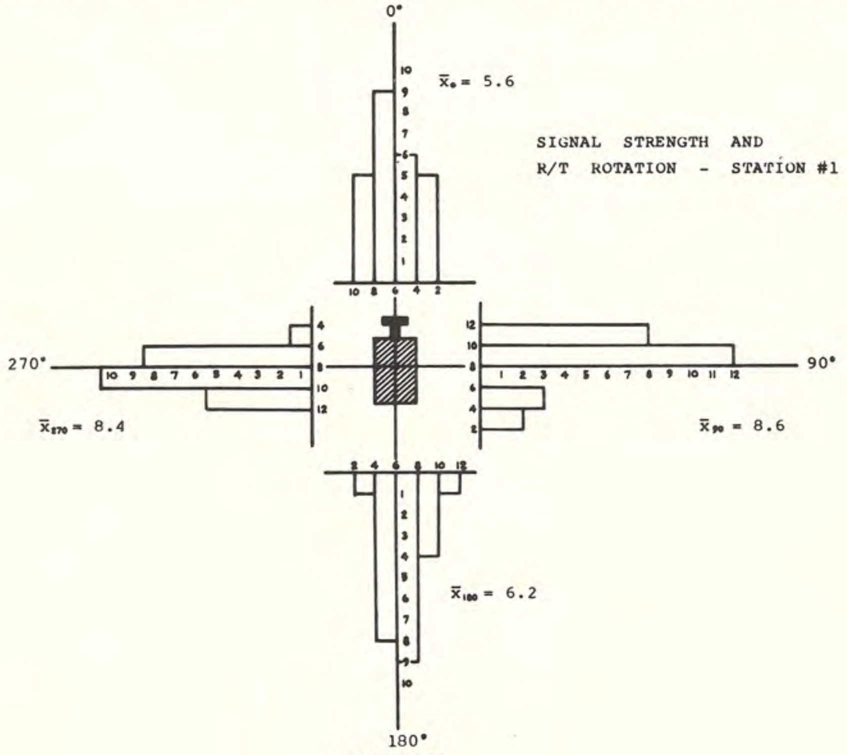

Figure 10

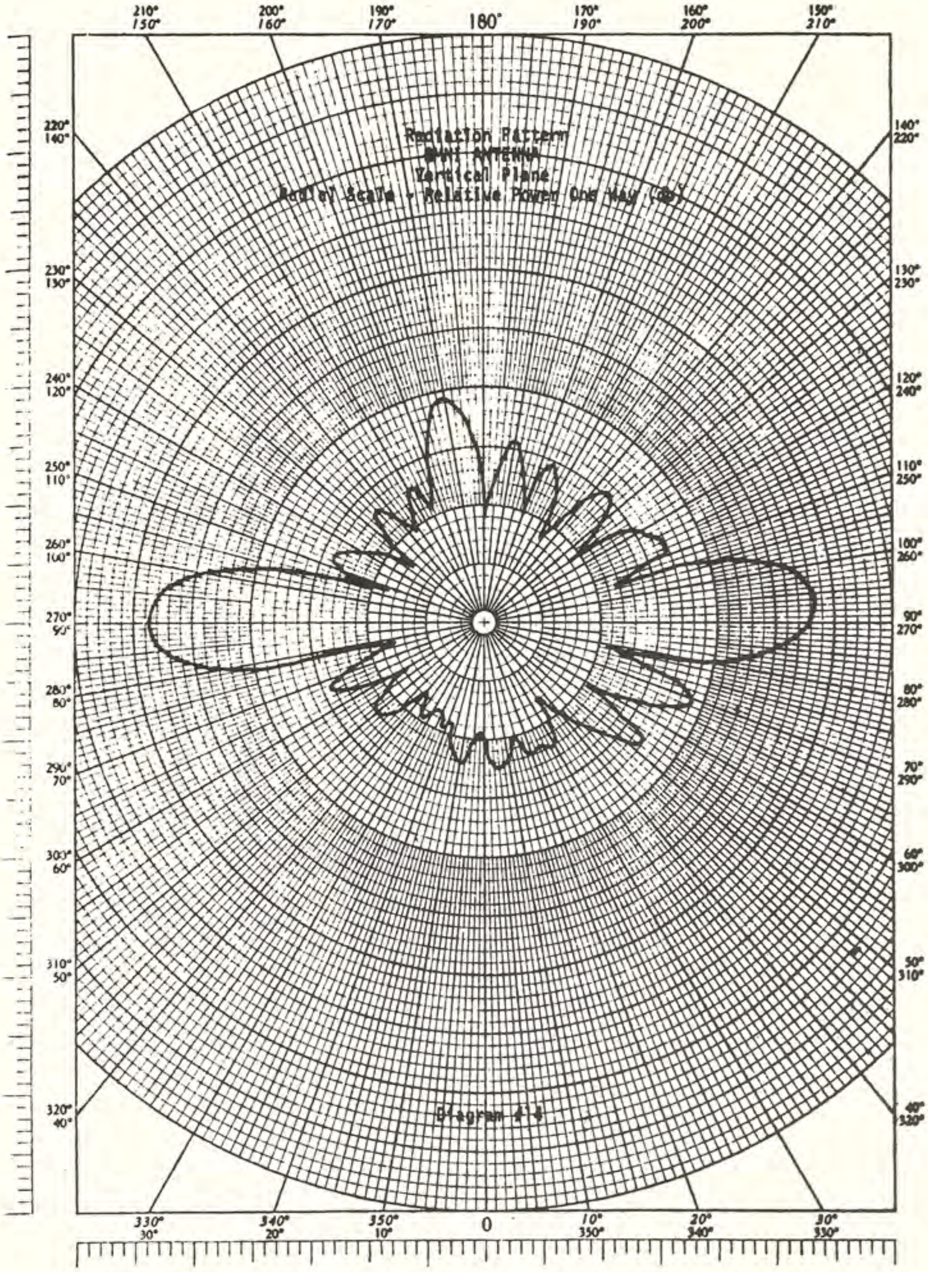

Figure 11

Since *Jubilee's* R/T unit was fixed in place to face forward the signal from the transponder was received along the units poor plane when she was running lines shoreward. Once the signal strength fell below the threshold level the "signal" was lost and the line terminated. However once *Jubilee* swung over onto an orthogonal course the signal was enhanced by being received along the good plane, the threshold level was surpassed and the "signal" regained.

Now if Mickey could repoint his R/T unit so that he was always receiving the signal along the good plane he could increase the usable range of his system by a considerable amount. A remote controlled rotator such as used for pointing television antennas might be an ideal solution. In this way pointing would be optimized and Mickey would be assured that once the signal was lost, maximum range had indeed been reached and he was not being plagued by some sinister force which was trying to ruin his survey!

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Charting the Beaufort Sea

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Victoria, B.C.

With the major field effort of the Canadian Hydrographic Service (CHS) being directed towards surveys in the Beaufort Sea this year, it is timely to look at the history of the exploration and hydrographic surveys in that area.

The history of the exploration of the Beaufort Sea is an integral part of the history of the search for the north-west passage. This search for a shorter sea route to the Pacific from Europe was a dream of seafarers for centuries.

Initially the search was motivated by commercial interests, but in the nineteenth century the motivation swung from the merchants to the scientists in an aspiration to explore and investigate the complexities of the north.

The Beaufort Sea lies on the south side of the Arctic Ocean on the north coast of Alaska and northwest coast of Canada. It is defined by Prince Patrick Island, Canada, at the northeast end, and Point Barrow, Alaska, at its western end (1). This wedge shaped area, lying as it does at the western end of a northwest passage, became the goal of the explorers from the east and later the starting point for explorers attempting a west to east passage.

To place the immensity of the area in perspective, it is somewhat larger than the combined area of the five Great Lakes with Great Slave and Great Bear Lakes thrown in for good measure (2).

It was named in 1826 by Sir John Franklin, R.N., for his friend Captain (later Admiral) Sir Francis Beaufort, Hydrographer of the British Admiralty (1), the same Beaufort who gave us the Beaufort wind and weather scale and who was "one of the greatest figures in the history of the navigational sciences" (3).

By the mid-eighteenth century a succession of failures from the east to find the north-west passage had discouraged further efforts, and it fell to Sir John Barrow, Secretary of the British Admiralty, supported by Sir Joseph Banks of the Royal Society, to rearouse interest in the passage in the early nineteenth century. This interest was scientific rather than exploratory, and in the period 1818 - 1849 a number of expeditions produced more knowledge of the Arctic than had been achieved heretofore (4).

The first major expedition to the Beaufort Sea was headed by Captain John Franklin, R.N., accompanied by Lieutenant Back, R.N., Dr. Richardson, and Mr. Kendall. This was Franklin's second expedition to the Arctic and it left U.K. in 1825, returning in 1827. Their objective was continued exploration of the coast from Coppermine to Icy Cape, Alaska, where Captain Beechey's *HMS Blossom* was expected (5).

The party travelled to New York, hence overland to Fort Chipewyan and followed the Mackenzie River to its mouth, arriving there on 18 August 1825. They wintered at Fort Franklin on Great Bear Lake, and the following year Franklin and Back went west from the Mackenzie delta to Return Reef, Gwydyr Bay, Alaska, while Richardson and Kendall, in the boats *Dolphin* and *Union,* journeyed east to Coppermine and thence to Fort Franklin on foot (5).

The intended rendezvous between Franklin and Beechey did not take place as Franklin turned back at Return Reef six days before a boat from *Blossom* reached Cape Barrow, some 160 miles to the west.

In 1826 the Hudson's Bay Company decided to send out two of its experienced men, Peter Dease and Thomas Simpson, to complete the coastal survey of the mainland coast. After a 2,000 mile overland journey from Fort Garry (Winnipeg) on the Red River, Dease and Simpson reached the mouth of the Mackenzie and pushed westward along the coast past Return Reef until stopped by ice at Cape Simpson, this Cape being named after George Simpson, Governor of all the HBC Territories (6). From Cape Simpson, Thomas Simpson set out on foot with a small group and reached Point Barrow on foot on 4 August 1837.

Thus the mainland coastline of the Beaufort Sea from Cape Barrow to Cape Bathurst was completed.

In 1845 the Admiralty mounted the Franklin expedition to attempt the navigation of the north-west passage. It was realized that the passage was of negligible commercial value, but nonetheless, considerable prestige would accrue from its successful navigation. Moreover, the learned societies in England welcomed and supported the opportunity of obtaining extensive Arctic observations and a considerable quantity of scientific instruments was aboard the ships of the expedition. The expedition was equipped for a three year stay in the Arctic, so that serious concern for it was not felt until 1849. Then public interest began to mount and numerous relief expeditions were launched until 1859, when definite news was discovered to explain the fate of the Franklin party. Although the principal object of the voyages launched during this period was the search for Franklin, they added an immense amount of new knowledge to the cartography of the Canadian Arctic (7).

The expedition was last sighted making for Lancaster Sound on 26 July 1845, and in 1848 a search was begun.

The 1848 expeditions included HM ships *Herald* (Captain Kellett), and *Plover* (Commander T. Moore), which were sent to survey Bering Strait and to send boats eastward to search for Franklin. Boats from *Plover* under Lieutenants Pullen and Hooper left Wainwright, Alaska, in July 1849 and reached the Mackenzie Delta in September of that year. They wintered at Fort Simpson and the following year reached Cape Bathurst.

After the unsuccessful search expeditions of 1848, a further six search parties were sent out in 1850, including, to the west, by the way of the Straits of Magellan, the Pacific Ocean and Bering Strait, HM Ships *Enterprise* (Captain Collinson) and *Investigator* (Commander McClure). *HMS Plover* (Captain Kellett) remained in Bering Strait to serve as a depot ship for the expedition.

From the time Collinson's two ships passed Icy Cape, Alaska, nothing was heard of this expedition till 1853.

On passage the *Enterprise* and *Investigator* became separated in the Pacific. McClure reached Bering Strait a scant week ahead of

Collinson and pressed on into the Arctic. He coasted to Cape Bathurst and then headed northeast and was beset in Prince of Wales Strait. Spring sledge parties surveyed the northeast coast of Banks Island. The ship was released from the ice in July 1851 but was unable to proceed farther north through Prince of Wales Strait, and so McClure came south and west about Banks Island, reaching the north shore of Banks Island in September, where the ship was frozen in permanently in Mercy Bay. McClure sledged to Winter Harbour on Melville Island in April 1852, and there he left a message which eventually saved him. The ship was iced in all that year and scurvy broke out. As the crew was about to abandon ship and sledge out to the east, Lieutenant Pim of *HMS Resolute*, one of the search ships which came in from the east, arrived. The *Investigator* was abandoned and the crew evacuated to the *Resolute* and thence eastward to England, thus accomplishing the north-west passage, albeit partly on foot. Despite claims and counter-claims, McClure and his crew were awarded the Admiralty prize of £10,000 for the discovery of the north-west passage.

Thus by 1852 the remaining unsurveyed coastline of the Beaufort Sea was that of Prince Patrick Island.

That year the British Government set out its last and greatest search expedition under the command of Sir Edward Belcher, a Canadian. The objectives were twofold, primarily the expedition was to continue the search for Franklin, and secondly, to search for Collinson and McClure, for whose safety there was mounting anxiety. HM Ships *Resolute* and *Intrepid* under Captain Kellett, lately of *HMS Plover* were to proceed to Winter Harbour, Melville Island, but due to ice only got as far as Dealy Island. During the fall of 1852 Lieutenant Meecham, while laying down caches for spring surveying and search parties, discovered McClure's message, giving his location on Banks Island, which eventually saved the crew of *Investigator*.

In the spring of 1853, Meecham, on a sled journey of 1,006 nautical miles, became the first European to set foot on Prince Patrick Island and charted the island south about to Discovery Point. Lieutenant McClintock of the same party, on an epic sled journey of 1,200 nautical miles, travelled north about the island as far as the northwest point, Cape Leopold McClintock.

By 1859 the Franklin search had for all practical purposes come to an end and the period of intensive surveying of the Canadian Arctic also ended. Most of the firsts had been achieved, and in particular, the Beaufort Sea coastline had been almost completely charted.

McClure had proven the existence of a north-west passage, but at that time its commercial application was worthless and no further major expeditions were outfitted. However, the challenge of making the passage by ship remained for the explorer, and in 1903 Roald Amundsen sailed from Norway in a forty-seven ton herring boat, the *Gjoa* and eventually completed the passage in 1906.

During the period 1913 to 1918 the Canadian Arctic Expedition under the leadership of Vilhjalmur Stefansson set out from Collinson Point, Alaska, late in March 1914. The party made a 96 day journey on sea ice and eventually reached shore near the northwest extremity of Banks Island. From their landfall they travelled south and en route corrected many errors of McClure's chart. They wintered near Cape Kellett, Banks Island. The following spring they struck out over the ice again and reached latitude 76°30'N., longitude 133°W., before returning east to reach Prince Patrick Island, where they surveyed the gap between Discovery Point and Cape Leopold McClintock thus closing the final gap in the Beaufort Sea coastline.

Due to illness Stefansson had to leave the expedition in 1917, and the following spring Storker Storkerson and a party camped on a large ice floe about 180 miles off the Alaskan coast, and for six months drifted in the Beaufort Sea, returning to land in November.

These expeditions by Steffansson and Storkerson disproved the existence of any land in the Beaufort Sea.

There was little activity in the Beaufort Sea between World War I and II, though Tuktoyaktuk Harbour was surveyed in 1930-32, and some reconnaissance sounding was done between Herschel and Pullen Islands in 1933.

During World War II the Royal Canadian Mounted Police schooner *St. Roch* (Sergeant H. A. Larsen), completed the northwest passage from west to east on a duty patrol, completing the voyage in two years, and in 1944 the same ship and master made the return voyage from Halifax to Vancouver in a single season.

The US Coast and Geodetic Survey began detailed hydrographic surveys of the Arctic coast of Alaska in 1940 and completed this work in 1952.

The first deep-draught ship to make the north-west passage was the Canadian icebreaker *HMCS Labrador* (Commodore Robertson), which in 1954 made the west to east passage, and, incidentally, became the first vessel to circumnavigate the North American continent (10).

From information provided by masters in the Hudson Bay Company service, the CHS published several large scale charts of the more important harbours and anchorages in use in the early 1950's.

This slow approach to charting the Beaufort Sea was quickly changed in 1955 when military considerations of the defence of the North American continent dictated construction of a defence warning system across the Arctic. The Distant Early Warning (DEW) line sites had to be built and supplied, and the inadequacy of existing charts necessitated prompt action.

The main impetus was American, and in addition to the USHO teams which surveyed the approaches to the DEW line sites, the *USS Requisite* and *USCGS Storis* sounded the proposed shipping route from Herschel Island east to Shepherd Bay at the southwest end of the Boothia Peninsula (8).

By 1957 the charts of the Beaufort Sea showed a safe shipping track west from Point Barrow and the CHS had completed a two season standard survey of Tuktoyaktuk Harbour.

In 1960 the Canadian icebreaker *CCGS Camsell* commenced operations in the western Arctic and hydrographers onboard added to the charts of the Beaufort Sea while the ship carried out her ice-breaking duties in support of the supply ships. However, in 1962, the CHS commissioned their own ship, *CSS Richardson* for work in the Arctic. For the first time the CHS had their own vessel from which to conduct hydrographic surveys, and no longer had to depend on other agencies providing ship time on an opportunity basis.

Mention must also be made of the efforts of the Polar Continental Shelf Project (PCSP) which was established in 1959, and which developed methods of sounding through ice in areas inaccessible to ships and also pioneered the use of hovercraft as sounding vehicles where its advantages in working on exposed coasts, subject to frequent changes in weather and ice cover, made it an ideal craft (9).

The passage of the supertanker *Manhattan*, from the east to the oil fields of the Alaskan slope to test the feasibility of the commercial use of the north-west passage, heralded yet another era of activity in surveying the Beaufort Sea. Her escort, the Canadian icebreaker *Sir John A. MacDonald* discovered a previously uncharted shoal in the Beaufort Sea, which had until then been considered a safe area for normal draught vessels. This shoal, or pingo-like-feature (PLF) was later named the Admirals Finger and its impact on charting the Beaufort Sea was immense and called for a complete re-evaluation of the existing charts. In 1970 the CHS mounted a major surveying effort in the area. The *Parizeau* and *Baffin* with their nine launches, worked offshore north of the Tuktoyaktuk Peninsula and found many more PLF's in the course of their work. This program continued with the *Parizeau* alone working out of Victoria each year for the 1971, 72 and 73 field seasons.

In 1976 *Parizeau* was damaged by ice prior to reaching the Beaufort Sea and in 1977 her place was taken by *Pandora II* on charter to CHS. She has undertaken the western Arctic program of the Pacific Region in the 1977, 78 and 80 seasons though due to ice conditions and the configuration of the Decca Chain the 73, 77 and 78 seasons were mainly spent in Amundsen Gulf.

The culmination of this work is this year's program of charting a ten mile wide corridor through 170 miles of the PLF area of the Beaufort Sea.

Oceanographic and Natural Resource charting was also undertaken during this period, commencing in 1970 when the *Hudson,* on the final leg of her historic Hudson '70 cruise, worked the Beaufort Sea. The honour of the first circumnavigation of the American continent fell to her on this cruise.

Modern technology has eased the task of the navigator, hydrographer, and scientific explorer in the Arctic. Satellite navigation, electronic survey positioning systems, ice reconnaissance flights, weather reports, radio communication, and the work-horse of the Arctic, the helicopter, are standard requisites for most work. But the isolation, the logistics problems, the rapidly changeable weather, and ice conditions, still have to be met and conquered.

The scientific exploration of the Beaufort Sea is not yet completed, though many of its mysteries have been revealed. We upon whom the task of completing the work falls must never forget the men whose names appear in this brief history, and who have passed on to us a heritage of courage and devotion to duty in the face of immense tribulations which we today, with our modern equiment and facilities, find hard to imagine.

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The Marine Arctic Route Reconnaissance System

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PROLOGUE

It's cold out, -30° C for weeks on end. The water is ice-covered, and will be for most of the year. Nature's elements combine to exert their particular form of persuasion. But an exploration company has discovered oil in the Arctic and, in order to get the product to market, underwater pipelines need to be built and ships need to penetrate further than ever before into poorly charted areas.

It's mid winter, a Hercules aircraft lands and a Cat-train is unloaded onto the Arctic ice. The electronic gear on-board the train moves along the proposed pipeline crossing, stopping every so often to collect information that will provide a detailed continuous bottom profile of the sea floor.

The pipeline crossing completed, the train moves on to survey the harbour approaches, so that large tankers can safely load their cargo. This time a search for navigation hazards is more important than complete and precise bottom coverage. The electronic gear on-board the Cat-train is designed to handle this aspect of the survey as well.

The data is processed on board the Cat-train and, when the surveyors are sure the job is complete and accurate, the Hercules arrives and returns the party to civilization. Then the information can be quickly distributed to the interested parties, and details of the next foray can be planned.

Introduction

For many years now the Canadian Hydrographic Service has been conducting Arctic surveys. A short working season, changing ice conditions, wind and extreme cold, all present a unique challenge for the hydrographer. The Arctic environment affects the operation of both the surveyor and his equipment.

The broadening search for oil and minerals in the Arctic in recent years, has meant that hydrographers must increase activities in the north to provide safe passage for vessels that are helping to push back Canada's frontiers in their attempt to retrieve our northern wealth.

Many of the present charts are based on spot soundings collected through the ice from helicopters or tracked vehicles. Though satisfactory for providing an overall general picture of the bottom, this technique does not provide adequate coverage in critical areas where shoals may affect shipping lanes or where bottom detail is required to lay oil and gas pipelines.

In an attempt to fill this void, the Marine Arctic Route Reconnaissance System (MARRS) was proposed by industry as a cost and time efficient method of conducting Arctic hydrographic surveys. The proposal suggested that a sonar array could be lowered through the ice, and a steerable 'pencil beam' could be rotated horizontally through 360°, and vertically through 90°, to provide

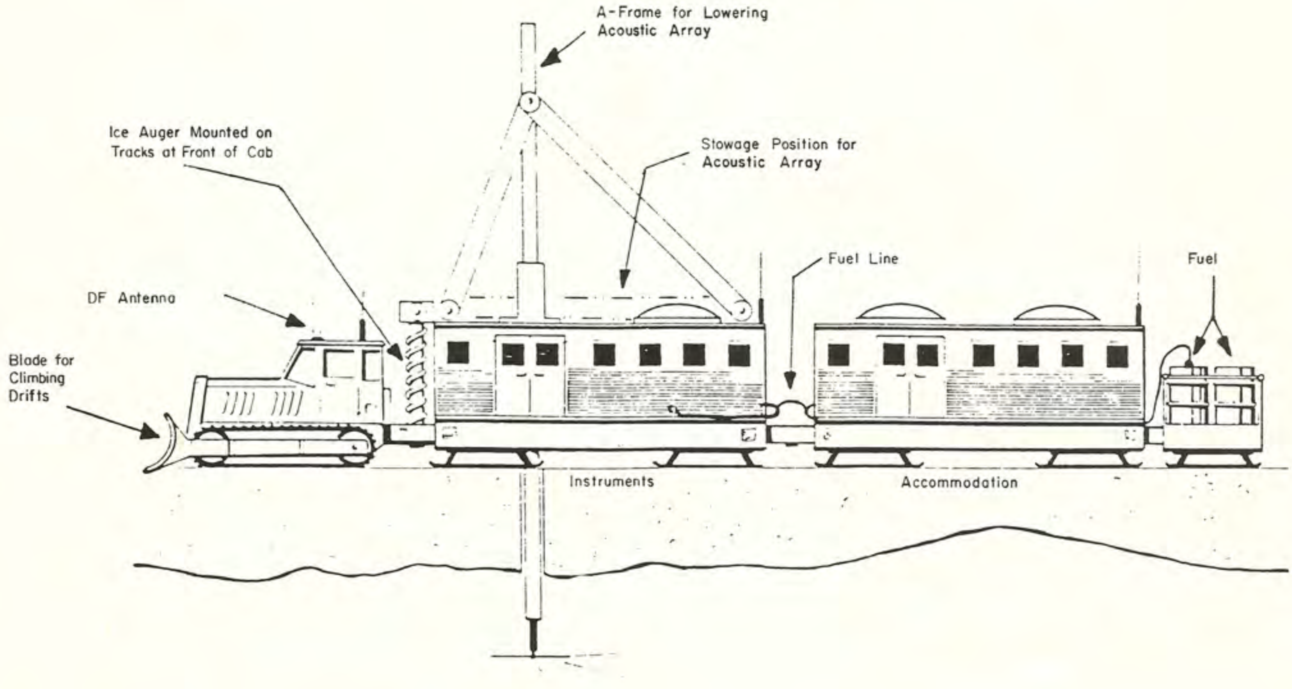
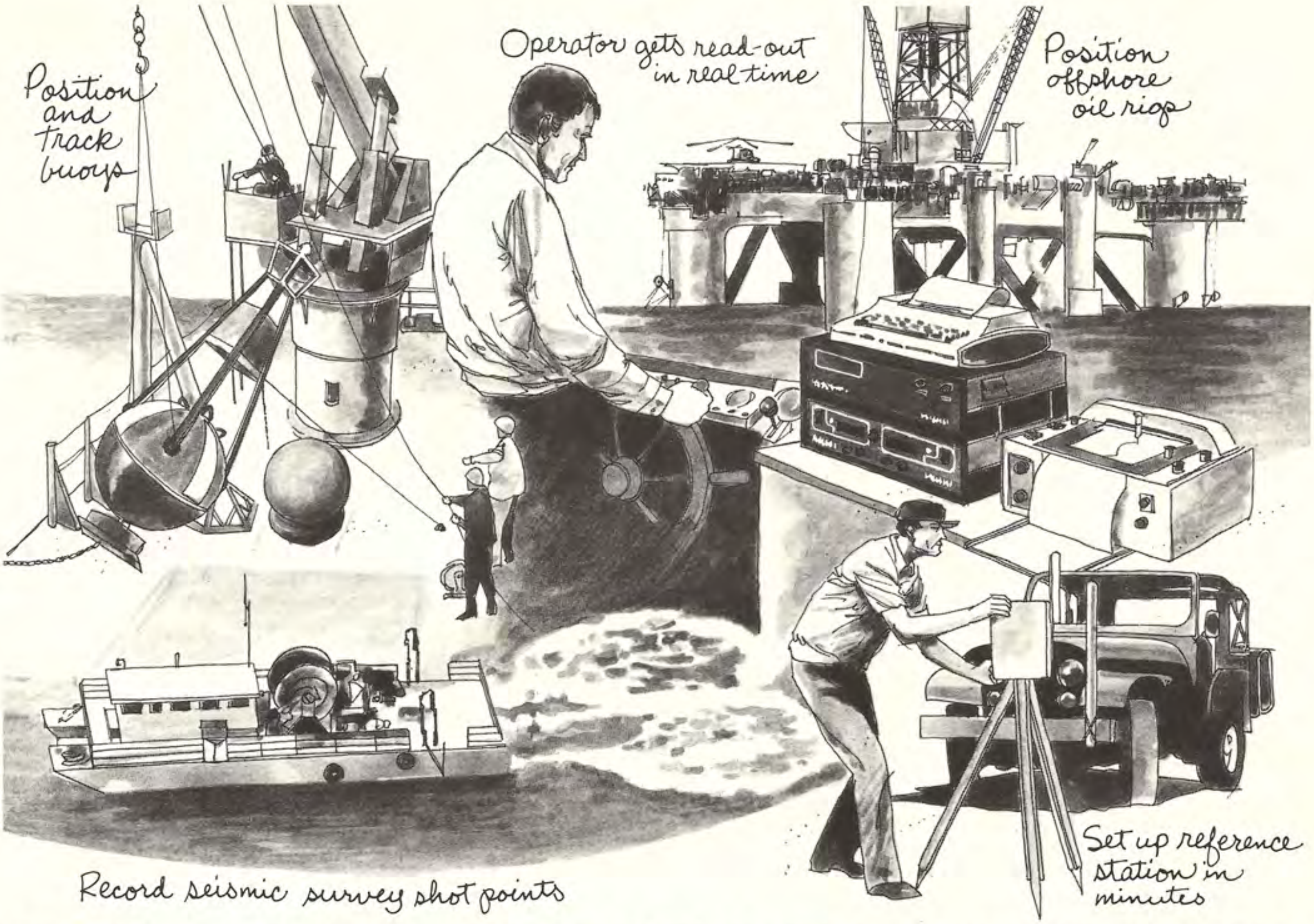


Figure 1: Survey Train (from MARRS Unsolicited Proposal)



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completed bottom coverage. The range was predicted to be ten times the depth to a maximum of 1000 metres for a mud bottom and 1800 metres for a rock bottom.

The complete system would be installed in a survey train consisting of a tracked vehicle to tow the train, an instrument van, an accommodation car and a fuel sled (see Figure 1). The train would be deployed and supported by aircraft, and could operate as long as there was an ice platform. A visual CRT display would be used to locate hazards during reconnaissance surveys of shipping channels. By recording the echo returns on magnetic tape, post processing could provide high density bathymetric data in areas, such as pipeline crossings, where accurate and complete cover is important.

MARRS Contract

The MARRS proposal was received in May 1976. In October, 1977 a contract was let to Marinav Corporation, Ottawa, to build and test a prototype MARRS sonar system. The design, manufacture and initial testing was sub-contracted to C-Tech Limited in Cornwall.

The design specifications were:

Operating range	$>$ 1 kilometre
Radius of precise coverage	$>$ 1.5 x depth
Radius of reconnaissance coverage	$>$ 10 x depth
Angular resolution and accuracy	1 degree
Slant range resolution and accuracy	1 metre

By the end of 1977 the study phase of the contract was completed, and Marinav recommended a dual frequency system — 68 kHz for the precise coverage and 30 kHz for reconnaissance coverage. A study of the dual frequency approach concluded in mid-1978. Due to high costs, the Canadian Hydrographic Service opted to proceed with the construction of a 71 kHz single frequency system. The MARRS equipment was operational in June, 1979. The contract was brought to a close when the system was field tested in Bedford Basin, near Halifax.

Survey Method

The MARRS is based on a three-dimensional concept. A small 'pencil beam' scans the bottom, measuring the slant range signal times for each one degree in elevation. The two-way travel times are converted to slope distances and the vertical angle is used to compute horizontal range and depth. On the ice surface, the position and pointing (azimuth) of the array are measured, to give a range-azimuth position for each depth (see figure 2).

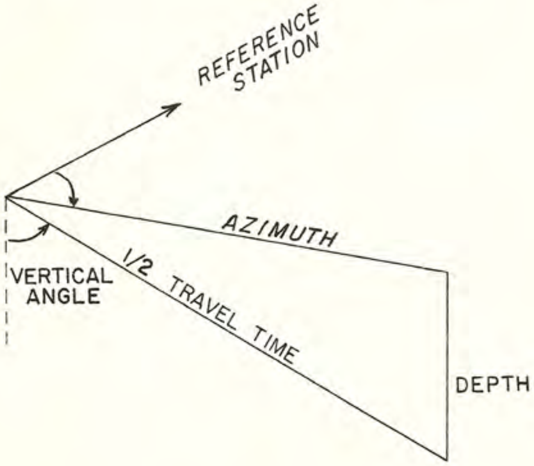

Figure 2: Three-dimension MARRS Concept

The underwater transducer array consists of two transducers, each about 160 cm long, mounted perpendicular to each other. The transmitting transducer lies horizontally, and sends a signal with a one degree horizontal beam width, and with a vertical beam width of 30 degrees (see figure 3).

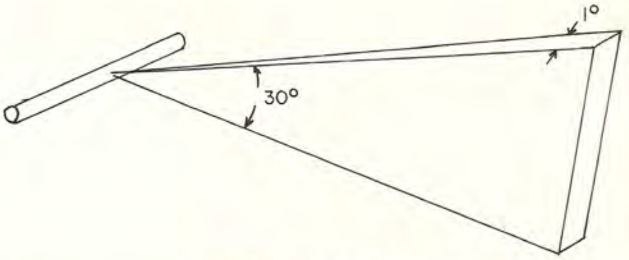

Figure 3: Transmitted Beam

The receiving transducer hangs below the transmitting transducer in the vertical plane, and has a one degree vertical beam width. It electronically scans 16 degrees up and down, by phase shift, to cover 32 degrees vertically in one degree steps (see Figure 4).

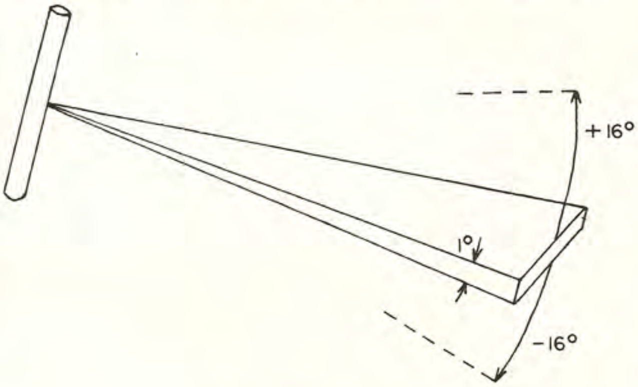

Figure 4: Receiver Beam

The overlap of the transmit and receive beam patterns forms a square one degree by one degree beam. When the centre line of the transmitted beam is pointing 15 degrees from the vertical, the receiver scans the bottom from directly below the transducer to 30 degrees away. Mechanical steps aim the transmitted beam at 15, 45 and 75 degrees from the vertical, for complete bottom coverage along one pointing (see Figure 5).

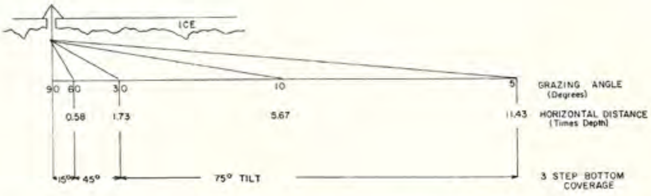

Figure 5: MARRS Bottom Coverage

Complete bottom coverage is achieved by rotating the array, in one degree horizontal steps, through 360 degrees.

Equipment Description

The two transducers, transceiver, and Tektronix CRT display were supplied by C-Tech Limited. Their description has been extracted from the 'Engineering Evaluation Report' prepared by C-Tech as part of the MARRS Final Report.

Transmitting Transducer (Projector)
The projector is constructed of an aluminum frame work that houses the transducer elements. The frame work is supported within a heavy wall aluminum tube. The active elements are exposed through an elongated slot in the tube. The assembly is completed with the mounting of two hard anodized aluminum end caps and the active portion is covered by a rubber tube (boot) which is banded to the end caps to make it water tight. Electrical connections to the projector are via a single, multi-conductor cable passing through a gland in one end cap.

The array consists of 372 ceramic elements mounted on stave bars; each element has its own front mass which couples to the water via the rubber boot. The array is designed and built symetrically about its central axis and the elements are wired in groupings to provide optimum shading to reduce lobes when driven from 10 transmitting sources. Each half of the array has five different groupings of elements (for a total of 10). The assembled projector is 7.94 cm in diameter by 160 cm long with 15.2 metres of cable. The assembled weight is 17 kilograms in air.

Receiving Transducer (Hydrophone)
The construction of the hydrophone is similar to that of the projector. The noteable exceptions are the use of 4 electrical cables and 124 active elements.

Each of the 124 active elements are connected through an impedance matching transformer to a pair of conductors in a cable. By this means all 124 elements are connected to the preamplifiers in the transceiver. This technique allows the formation and steering of the receiving beams. The completed hydrophone is 7.94 cm in diameter by 162 cm long with 4 cables 15.2 metres long. The assembled weight is 35 kilograms in air.

Electronics Transceiver
The electronics transceiver is of solid state construction, utilizing a modular concept made up of 55 printed circuit assemblies, 10 transmitter modules and associated power supplies. The electronics are housed in a cabinet that is 134 cm high, 57 cm wide, and 44 cm deep. The transceiver weighs 104 kilograms. The transceiver contains the preamplifiers, the beamformer, the phasing and suming circuits, the transmitter, the power supplies and the timing, scanning and sweep deflection circuits for the real time display.

Visual Real Time Display
The display is a Tektronix model 613 variable persistence display that utilizes the "A" and "Y" deflection outputs from the transceiver. The "Z" axis is intensity modulated by the echo information. The display is 28 cm high by 33 cm wide by 53 cm deep and weighs 19.5 kilograms.

Tape Recorders
The magnetic tape recorder obtained through the MARRS contract is a Sangamo Sabre VII, 7 track, reel to reel system. It uses l.3 cm tape on a 38 cm reel. There are seven record/replay speeds. It measures 66 cm high, 48 cm wide and 30 cm deep and weighs 50 kilograms.

The magnetic tape recorder used for the Arctic tests is a Hewlett Packard 3960A Portable Instrumentation Recorder. It has four tracks and uses 0.64 cm tape on an 18 cm reel. The unit measures 48 cm by 38 cm and is 19 cm high. It weighs 23 kilograms.

Pre-recording/Data Processing Unit
The pre-recording/data processing unit was built by Marinav Corporation. It provides tilt and azimuth information to the tape recorder through manually operated front panel switches. The tilt data is also sent to the CRT display. The data processing section of the unit deciphers the tilt, azimuth and timing information from the tape and digitizes the recorded signal for post-processing by a computer. The unit is 13 cm high, 43 cm wide and 23 cm deep.

Array Deployment System
The transducer deployment system (see figures 6 and 7) was built by the Engineering Services Section of Environment Canada at the Canada Centre for Inland Waters. The above ice portion of the structure is a 1.2 metre high tripod. The vertical support is a 10 cm diameter aluminum pipe in various lengths. A survey theodolite is mounted on top of the pipe for measuring horizontal angles and pointing the transducer array.

Figure 6: MARRS Deployment System Tripod

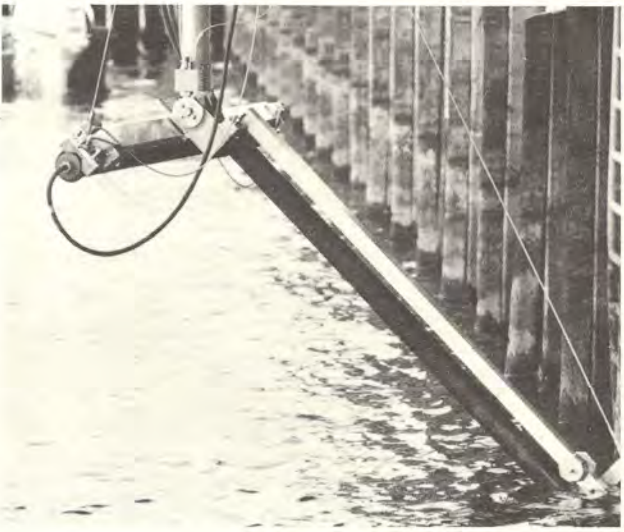

Figure 7: Transducers Deployed

System Accuracy
The MARRS was designed to have an operating range of more than one kilometre with an angular resolution and accuracy of ± one degree and a slant range resolution and accuracy of ± one metre.

The system was designed to operate from a tracked vehicle. The self-noise level of the MARRS plus the vehicle is an unknown parameter, but Marinav considers that it is below the noise level of a 25 knot wind over shorefast one-year ice. Marinav lists calculated maximum slant ranges at 71 kHz, for different bottom types and grazing angles, in Progress Report 5. Figure 8 shows the results graphically. A lower noise level should theoretically increase the slant ranges.

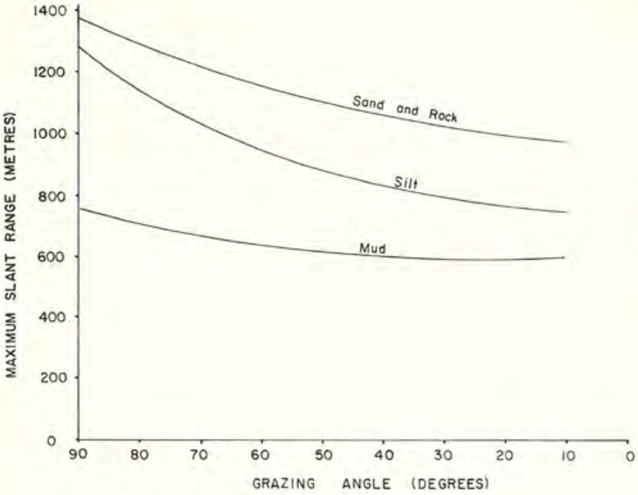

Figure 8: Maximum Slant Ranges

The minimum slant range is at the near-field/far-field interface, the point at which the one degree beam is properly formed. For the MARRS this distance is 104 metres. Data can be collected over shorter ranges, but beam width and beam pattern are uncertain.

The angular accuracy and resolution are the major precision drawbacks of the system. One degree is 17.5 metres wide at one kilometre. This problem is compounded by the shallow grazing angles at long ranges. A 1000 metre slant range beam, intersecting a flat bottom at ten degrees, would cover an area 100 metres long by 16.6 to 18.4 metres wide (see Figure 9). The depth would be 174 metres. The MARRS could receive a possible 130 returns from this area, but all are considered to be right on the centre line of the one degree beam. The bottom would appear to be sloped at ten degrees, with the first returns shallowest.

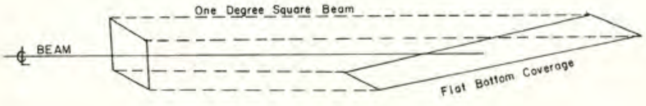

Figure 9: One Degree Bottom Coverage

The depth accuracy due to the ± 1 degree vertical angle resolution is limited to ± 17 metres. The positional accuracy would be ± 21 metres, made up of a vertical angle component (3 metres), a slant range component (1 metre) and a horizontal angle component (17 metres). Figure 10 shows the depth and position accuracy limit caused by the ± one degree verticle angle specification. On a rough bottom, shoaling gives larger grazing angles, but does not improve depth accuracy. The accuracy problem may be compounded even more depending on the ability to precisely point the array.

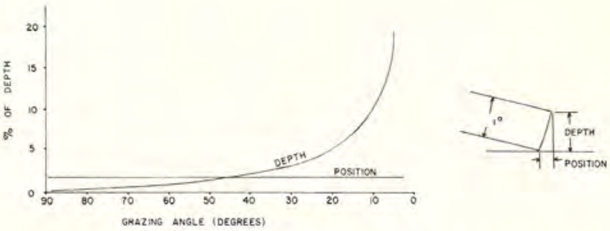

Figure 10: Tilt Angle Accuracy (∓ 1 degree) Flat Bottom

Another source of error, when taking soundings with the transducer pointed anywhere but straight down, is ray-bending. Because the velocity of sound through water changes with depth, the beam is refracted, upward when velocity increases, and downward when velocity decreases.

Arctic ice-covered waters are nearly iso-thermal. Velocity increases of 10 m/sec over a 200 metre depth range are common under non-melting conditions and are mainly caused by salinity. Figure 11 shows the ray-bending effect at a depth of 100 metres for various vertical angle transmissions. The sound velocity ranges from 1436 m/sec at the surface, to 1443 m/sec at a depth of 100 metres. Looking back at the effects of a one degree error in tilt angle, (figure 10), it is evident that ray-bending errors are considerable, even in the Arctic.

The accuracy and error graphs show large inaccuracies in the reconnaissance sector (between grazing angles of 0 and 30 degrees). Unfortunately, most of the MARRS survey area is covered by shallow grazing angles (see figure 5). The 5 to 30 degree sector covers 44 times the area of precise coverage (between 30 and 90 degrees).

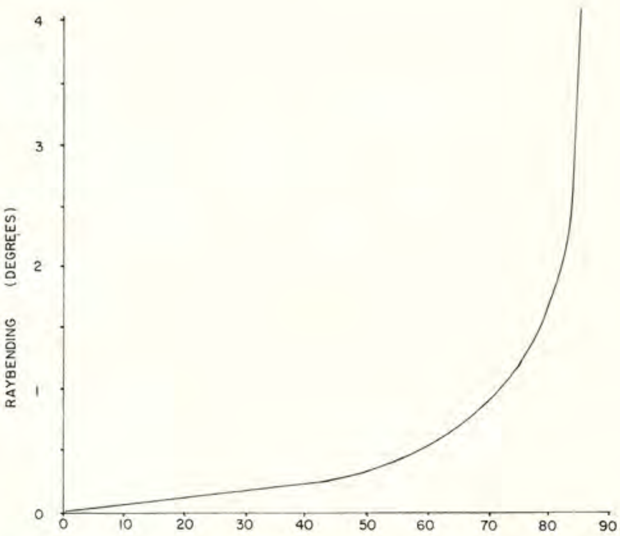

Figure 11: Arctic Ray bending at 100 m Depth

The design limit of the system is a grazing angle of five degrees, because of limited signal return at grazing angles less than five degrees. The use of a ten degree minimum grazing angle, rather than five degrees, reduces the survey area by 75% in water depths less than 100 metres. So it is obvious that the feasibility of the system depends on the usefulness of the shallow grazing angle data. Figure 12 shows the radius of coverage at different depths with the grazing angle or design maximum slant range as limits. The maximum slant range can vary considerably with bottom type and grazing angle. A small section of the graph is shaded where the system depth accuracy would meet Canadian Hydrographic Service Standing Order specifications of 1% of depth in water greater than 100 metres deep.

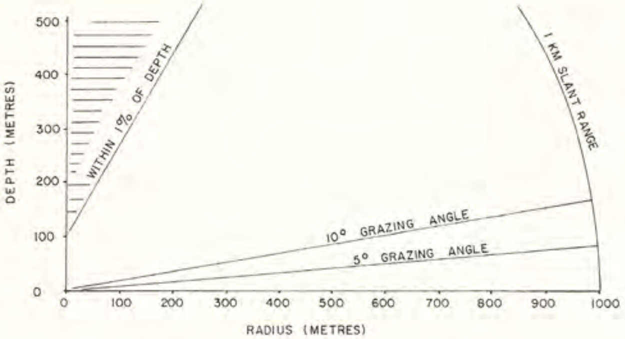

Figure 12: Radius of Bottom Coverage (Flat Bottom)

Bedford Basin Field Test

In March 1979, Marinav conducted a conventional hydrographic survey in Bedford Basin, near Halifax, in the area surrounding a test barge belonging to the Defense Research Establishment, Atlantic (DREA). The survey was plotted at a scale of 1: 2500 with line spacing of 25 metres (see figure 13). Range-range positions were obtained from a Del Norte Trisponder system. The survey launch and crew, and an Edo 9040 echo sounder were made available to Marinav from the Canadian Hydrographic Service, Atlantic Region.

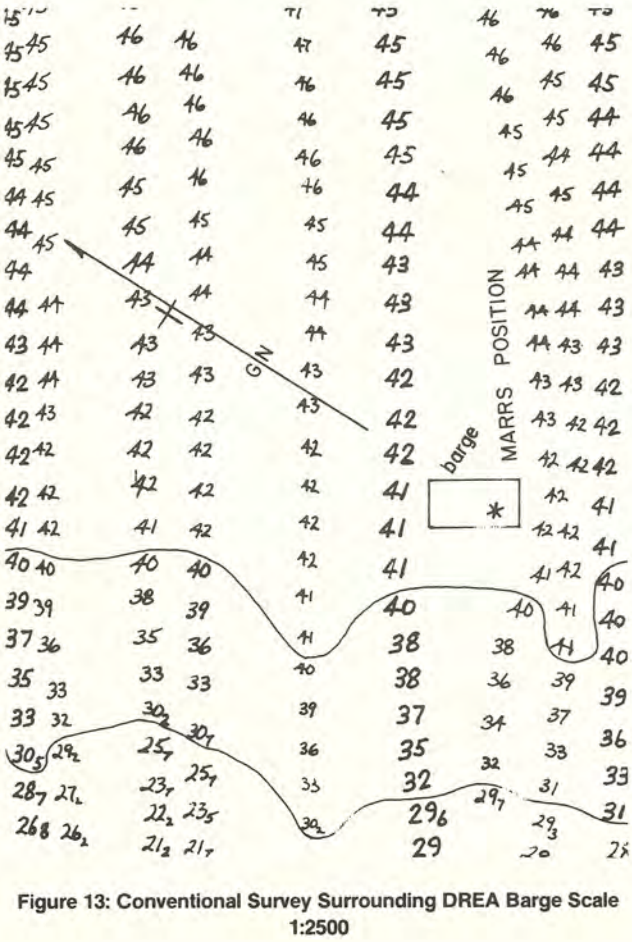

Figure 13: Conventional Survey Surrounding DREA Barge Scale 1:2500

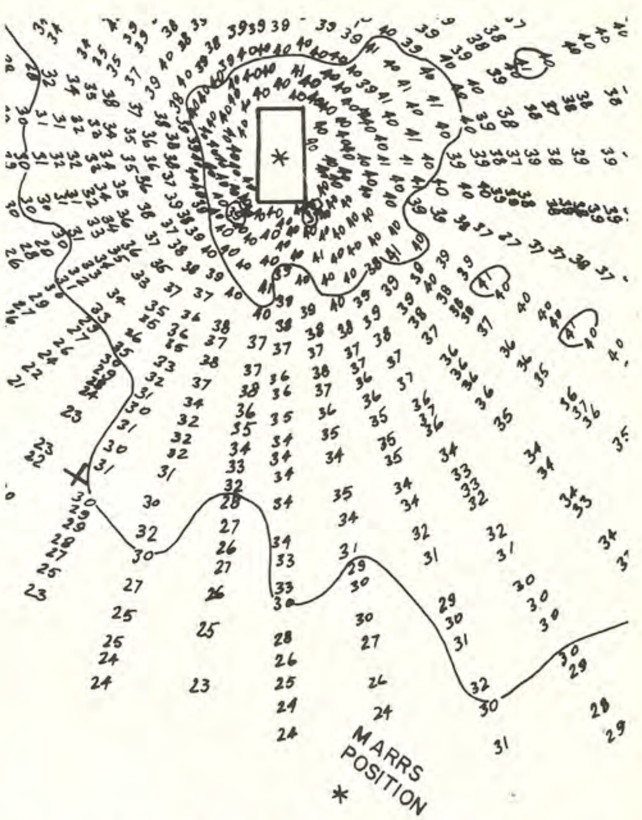

Figure 14: MARRS Data Corrected for Ray-bending Scale 1:2500

The MARRS equipment was field tested by Marinav and C-Tech personnel on July 1, 1979. The transducer array was lowered three metres into the water below the DREA test barge, and data collected every ten degrees of azimuth. The same azimuths were scanned on each of the three tilt angles of 15, 45 and 75 degrees from the vertical. A round of 36 pointings (one tilt angle) took anywhere from one to four hours to complete, with each subsequent round taking less time than the first, as the operators became familiar with the equipment. The 16 by 30 metre barge was securely moored, and the observed position of the sonar array only varied up to half a metre from the mean position. The barge orientation changed by up to 1.2 degrees from the mean azimuth. Pitch and roll, which could have a significant effect at shallow grazing angles, were not measured.

All the depths had tide reductions and sound velocity corrections applied. The sound velocity varied from 1494 m/sec at the surface to 1455 m/sec at 40 metres deep, causing large ray-bending errors for the smaller grazing angles. The CRT display showed the bottom rising to the surface at a slant range of 250 metres. After the ray-bending corrections had been applied during post-processing, there were still large depth differences between MARRS data and the conventional survey (compare Figure 13 and Figure 14). There was no evident pattern to the differences. The error spread in the precise coverage area (up to 70 metres away from the barge) was from one to five metres; the discrepancies in the remaining MARRS data were from one to 18 metres. The MARRS data was consistently shallower, so Marinav decided to adjust all the tilt angles by 3.5 degrees to get deeper soundings, from which they produced a second sounding plot (see figure 15). This resulted in depths that varied from 8 metres too shallow to 10 metres too deep, but again there was no apparent pattern when compared to the conventional survey data. It was impossible to compare the data on the second plot directly with the data on the first MARRS plot, since a different set of data points were selected for plotting. The maximum slant range obtained with the MARRS during the test was 250 metres.

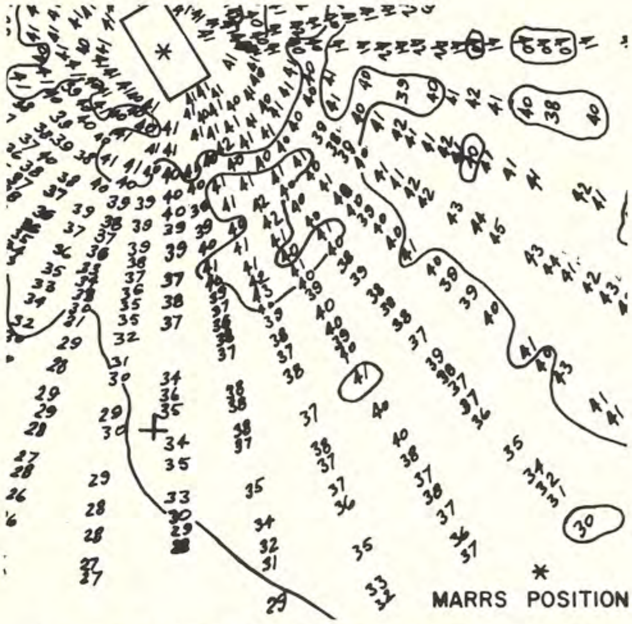

Figure 15: MARRS Data Adjusted by 3.5° Tilt Scale 1:2500

The Bedford Basin test was inconclusive. Because of the limited water depth, the maximum range of the system could not be evaluated. Discrepancies between MARRS data and conventional survey data could be attributed to a number of factors; the non-homogeneous nature of the water, the inability to accurately measure the tilt and azimuth of the array (hence the arbitrary 3.5 degree 'fix'), and the near-field effect. Observers on both sides felt that to bring the test to its logical conclusion, the MARRS had to be tried in the Arctic, under the conditions for which it had been designed. No one knew exactly what to expect from the close proximity of ice and transducer.

Arctic Field Test

In April, 1981, the Canadian Hydrographic Service conducted MARRS field tests near Resolute, NWT. Before the MARRS could be shipped north it required inspection, repairs and testing at C-Tech Labs in Cornwall. During the tests, excessive nose entered the MARRS when the SAbre VII tape recorder was connected to record test data. The noise could not be eliminated or distinguished from real data returns, so the recorder was replaced by a Hewlett Packard 396A four-track recorder for the Arctic tests.

Four Canadian Hydrographic Service personnel arrived in Resolute on April 11. Meals and accommodation were provided by the Polar Continental Shelf Project (PCSP) of the Department of Energy, Mines and Resources (see Figure 16).

Figure 16: PCSP Camp in Resolute

The MARRS test area (see Figure 17) was six kilometres west of Resolute in an area that had been surveyed in detail at a large scale by CHS, Atlantic Region in 1976. This provided a good comparison for data collected with the MARRS. Line spacing was 50 metres, plotted at a scale of 1:5000. (See Figure 18).

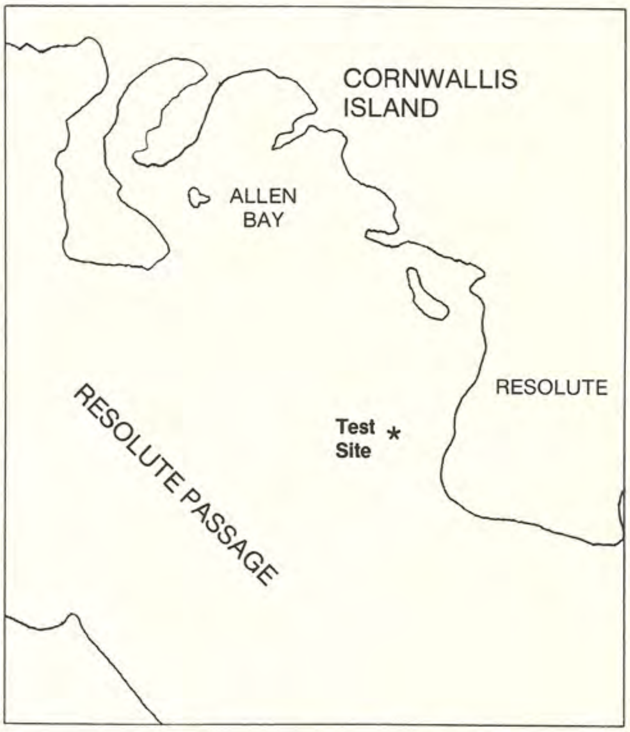

Figure 17: MARRS Test Site Scale 1:250,000

A Modified Bombardier SV 301-D tracked vehicle was used for the tests. It is powered by a four cylinder Perkins diesel with a four-speed manual transmission. An auxiliary generator provides 110 volt power. The overall length of the vehicle is 4.1 metres. It is 2.3 metres wide, 2.9 metres high and weighs 5000 kilograms. The vehicle has a two-man cab in front and a lab, 2.5 metres long, 1.9 metres wide and 1.9 metres high, in back.

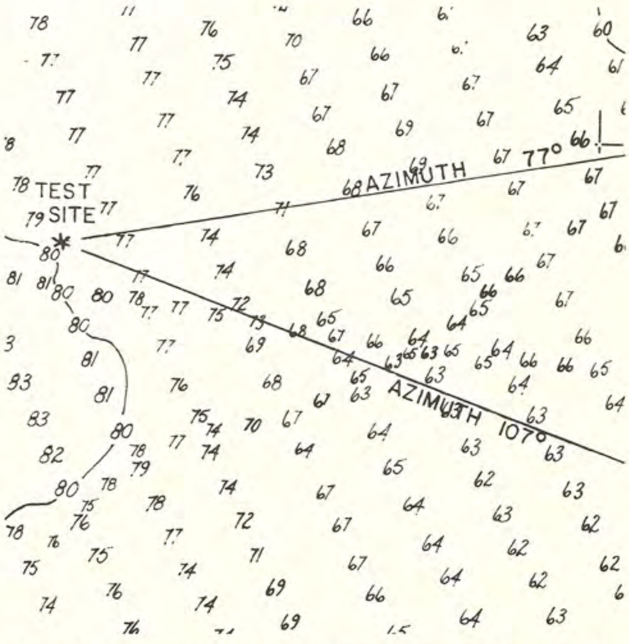

Figure 18: Portion of Field Sheet Showing Test Site Scale 1:5000

Equipment was transported to the test site in the tracked vehicle (see Figure 19) while a PCSP helicopter was used to recover horizontal control and put the Mini-Ranger III positioning system on the air. The wooden stations, erected in 1976, were found near each control point, and made recovering control easier than anticipated.

Figure 19: Tracked Vehicle Near Test Site

The test site was three kilometres offshore, over 80 metres of water, where the ice was 1.6 metres thick. A 70 cm diameter hole was drilled in the ice and the MARRS tripod erected and bolted to the ice over the hole. A winch was used to lower the transducer assembly through the ice (see Figure 20), to a depth of 3.4 metres. The transducer array was leveled with a carpenter's level, and aligned using the theodolite mounted on top of the MARRS tripod (see Figure 21). A longhouse tent covered the hole and heat lamps were used to keep the hole from freezing over. The array was 1.8 metres below the ice.

Figure 20: Transducer Assembly Being Lowered Through the Ice

Figure 21: MARRS Tripod and Theodolite

Transducer cables were connected to the transceiver, which was housed in the lab on-board the tracked vehicle (see Figure 22). When all the equipment was connected and the power turned on, the CRT filled with noise. When the transducer was fired, no bottom trace was discernable from the noise on the screen.

Many attempts were made to eliminate the noise problem, but the only one that worked was to connect the four receiver cables in the wrong order.

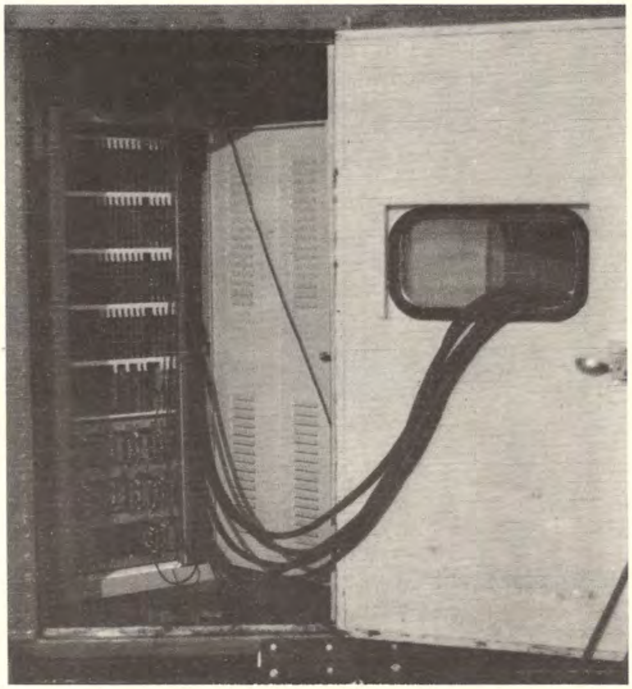

Figure 22: Transceiver On-board the Tracked Vehicle

The system appeared to work, so the transmitted power level was adjusted to receive as little noise as possible without eliminating bottom returns (or what were thought to be bottom returns) using the CRT display as a reference. The power level adjustment was very sensitive; a tiny adjustment would produce far too many or far too few returns. Once a reasonable setting was established, data was recorded for each of the three mechanical steps, measured at 19, 46 and 76 degrees.

To record data for every degree horizontally would have taken ten hours, so the pointings were spaced to give adequate coverage at a scale of 1:5000, the same scale as the existing field sheet. The time required to complete one round of 13 pointings was eight minutes; one round of 61 points took 30 minutes. Photos of the CRT for some pointings are shown in Figure 23. Each pointing was scanned twice to check the repeatability of the system. What were thought to be bottom returns at a tilt of 76 degrees (Figure 23c) turned out to be scattered noise.

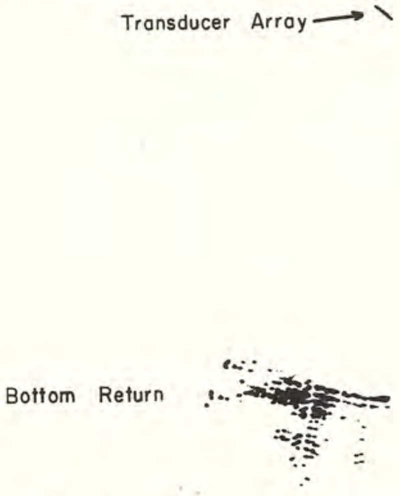

Figure 23a: CRT Display — Tilt 19°

Figure 23b: CRT Display — Tilt 46°

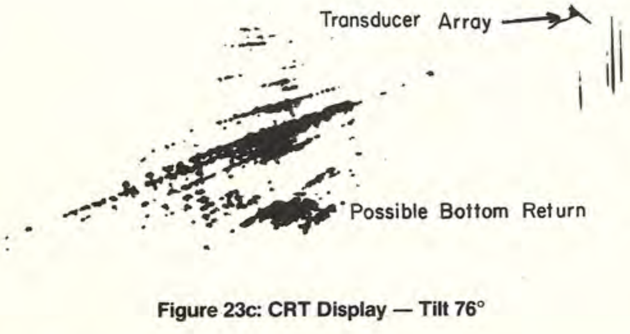

Figure 23c: CRT Display — Tilt 76°

The transducer array was lowered to three metres below the bottom of the ice to try to improve the results, but this had a negligible effect. The depth to which the array could be lowered was limited by the length of the transducer cables, which had to reach the tracked vehicle parked outside the tent, and by the length of pipe that the transducers could be suspended from and still remain stable.

The MARRS was moved to a second location, 250 metres away from the first test hole. A target was lowered through the first hole to a depth of 34 metres so that pointing, tilt angle and effective beam width could be tested from the second hole. The target (a 30 cm cube) could not be detected by the system. The following day an attempt to record MARRS data at the second test site was thwarted. Noise was present on all scanning beams displayed on the CRT, regardless of the order in which the receiver cables were connected. The source of the noise was traced to the transceiver, but could not be isolated in the field, bringing an end to the MARRS tests.

Test Results

MARRS data was processed by the Canadian Hydrographic Service in September, 1981. A Zilog 80 microcomputer development system, which had a sixteen bit data port necessary to receive data from the Marinav data processing unit, was used to transfer recorded MARRS data to floppy disc. Data was then transferred to a PDP 11/34 processing system where it was edited and corrected to compensate for ray-bending using the formulae supplied in Marinav's Progress Report 10. The slant-range time and corrected tilt angle were converted to horizontal distance and depth, and MARRS depth trace plots were produced. The depth profile from the 1976 field sheet is shown as a solid line.

The MARRS depth traces include data from each of the three tilt angles. Refer back to Figure 18 for the origin of the field sheet depth profile.

Obviously the MARRS data points should all fall close to this line, and they do at the lower end of the 19 and 46 degree tilts. They are even fairly accurate (within a couple of metres) directly below the transducer array. How, then, do we explain the rest of the data in particular that data collected on the 76 degree tilt which seems to be just so many random points?

There were obvious receiver problems, since we could not hook up the receiving transducer in the proper order. Hooking it up in other orders made no difference to the displayed bottom profile, which could be seen on the CRT between the noise, for various combinations. Order seemed to have no effect, but presumably it should have.

Another problem was that the one degree beam had not properly formed in the near-field (ranges less than ~~14~~ 104 metres). Echoes received from outside the presumed one degree beam cannot be separated from good data. As the transmitting transducer is pointed closer to the bottom of the ice (closer to horizontal), the chance of receiving data from ice, instead of the bottom, increases. This is mot likely what happened at the 76 degree tilt, to produce such scattered and unusable results. Naturally this would reduce the effective range of the system. In this case it was reduced to less than 120 metres, when slant ranges in the order of 800 metres were expected.

Conclusions

In areas where the one degree beam has time to form (deeper than 104 metres) there is less of a requirement for a precise system. It is somewhat inconsistent that the system should function more accurately in deeper water. It is the shallow areas (less than 100 metres) where a system of this type would most often be required, such as for surveying harbours, bays and narrow channels. For precise coverage in shallow areas the MARRS is unable to produce satisfactory results.

The electronics in the transceiver and CRT are too delicate for prolonged use in a field environment. Too big for a helicopter, it must be transported by tracked vehicle. The ride can at best be described as cruel, for men and equipment alike. This factor may have affected the MARRS performance.

The usefulness of tracked vehicle trains in the Arctic appears to have some limitations. The train is too large for a twin Otter or similar aircraft. It would need to make long over ice voyages or travel in a Hercules to arrive at the survey area. Ground travel over long distances is slow, uncomfortable and provides a number of logistics problems. A Hercules does not just land anywhere.

Even if the tracked vehicle trains could be easily deployed, there is the constant punishment to men and equipment, including the train, to consider. The vehicle and equipment would require constant maintenance. During the Arctic test the tracked vehicle made a round trip of 12 kilometres a day for eight days. In that short time it had three flat tires and threw the right track once. The engine quit three times and the vehicle had to be towed home once. The generator suffered cracked fuel lines and a broken fuel pump. These mechanical problems were attributed to the thumps and vibrations experienced while moving over the ice. All this travelling at five kilometres per hour. Luckily there were no pressure ridges to traverse.

The method of deploying, leveling and aligning the MARRS transducers, although effective, was crude. Considerable effort would be required to produce a working system.

A continuous bottom profiler for Arctic Surveys is not only desirable but necessary for detailed large scale surveying. The concept of achieving complete bottom coverage through one hole in the ice is feasible, but the present MARRS configuration does not meet our requirements. To be useful, a system would have to be less bulky, more durable and easily deployed.

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A Review of Digital Terrain Modelling Applied To Hydrographic Charting Activities

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INTRODUCTION

The requirement of a digital terrain model (DTM) is that of providing a mathematical representation of any single valued 2-variable function. Often, one wishes to model the earth's surface with particular emphasis being placed on the ocean depths. A DTM should be capable of estimating the surface value at positions not directly input to the model.

A basic problem exists. Mathematical methods are very difficult to apply to entities as unpredictable as the earth's surface. For example, it takes much more than mathematical knowledge of the earth's surface in the prairies of Canada to predict either the Rocky Mountains or the Canadian Shield. While the earth's surface is continuous, overhanging cliffs present areas where it is not single valued. In addition, the surface has many areas which could not be described as smooth. Given much information on near points, it is not possible to predict, with definite accuracy, the elevation of intermediate points. This gives rise to the question of whether any estimating activity, other than the most basic, is justified.

DTMs that do not use sophisticated means of mathematical analysis tend to yield unacceptable angular surface representations. The question that arises is how much mathematical analysis should be used to honor the integrity of the data yet produce an acceptable representation.

Digital Terrain Models — Overview

The requirements for terrain modelling by various branches of science can be considered as falling into two distinct groups:

- the modelling of continuous 3-dimensional surfaces often referred to as digital elevation models;
- the modelling of 2-dimensional areas with attributes, variously referred to as thematic, spatial or geographical modelling.

While most application areas tend to favour one of these varieties of models, many require capabilities in both.

This document is primarily concerned with the 3-dimensional models. The developing of contouring capabilities, digital charts and automatic terrain navigation require a 3-dimensional representation.

3-Dimensional Models

Digital terrain models can be generated from various forms of input data, including:

i) **High information surveyor data points.** A knowledgeable surveyor can choose precisely the data points needed to subdivide the area of interest into smooth surfaces. Inherent in this data would be the definition of the areas. This type of input has many advantages but is only possible when the surface under consideration is visible, i.e. can be seen and analysed.

ii) **Sparse grid data.** A 2-dimensional mesh can be theoretically placed over the area of interest. The surface is sampled at, or as close as possible to, the resulting mesh intersections.

iii) **Dense grid data.** Applying automated photogrammetric techniques, the surface can be sampled at constant intervals along equi-spaced lines.

iv) **Contour lines.** By using photogrammetric techniques, or digitising already existing contour maps, X, Y positions which have constant elevation can be input.

v) **Line data with crossties.** This form of data is obtained by sampling the surface at intervals along many parallel lines in one direction, and a few lines (crossties) which cross them. Typically, the spacing of readings along each line is significantly smaller than the spacing between lines. It is also often the case that the X, Y values to be associated with each reading are not exact. If this is a possibility, procedures are required to correct errors by comparing crosstie data with the line data.

Whichever means of supplying data is used, a large number of points are generated, usually with a minimal knowledge of logical connections other than that supplied by the coordinates.

Regular Rectangular Grids

The first method devised to structure the digital terrain model was the regular rectangular gridding technique. In this method, a regular mesh in X and Y is placed over the area of interest, and surface values are stored at each mesh intersection (often referred to as a grid point). Of course, the input data does not provide the surface values at precisely the mesh intersections, so interpolation techniques are used to estimate these values.

The surface is thus modelled by a large array where the surface value is explicitly scored for X, Y locations implicitly indicated by array position.

This model makes it very easy to extract values in any specified X-Y area, and to examine surrounding values. Arrays are a very basic computer data structure as well as a much studied mathematical concept. Many systems have been developed to produce and manipulate grids (from the various types of input) and extract and display various types of information about the surface as required by different disciplines.

The two main objections to this system of modelling 3-dimensional surfaces are:

i) To satisfactorily represent rough or steep terrain, the mesh interval size must be quite small. Thus, flat areas in the same model contain much redundant data.

ii) When choosing an interpolating technique, two factors must be considered:
   - the accuracy with which the original data input points can be reproduced, and
   - the degree to which the overall trend of the land is well represented.

Ideally, accuracy should be high in both areas. However the techniques available tend to favour one or the other of these factors but not both [Davi].

Triangulated Irregular Networks (TIN)

Due to the objections related to grids and possibly a more recent emphasis on the non-mathematical nature of the earth's surface, another system is presently obtaining much research attention.

This system, often referred to as the Triangulated Irregular Network (TIN) system, models the surface by joining the input data points to form triangles; thus representing the surface by many planar triangles. Due to the fact that the triangles may be of any size, the redundancy problem associated with gridding is eliminated. In addition, no interpolation is used in the formation of the data structure. However, it should be noted that in many applications, (i.e. contour formulation), some values must be interpolated (i.e. the exact position at which the surface cuts a specific contour plane).

This system is clearly economical in the number of data points which must be scored to accurately represent the surface. When high information surveyor data is available the model is easily constructed. When other forms of data input are used, two steps usually must be taken:

i) the input data points are often redundant, and have to be appropriately sampled;

ii) the connecting lines forming the sides of the triangles must be selected.

There are many algorithms available to accomplish the first step; this process is often applied to line data prior to producing grids. Algorithms presently in use for the second step tend only to consider the X and Y values of the input points, and hence may not produce the best surface representation.

Since the TIN model has been developed relatively recently, the available application routines are not so numerous.

The main objections to this system are:

i) The surface is represented by triangular planes which are not usually available as input. There are many different possible networks of triangles that can be fitted to a given series of input data points, giving different surface representations. The differences in representation are clearly noted in resulting contour maps.

ii) Processes involving the extracting of Z values for a specified X-Y area must use time consuming searching algorithms.

iii) Due to the minimal interpolation used in the system the resulting contour maps tend to be significantly more angular than those produced by hand or by grid models.

GRIDDING

Most production Digital Terrain Model (DTM) systems utilize a regular rectangular grid. There are a wide selection of systems currently in use.

Data Structure

In the gridding technique a theoretical mesh, regularly spaced in the X and Y directions, is placed over the area of interest. A surface value is stored for each mesh intersection. Given the position of the surface value in the grid, the corresponding X and Y values can be easily calculated and thus need not be explicitly stored.

When dealing with large areas of interest, particularly small mesh intervals or hardware with limited main memory, grids are usually subdivided. Typically, the grid is broken into equal size grid blocks, aligned horizontally and vertically. In addition to solving memory problems, the concept of a grid block facilitates the transferring of data to and from auxiliary memory while still retaining maximum ease in the identification and retrieval of a surface value from a specific mesh intersection.

The storing and retrieving of grid block data is commonly achieved via indexing techniques, whose characteristics are usually machine dependent. These techniques, in most cases, allow for the suppression of empty grid blocks.

The choice of mesh intervals is critical. The determining factors include the type of input data and the applications of the resultant grid. In general, for line data, the mesh interval should be chosen such that two (2) grid points lie between adjacent lines. Smaller mesh intervals may be required for more detailed contours. However, care must be taken not to extract more detail than can be provided by the input data.

Interpolation Techniques

Given a series of sample data points a variety of interpolation techniques are available to compute surface values on the predetermined regular, rectangular mesh. In this discussion the term Z-value will be used to denote a surface value.

a)Linear Interpolation

This technique is only used when the sample data points form a dense grid. Raster scanning photogrammetric plotters can provide such input data.

Note: More sophisticated interpolation methods are often applied to such data.

b)Weighted Sum

This technique involves the computation of a z-value at a grid intersection by a weighted sum of z-values from neighbouring data points [Shep]

$z = \Sigma w_i z_i$
where w_i = weight for observation i
z_i = z-value at observation i

The weight w_i must reflect the distance, d_i, between the grid intersection and the observed value. Typically, w_i is inversely proportional to d_i^n, where n ranges between one (1) and six (6). As n increases, the input data points are more closely honored while less emphasis is placed on the overall shape of the surface [Davi].

Clearly, all input data points are rarely used to interpolate a particular z-value. The number of neighbouring data points selected for interpolation has a direct influence on:

- the time for computation;
- the emphasis placed on the overall shape of the surface.

A smoother representation of the surface (i.e. less honoring of the individual input data points) will result when an increasing number of neighbouring data points are utilized [Cram] [Davi].

Criteria for choosing neighbouring input points clearly must include the distances from the grid intersections. However, this criterion is not sufficient as exemplified by the interpolation of contour data. In the interval between contour lines, z-values are strongly influenced only by the closest contour line. This generally results in the production of a step function in the representation of the surface.

One method of eliminating this difficulty is to ensure that an adequate number of octants or quadrants radiating from the grid intersection contain input data points.

Another method related to the Weighted Sum interpolation technique ensures that the weight assigned for a particular input data point reflects the relative locations of neighbouring data points [Shep].

Usually neighbouring points are searched for by examining those in a circle surrounding the grid intersection. In cases where it is known that the surface trends are likely to run in specific directions (e.g. magnetics data) this bias can be introduced into the grid by searching an appropriate ellipse [Smit].

c) **Weighted Least Squares (Polynomial) Fit**

This technique involves fitting a polynomial P to the neighbouring points minimizing a weighted least squares function of the form

$$\Sigma w_i(Z_i - P(x_i, y_i)).$$

The weight assigned to a neighbour would typically be inversely proportioned to $d_i^n + C$, where C reflects confidence in the precision of the data. If C is large, the distance factor will be less pronounced and hence the trend of the surface will be smoother [Cram].

The choice of neighbours will influence the grid representation in a manner similar to that discussed for the weighted sum technique.

Another influencing factor is the degree of the polynomial chosen. If it is 1, no interpolated point will have a z-value higher or lower than that of the neighbours. A higher degree fit will permit interpolation to higher values.

d) **Kriging**

This technique is based on choosing a linear estimation that takes into account the spatial structure of the surface [Chil]. To achieve this the mean trend and variance are estimated, and a solution is found which has a null mean error, and minimizes the variance of the error. The resulting grid will tend to accentuate highs and lows if an appropriate variance formula is used. While this method does not tend to conform to usual grid evaluation techniques [Davi], it may have properties that are useful to the particular requirements of bathymetry.

e) **Growth Technique**

In this technique many passes of the grid are made. In the first pass, z-values are interpolated for grid intersections which are very close to the input points thus honoring the data as closely as the mesh interval will permit. In subsequent passes, grid points adjacent to those with previously computed z-values, are assigned values using a combination of extrapolation from adjacent grid points and interpolation between surrounding, if distant, grid points.

This technique honours the data as nearly as the mesh interval will allow. It also tends to be less sensitive to the distribution of the input data points.

Grid Enhancement Techniques

Once grids have been interpolated, they can be enhanced either by filtering the existing grid or inputting ancillary data.

a) **Filtering**

There are numerous mathematical procedures that can be applied to a grid in an effort to remove local noise error. Applying filtering tends to give a smoother representation of the surface. A by-product of this procedure can be feature detection [Rauh].

It should be noted there is a school of thought that, due to the nature of terrain not being particularly mathematical, such processes applied to terrain surfaces may give more acceptable surfaces, especially as represented by contours, but should not be justified as error correcting processes.

b) **Ancillary Data**

It is often the case that specific features of the surface being represented are known to exist. These include:

- trend lines, for example, linear magnetic anomalies;
- discontinuity lines, for example, creek beds;
- faults, for example cliffs.

Such data can provide:

- a continuous 3-dimensional line which the surface passes through, and a tangent line which lies in the tangent plane to the surface (trend and discontinuity lines);
- an indication that data points on the opposite side of the line should not influence the interpolation of grid z-values (discontinuity and trend lines).

The latter factor can be easily handled in interpolation algorithms by either appropriately adjusting weights or by altering the search area for neighbouring points [Shep].

The former supplies additional information that could be used in the area surrounding the line [Cram].

Fault lines may be required in further processing of the grid, i.e. defining contours. They may be stored in the grid by using low order bits as a tag to indicate which grid points best define the fault.

Contouring

The most basic contouring method involves a process which originates a contour line by:

- searching the grid until a mesh interval which crosses the contour level is found;
- identifying the location at which the contour crosses the mesh interval by linear interpolation.

Given that the contour enters the rectangle defined by grid points $P_{i,j}$, $P_{i+1,j}$, $P_{i+1,j+1}$, $P_{i,j+1}$, at least one of the z-values must be higher, and one must be lower, than the contour level. Therefore there must be at least two mesh intervals through which the contour should run; one through which the contour line being built entered the grid rectangle and the other through which the contour line will leave the grid rectangle.

Using this process the contour line can be extended until either the edge of the grid is reached or the contour reaches the point at which it originated.

The mesh intersections can then be joined by straight lines if the mesh intervals are small, or by curve fitting routines.

A difficulty arises if the contour level intersects not two, but all four sides of the rectangle. This saddle or pass problem occurs since there is insufficient information to indicate which of the three remaining sides should be used to define the point at which the contour line should leave the rectangle. Typically, the choice made is inherent in the order in which mesh intervals are checked. For bathymetric data, care would have to be taken to ensure the problem was resolved with reference to the z-values.

Numerous contouring systems are in existence. They vary in:

- efficiency;
- the variety of contours that can be plotted;
- the ability to plot different contour levels between various levels, for example contours at 10 metre intervals between 0 and 100 metre, 50 metre levels between 100 and 1000 metres, and 100 metre levels thereafter;
- the ability to label some or all contour levels;
- the ability to plot different contour levels with different line types of widths, i.e. plot contours at 10 metre intervals, but accentuate them at 100 metre intervals;
- the choice of plotting only some, or none of the contour lines in areas where they are too close, in steep areas;
- the choice of indicating highs and lows, possibly with the corresponding surface values.

Another contouring technique involves the fitting of a surface to each grid rectangle. Care must be taken to ensure that the surfaces join in a continuous and smooth manner at the mesh intervals. One procedure involves using a least squares fit to determine the slope at each grid intersection, then using these values with the z-values to fit a third degree polynomial in X and Y using 12 coefficients [Janc]. This method tends to result in smoother contour lines.

Other Grid Applications
As grids have been used to model data for a considerable length of time, many computer programs have been written utilizing the grid format. Applications include:

a) **3-D views of the model**
There are numerous routines which given the viewpoint (i.e. the position of the eye) and the view direction, expressed either by a unit vector or by the point being examined, will draw the perspective view with hidden lines eliminated. They vary in:

- their ability to handle arbitrary viewpoints, especially those in the grid area;
- their treatment of the surface as either a thin sheet or a solid object extending downward;
- their ability to mark points on the surface which are visible;
- the lines chosen to represent the view; could be only those in one of the X or Y direction, both the X and Y direction, perpendicular to the view direction or both perpendicular and parallel to the view direction.

b) **Computed variations of the model data**
Typical values that are required to be calculated and displayed include:

- slope and aspect;
- drainage or catchment areas;
- surface specific features such as ridges, creeks, peaks, pits and passes (saddles);
- interviewability of points;
- sun and wind exposure.

c) **Thematic applications**
2-dimensional or thematic data (e.g. geological data) can be represented in a grid format. Here the grid point could be taken to indicate either a rectangle centred at the X-Y value, or a specific one of the four rectangular cells surrounding it.

Various types of such grids are computed from elevation grids, such as classifications of slope, hours of sunshine, drainage, etc.

Spatial data represented in grid format can be easily overlayed to obtain suitability grids (e.g. areas with less than 10% slope, at least 8 hours sunshine on winter days that belong to a specified drainage area).

Typically the data is displayed by shading each rectangle according to the z-value at the associated grid intersection, but curves can also be fit to the boundaries surrounding the area.

d) **Navigation systems**
These systems work on either the ocean bottom to aid in ship navigation or the earth surface for aviation purposes.

The NAVACE system as described in literature from Electrospace Systems Incorporated works on relative ocean depths. Given a last location on the grid and a change in soundings since that reading, a new position is calculated. Clearly, some ambiguities could arise indicating a necessity to accept more soundings before a resolution can be determined. Speed and direction, either from the ship, or as last calculated can also be used to help resolve ambiguities [Aber][1].

The terrain of the ocean bottom is clearly very important in marine navigation. When traversing flat areas the above mentioned method of navigation would be very difficult if not impossible [Sved].

Another problem which can occur with ocean bottom navigation is occasioned by constantly shifting bottom contours which is especially prevalent near shore. This can be solved by using a first sub-bottom reflection both in the grid and in the readings taken by the ship [Aber][2].

A method of aviation navigation using horizon evaluation could possibly be adapted to marine navigation. [Carl].

e) **Model overlaying**
A very large area of interest is often broken into overlapping models before grids are constructed and contour maps are produced. Since grid points at the edge of each model were interpolated without the knowledge of the input data of the adjacent model, a discrepancy can occur between models. Thus the resulting contours mismatch at the edges. This does not tend to be a problem in steep areas but can be significant in areas where the surface varies only slightly from below to above the requested contour level, over a large surface distance.

This problem can be handled by simply averaging the values for the overlapping areas. Some model overlaying routines also introduce these alterations back into each model to maintain the continuity of the surface.

Variations
Variations to the basic rectangular grid have been suggested, and occasionally implemented, to make it less redundant in flat areas while still maintaining its precision in steep areas. These include:

a) Permitting an element in a grid to point to a further grid block rather than holding a single z-value.

   This could be implemented by using the least significant bit as a switch to indicate whether this was a z-value or a pointer. While this method maintains the basic simplicity of the system, and would permit a random grid intersection to be extracted with a minimal number of accesses, it could involve a large number of additional grid blocks if a fairly large proportion of the model represented a steep surface.

b) A method of defining an irregular grid over the area, such that more grid points are stored in steep areas where assumably more input data would be given and correspondingly fewer in flat areas.

Unfortunately two important advantages of regular rectangular grids are lost in this procedure:

- the lack of necessity to explicitly store the X and Y values;
- the ability to extract the closest grid point to a given X, Y value without searching [Shmu].

c) Another grid variation has been often suggested. That is the formation of a regular triangular grid, i.e. adjacent X rows are offset by half the mesh size. While this format could be expected to yield a better approximation of the surface, with minimal alterations to the system, no reference to any implementation could be found.

TRIANGULATED IRREGULAR NETWORKS (TINs)

This method of digital terrain modelling systems honors the original set of data points. A network of triangles is produced over the surface by joining appropriate data points. This method has become very popular in Western Canada primarily due to the work of Peucker *et al.* at Simon Fraser University. It overcomes the two main objections to the grid techniques in that input data points are maintained exactly, and since the point distribution need not be uniform, redundancy in flat areas can be reduced. The TIN technique tends to be more in the research mode rather than a state of active production.

Data Structure

There can be one, two, or even three data files associated with any model:

- the point file;
- the triangle file;
- the connecting line file.

It is certainly redundant to maintain the three files for any model. The point file, in differing formats, is used by several systems described. The triangle file is also explicitly kept in some systems; it can also be deduced from pointers in the point file. The connecting line file is not maintaned by any of these systems, but is temporarily deduced and used in specific routines.

a) **Point file**

This file stores the data points as X, Y and Z values. Other information, such as slope, can also be stored.

If used as a secondary file, no other information needs be stored in the point file. However, it may be useful to also store pointers to neighbouring triangles.

When used as the only system file, the point file must store enough information to capture the network. This can be done by storing pointers to all points which are connected to an identified point, in a clockwise (or counter-clockwise) order [Peuc][1]. Thus, triangles that radiate from a point p with pointers to $p_1, p_2, \ldots, p_n$ are $<p, p_2\ p_3>, <p, p_2\ p_3>, \ldots, <p, p_n, p_1>$. If the network is correctly formulated, p_{i+1} and p must appear consecutively in point p_i's list (or p_{i+1} must be the last element and p the first element). This method appears to be the most economical from a storage viewpoint, however, it does not permit the storing of thematic data.

b) **Triangle file**

This file contains pointers to the three defining points and to the three neighbouring triangles, as well as any attribute information required.

If this file is used as a secondary file with the point file, it may not be necessary to maintain pointers to adjacent triangles.

c) **Connecting line file**

This file contains pointers to the two ends of the line. If used with a primary triangle file it would also contain pointers to the two neighbouring triangles.

If a particular model is too large to be maintained in memory, it will be necessary to subdivide it into smaller areas. Boundary points will need to be stored in two or more areas.

Input Data Points

TINs are particularly useful when knowledgeable surveyors can provide precisely the data points that best divide the terrain into planar triangles.

When dense raster photogrammetric data is used, it is necessary to select those points which best represent the surface. This can be achieved by choosing surface specific points and adding others, as required, to provide further definition [Peuc][2].

Another method of handling dense raster data also produces an interesting structure on the resulting triangles. The rectangular area is intitially divided into four triangles. Each triangle is then checked to see if it represents the surface to within an error tolerance. If not, it is subdivided into four smaller triangles using additional data points (as close as possible to the mid points of the edges). This process is repeated until all triangles satisfy the tolerance constraints. While the resulting network is definitely a variation of a TIN, it has some useful searching properties [Soto].

When line data with cross ties are used it is necessary to resolve any discrepancies between cross tie data values and line data values. Since no interpolation or averaging techniques are used, these discrepancies will appear in the surface representation.

Since line data tends to produce dense input along each line, it is often useful to eliminate redundant points. [Doug], [Brou] and [Page] describe some techniques that could be utilized.

Triangle Formation

Most TINs treat the triangles as planes, or at least assume connecting lines lie on the surface. Therefore, different triangular networks on the same set of data points result in different surface representations. The triangle formation procedure is thus very pertinent to the accurate representation of the surface.

A saddle or pass problem, similar to that discussed for grid rectangles, exists for TINs. In this case four data points p_1, p_2, p_3 and p_4 which form a quadrangle would have p_1 and p_3 with high values and p_2 and p_4 with low values. If the network divided the quadrangle into triangles $<p_1,p_2,p_3>$ and $<p_3,p_4,p_1>$, the area in the centre would be represented with higher values. On the other hand, using triangles $<p_1,p_2,p_4>$ and $<p_2,p_3,p_4>$, the centre area would be represented with low values. A circumstance such as this could easily occur in the utilization of line data.

Triangles can be defined either by automated or manual means.

a) **Automated**

When constructing a TIN from dense raster photogrammic output, algorithms that find surface specific features such as defined by [Peuc][4] or used for gridded data could be used to define some of the required connecting lines.

Algorithms which construct triangles from the point file typically use only the X and Y values to choose the required triangles. The criteria for choice include:

- ensuring the circle which circumscribes the triangle has no interior data points [Cram];

- maximizing the minimum perpendicular distance from a point to the opposite side [Gold]2.

These criteria can be met by initializing with any triangular covering network, then optimizing by making subsequent passes of the file which consider the quadrangle formed by two neighbouring triangles; and altering it if it does not meet the criteria.

As neither of these criteria consider the Z-value, it may be useful to force certain connecting lines to be utilized, i.e. those found when extracting "surface specific" features. This could be achieved either by introducing further data points along these lines, or by flagging lines as mandatory so that the optimizing procedure does not alter them.

b) **Manual**

If the input data points chosen to best divide the terrain into planar triangles and the connecting lines necessary to form these triangles are both provided, the most satisfactory surface representation could be accomplished. Even if the input data is not achieved in this manner, it may be best to manually input the triangles. However, in this process, the operator will generally need a contour map, and hence tend to propagate any errors found in that map.

Contouring

In most TINs it is assumed that the triangles form planes defining the surface. Contours are thus drawn by intersecting the triangle plane with the contour slope, resulting in sharp corners (rounding of corners is possible). The resulting contours tend to reflect the triangular formation.

More pleasing maps can be drawn by either deducing or inputting slope values for the data points, and utilizing these values to end the triangular planes. Care must be taken to ensure that this results in a continuous smooth surface [Gold]2.

Other Applications

Due to the fact that TINs are a much more recent method of modelling digital terrain, their applications tend to be more in the research stage than in production mode.

a) Slope and aspect maps are easily produced by calculating the slope of each triangle in a TIN, and presenting a map showing the appropriately shaded triangles.

b) Surface specific features can be easily displayed if indicated by the triangle formation. One system extracts this data and uses it as a secondary data structure to aid in other applications [Peuc]1.

c) 3-D views have been accomplished using TINs by tracking the required lines across the area.

d) Interviewability can be achieved by tracking the lines joining the 2 points in question.

e) Overlaying TINs with spatial data can be accomplished using techniques developed for overlaying polygons; with the added feature of calculating an additional Z value for any points added to the TIN. [Litt]

EVALUATION DISCUSSION

Available Systems

A major difficulty encountered in endeavouring to compare the two predominant terrain modelling techniques is the distinctly different quantity of activity that has been undertaken in each field. Grids are so common in describing 3-dimensional surfaces that numerous partial systems are available [Coul], [Wood]. Case studies abound, [Tesh] [Cros]2, [Turn], [Herm] and complete data base management systems exist [Elas]. Indeed, grid based systems are so common that a new one is not likely to be advertised in research literature.

On the other hand, TINs are relatively scarce. Two of the three systems were developed in a University environment. Few case studies are available [Gold]3, [Gree] and theory papers are still to be published [Robs]. While grid supporters are unlikely to feel called upon to support the gridding portion of their system, TIN supporters often make reference to the advantages of their systems [Mark]1.

Accuracy

Thus we are comparing a known system to an unknown system. While many qualitative studies have been carried out on the known system, gridding (i.e. [Davi] compares accuracy for different interpolation methods, [Acke] deduces the grid computed contours are as accurate as hand drawn contours), one must theorize on the merits of TINs. Of course, the input data points, or a selected subset, are directly represented in TIN models, while they can only be kept to the nearest mesh interval, at best, in grid models [Gold]2.

a) **TIN Systems**

While a TIN can give a very accurate description of a visible surface when the input data points are knowledgeably selected (with triangular planes in mind), it cannot be assumed to do this with all networks fitted to the data points, as evidenced by the different contour maps produced by different networks. Therefore, their accuracy in representing line data of the type predominant in hydrography must depend on how well the triangles are fitted to the input data points, and whether, in fact, the input points are critical enough to allow an accurate TIN to be derived. Assuming the latter factor is possible, or that the input data points can be somehow augmented to satisfy this criterion, it seems unlikely that the automated methods of triangle formation presented to date are sufficient for bathymetry due to the fact that they do not incorporate any Z-values, but work only on the X and Y values. It seems possible that a system could be developed to construct better networks when some bias can be used, i.e. connectivity factors in magnetics or shoal conservative considerations with bathymetric data. When endeavouring to produce an unbiased representation, it is not clear that any better method could be automated although further research may show this to be invalid. Improved manual triangulation would probably require the operator to consult an already existing contour map which would tend to propagate any errors in that map.

In summary, TINs can represent visible data very accurately; their accuracy, at the present state of technology, for line input, depends heavily on the triangular network chosen. Biases can be represented in the system but these do not permit interpolation of values outside the extremes of the input data points.

b) **Grid Systems**

The ability of grids to accurately represent a surface depends on the interpolation technique used. There tends to be a trade-off between the ability to reproduce the Z-values at the input data points, and the ability to accurately predict Z-values at other places on the surface. There exist interpolation techniques which permit connectivity biases of the variety required for magnetics data. A simplistic approach in placing emphasis on the shallower aspects as required for bathymetric data might be accomplished by more heavily weighting shoal input data points (in either the weighted sum or the weighted least squares polynomial fit). The Kriging method of interpolating grid values places emphasis on either extreme. Many interpolation methods permit grid Z-values to be established beyond the extremes of the input data values.

Data Storage

The main disadvantage of the TIN system over the gridding system is the number of points that are stored. For each TIN point, many values besides the surface value must be stored, i.e. the X and Y values and various pointers, at least (12 × N) - (6 × B) - 12 where N is the number of points and B the number of boundary points [Peuc][1] resulting in the necessity for (15 × N) - (6 × B) - 12 words of storage. Since gridding techniques require only one word of storage for the Z-value, plus a minimum of overhead (e.g. the start X and Y values and the X and Y mesh intervals), just under 15 grid point Z-values can be stored in the same space required for a single TIN data point. When the minimal surface sampling necessary for accurate representation in a TIN surface is used, and the terrain surface has some very rough areas and some very flat areas, this ratio would easily be surpassed.

When considering line data as input, there are several factors which would control the size needed for each system. The controlling factor for TINs would be the number of input points along the line that were deemed necessary to accurately represent that line. For gridding systems assuming a grid interval of ½ to ⅓ the smallest distance between lines, the factors involved would include the smallest spacing between lines and the ratio of the distance between readings along a line and the distance between lines. If one assumes the line spacing to be equal and the ratio to be r, then between 4N/r and 9N/r grid points would be generated. This gives a rough estimate to the amount of weeding of data along input lines required to achieve an economical (storage wise) TIN structure.

Applications

Once a surface model has been generated there is a variety of information that may be required from it. Due to the fact that gridding systems have been in production mode for many years, there are many more polished application routines available. Similar routines for TINs would have to be developed.

a) **Check Contouring and Digital Charts**

The accuracy of contour maps depends, of course, on the accuracy of the surface representations. The aesthetic qualities of the map depend on the smoothness of the representation. For this reason, users of grid systems often require smoothing and filtering techniques to be applied to grids prior to contouring. It would be necessary to insure that the saddle problem was correctly solved for bathymetric data. Contour maps of very high standards can be produced. When the TINs are considered as triangular planes, the resulting contours are quite angular. They have been made more aesthetic by permitting the triangular surfaces to be non-planar.

Digital charts could be drawn from either system with differing problems. When drawn from a gridding system, it is quite likely that too many values would be present and choices would have to be made as to which were appropriate. Due to the importance of accuracy in digital charts for navigation, it may be deemed unsatisfactory to use interpolated values and hence they would have to be produced directly from the input data.

In TIN systems, the number of points may be insufficient to produce a chart with enough detail, and additional values would have to be interpolated. Again, this may be deemed inadequate in which case the input data would have to suffice.

To compare one gridding surface representation to another would be very straightforward if the grid intersections were coincident and would involve little manipulation otherwise. If a hand contoured map was digitized it would involve some point in polygon techniques familiar to thematic models to indicate any grid positions whose Z-value was on a different side or a contour level. Grid values can be easily modified and these modifications can be farmed out to surrounding values if required.

It is a much more complex task to compare TINs due to the fact that the representation is so dependent upon the triangle formation. It would not be sufficient merely to consider the data points in the comparison, but rather the entire triangular plane must be taken into consideration. This may be achieved by using polygon overlaying techniques to form a new TIN.

b) **Navigation Systems**

Navigation systems based on gridding models are presently employed in the fields of marine and airborne navigation. Similar techniques could be applied to TIN models. However, one of the disadvantages inherent in TIN representations is the comparative difficulty in finding the data point closest to a particular X, Y value, and in subsequently moving around the network in a fast and systematic manner. For instance, to investigate all points within a certain radius of a grid intersection, a simple procedure could be established that would not require any distance calculations. A similar technique could not be applied to TINs due to the unpredictability of distance between points. Detailed investigation of timing aspects would have to be made to determine if a TIN system could be sampled quickly enough to become an effective navigational aid.

c) **Thematic Overlays**

When endeavouring to combine thematic models with gridded terrain models, the process is straightforward if the thematic model is gridded, but requires point in polygon techniques for polygonal models. TIN models are very similar to polygonal thematic models and variations to polygonal overlaying methods exist to combine the two.

d) **Other Applications**

Many of the surface manipulations often required, i.e. slope and aspect calculations, have been achieved on both systems. Mathematically combining different measurements for the same area is straightforward for grids. In a TIN system with the same data points and triangular network it would be equally as straightforward. However if different input data points were chosen to represent the different surfaces, or even if the same input points were used, but the triangular formations varied, the problem of combining the TINs would require the use of polygon overlaying techniques.

CONCLUSIONS

The main objections to a grid system are:

i) data redundancy;

ii) inability to accurately represent input data values.

The problem caused by data redundancy is that of excessive storage requirements. Due to grid block techniques this storage does not extend to main memory; gridding systems have been established on significantly smaller computers than TIN models. The problem is then reduced to one of auxiliary storage. The inability to represent input data values exactly may be significant when the input values are high in information content. However, when, in general, that is not the case, care can be taken to respect the input data values to the nearest mesh intersection.

Further, despite the fact that it may be difficult to justify sophisticated mathematical techniques being used to predict surface values at a variety of locations, these techniques do lead to feature detection or indication methods which are particularly useful when endeavouring to produce navigational charts.

On the other hand, the main advantage of a TIN model is its ability to represent a surface using only a minimum of high information points. This advantage is substantially countered when the high information points are not available for input as is the case with line data input.

The disadvantages of the system however remain very much intact, particularly the problem of triangle formation. While there exists the possibility that further research will solve this problem, the remaining uncertainty does not justify the system at this point in time for hydrographic applications.

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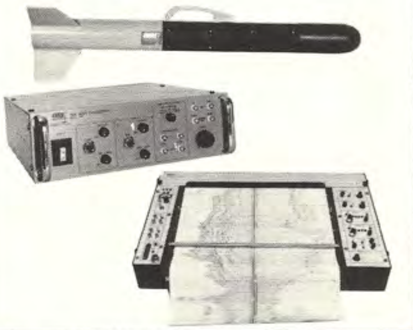

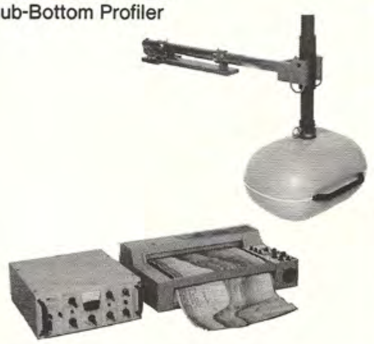

"Smart" Digitizer Proven in Arctic

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INTRODUCTION

During the months of July, August and September of this year, a new "smart" digitizer was used with good results by the Canadian Hydrographic Service in the Beaufort Sea. This digitizer, a Meyer Systems Inc. (MSI) Model G1097 Bottom Tracker, is a successful, state of the art approach to depth digitizing.

The vessels used during the cruise included the C.S.S. HUDSON, a large scientific research vessel (figure 1), and five 25 foot (7.62 metres) fiberglass survey launches. The launches had a semi-planning hull, an enclosed cockpit area and were propeller driven with an inboard diesel (figure 2).

Photo by R. Belanger

Figure 1

Photo by M. Foster

Figure 2

Each launch was equipped with a Simrad Skipper 802 Echo Sounder, a MSI G1097 Bottom Tracker, an Argo Position-Location system and a C.A.T. PHAS (Portable Hydrographic Acquisition System). There was also a TV monitor for the positioning system and a VHF radio system. Figure 3 shows the interior of a launch.

Photo by M. Foster

Figure 3

The sounder's transducer was a 50 KHz, 15° resonant ferrite pinger. It was mounted inside a survey launch, well forward of amidships, in a cylindrical, fiberglass well. This well was mounted to the inside of the launch's fiberglass shell and the hull was not penetrated. Protective pads were fixed to the tranducer's face to prevent damage when the tranducer was resting in the well and on the hull. The transducer was kept flooded.

The location of the tranducer was carefully chosen. Considerations of noise pickup and vibration due to aeration, propeller noise, cavitation noise, engine noise, vibration, and stern wake determined that the transducer should be mounted well forward of the engine and stern. Mounting too far forward, however, was not desirable due to aeration.

Prior to the Cruise

Prior to embarking for the Beaufort Sea, every piece of equipment was thoroughly tested and verified as being fully operational. The G1097 Bottom Tracker was the "new kid on the block" and received very close examination by scientific and technical staff at the Institute of Ocean Sciences (I.O.S.) Patricia Bay, Sidney, British Columbia.

The Bottom Trackers were first calibrated with the video signal from the Skipper 802, then calibrated for group-delay and digital processing delays with a custom-built calibrator. The Bottom Trackers were then put through preliminary sea trails in and around Saanich Inlet. A known transect, from I.O.S. around the north end of the Saanich Peninsula past the Swartz Bay Ferry Terminal to an area referred to as "Turn Point", provided a final test over known terrain with many flats and cliffs. Crossing ferry wakes provided excellent bottom-lost tests since large vessels' propeller wash can completely obscure bottom for several seconds. During the transect tests, small schools of fish and loose vegetation caused no loss of bottom.

Surveying in the Arctic

Four launches performed line-surveying, with a fifth launch in reserve. When weather permitted, two eight-hour shifts were run every day. Weather conditions were sometimes pleasant, but usually rough (figure 4). There were extended periods when the high speed launches' crews had to be strapped down to minimize possible injury due to the rough conditions. Crews estimated that, during these conditions, they were airborne up to 40% of the time. Through these punishing conditions, the MSI G1097 Bottom Tracker tracked and digitized reliably. Conventional digitizers would have failed or faltered badly in these situations, but the Bottom Tracker still tracked and digitized well over 60% of the time (subjective estimate from close examination of echograph). Obviously, recognition and tracking algorithms in the Bottom Tracker performed their tasks well. The superior performance under adverse conditions won operator confidence and acceptance.

Photo by M. Foster

Figure 4

Operating the Bottom Tracker

Operating the Bottom Tracker was straight forward. Controls were simple, well grouped and clearly defined (figure 6) (1) power and display illumination; (2) tracking and alarm; (3) Multi-Function display parameters. The automatically temperature-controlled liquid crystal displays (LCDs) were easily read under all ambient-light and temperature environments. The audio alarm (fully adjustable) provided clear enunciation: (1) a warble for tracking-lost condition; (2) a clear "beep" when data-keys on the keypad were pressed.

Figure 5

Separating the "Depth" data display from the other parameters proved to be very functional. Depth could always be seen even when entering new parameter values in the Multi-Function groups. The tracking on/off indicator, an "underline" at the left most of the Depth display, was augmented by an "L" above the underline whenever tracking had failed and bottom was lost. The Multi-Function display showed funtional groups (pairs) such as Speed of Sound and Verify Margin. Entering values was as simple as dialing a telephone or using a calculator.

Putting Bottom Tracker Into the System

The MSI G1097 Bottom Tracker is connected with 3 coaxial cables (BNC type connectors) to the Skipper 802 echo sounder, and with one multi-line cable (one Bendix-type connector) to PHAS. The echo sounder provided Video and Trigger, and received Verify. The Video was the "raw" received echo signal which was TVG-modulated. The trigger was a TTL-level pulse indicating the instant of transmission. Verify is a low-asserted TTL-level pulse sent to the sounder to produce the typical Verify Line. In this way, the Bottom Tracker depended upon the sounder for good video signals and precise transmission synchronism, and the sounder depended upon the Bottom Tracker for a clear verify mark. The MSI G1097 Bottom Tracker sent 6-digit, parallel BCD data plus status (Tracking On, Bottom Lost, etc.) information to PHAS. "Handshake" lines indicating valid data were also provided to PHAS. All lines to PHAS were TTL compatible.

Table I. MSI G1097 Bottom Tracker Variables Specifications

Variable	Units	Minimum	Default	Maximum	Resolution	Int. Acc.
Depth	(metres)	0.1	10.0	1,600.0	0.1	± 0.009
Sampling	(metres)	-	0.10	-	0.10	± 0.009
Speed of Sound	(m/s)	1400	1463	1600	1	± 0.09
Sampling	(μs)	125	137	143	0.09	± 0.009
Verify Margin	(metres)	0.0	0.0	999.9	0.1	± 0.009
Draft Margin	(metres)	0.0	0.0	99.9	0.1	± 0.009
Tide Margin	(metres)	0.0	0.0	99.9	0.1	± 0.009
Slew Sound Speed	(seconds)	0.5	-	0.9	-	(RC-TC)

Basic Sections of the MSI G1097 Bottom Tracker

The MSI G1098 Signal Card Computer (SCC) is the Bottom Tracker's intelligence. The Analog Front End Processor (AFEP) receives raw Video and Trigger signals from the sounder. It also sends the Verify pulse to the sounder. The Speed of Sound Translator (SST) performs all critical sampling and basic timing functions within the Bottom Tracker except for the AFEP group-delay correction (performed by SCC). The PHAS board buffers and delivers BCD data, status and data valid signals to PHAS. The Front Panel Board provides the mounting substrate for the front panel controls and displays. The power converter board receives +24VDC to +28VDC ship's power and makes it suitable for circuits within the Bottom Tracker.

A Note on the MSI G1097's Software "Smarts"

The excellent dynamic performance of the Bottom Tracker is accomplished by a judicious application of elements of digital filtering, image qualifying, anti-aliasing, adaptive depth and signal (2-dimensional target) tracking, automatic windowing exclusion — functions and expectation (prediction) qualifying.

Also, the AFEP filters' group delays are corrected in software. To accommodate the rapid real-time processing required, software is totally interrupt driven. All displays and switches for the Bottom Tracker parameters are also software driven. State-of-the-Art hardware relieves the software of much overhead and functions inappropriate for software dedication.

Summary

Reliable, high-speed hydrographic surveying (weather permitting) is a reality in waters as rough as those encountered in the Arctic this summer. The instrumentation combination aboard the launches performed well. In particular the G1097 Bottom Tracker gave good service under adverse conditions. Reliable bottom tracking and digitizing (at higher speeds) won the crews' confidence and probably translated into lower survey "line-mile" costs.

Mathematics and Computing Syllabuses for Hydrographers in Canada

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Department of Surveying Engineering
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Revised version of a paper presented at
FIG XVI International Congress
Montreux, Switzerland, August, 1981

Abstract

Training for hydrographers in Canada is available through a two-level in-house course offered to its employees by the Canadian Hydrographic Service; through two or three year courses in surveying technology with a specialization in hydrography; and through Surveying Engineering and Survey Science degree courses with electives in hydrography. In addition the new Canada Lands Surveyor commission has provision for the discipline of hydrographic surveying, as well as other fields of surveying. In this paper, the mathematics and computing components of each of these four curricula are presented, and compared with that proposed in the FIG/IHO Standards of Competence for Hydrographic Surveyors.

INTRODUCTION

Syllabuses for the training of two categories of hydrographers are presented in Standards of Competence for Hydrographic Surveyors, sponsored and approved jointly by the Federation Internationale des Geometres and the International Hydrographic Organization (FIG/IHO, 1981). A *Category A* hydrographer will have a broad, in depth training in all aspects of the theory and practice of hydrography, and will be able to develop, design and execute any type of hydrographic operation. A *Category B* hydrographer will be trained in the various hydrographic skills, and will be able to execute hydrographic tasks (including data analysis) without direct supervision.

In Canada, training for hydrographers has traditionally been provided by a two-level (Hydrography I and II) in-house course by the Canadian Hydrographic Service (CHS). During the past several years, with the encouragement of the CHS, both universities and technology institutions in Canada have begun to develop programs in hydrographic surveying.

Until recently the Dominion Lands Surveyor commission was limited to cadastral or land surveys. This is now replaced by the Canada Lands Surveyor commission (CLS) which has been broadened to include the disciplines of hydrography, photogrammetry and geodesy.

These developments are ongoing, and none of these programs has yet been submitted for review and certification to the FIG/IHO International Advisory Board. However, in general the expectation is that the technology institution programs and the CHS Hydrography I program should produce Category B hydrographers, and that the university programs, the CHS Hydrography II program, and hydrographers who qualify for the CLS commission should meet the Category A standard.

Within this context this paper reviews the mathematical science components of the various syllabuses for hydrographic training in Canada. To provide some structure for this review, we first state the definitions of hydrography and of mathematical science which we will use, and then present a rationale for a mathematical science syllabus to meet the needs of Category A hydrographers over the next decade.

DEFINITIONS

We define hydrography, in its broadest sense (UNESCO, 1979), as the science of measuring and depicting (a) the nature and configuration of the seabed (its bathymetry, geology, and geophysics), (b) its geographical relationship to the landmass (positioning and navigation), and (c) the characteristics and dynamics of the sea (tides, currents, waves, and physical properties of seawater). While hydrographic information has been traditionally used for safety of navigation (particularly in coastal waters), it is now also used as a planning and management tool in the management of the coastal zone (for port construction, erosion control, waste dumping, aquaculture, and national boundaries); for mineral resources in the Exclusive Economic Zone (EEZ); and for ocean-wide environmental management (for example, using tide and current information to trace the path of pollutants).

The mathematical sciences are considered to consist of mathematics itself, plus related disciplines such as statistics and computer science. Although boundaries have become blurred, mathematics traditionally has been considered to contain the branches *algebra* (based on the concept of *number*), *geometry* (based on the concept of *space*), and *analysis* (based on the concept of *limit*) (James and James, 1976). Since spatial relationships are the primary concern of all branches of surveying, including hydrography, it is natural that geometry is the most relevant of these to our work (Vaníček and Krakiwsky, 1981).

RATIONALE FOR A MATHEMATICAL SCIENCES SYLLABUS FOR HYDROGRAPHERS

In general, *mathematics* is used in hydrography to formulate models relating our observable quantities (time delay, angle, water level, etc.) to the quantities we seek (position, depth, amplitudes of tidal constituents, etc.), and to other related parameters (constants, error terms, etc.).

From *statistics* the specialized protocol called *adjustment calculus* has been developed to use these mathematical models, while handling the errors associated with the measurements.

Numerical algorithms and techniques from *computer science* are usually used nowadays in performing the actual calculations.

Let us consider what topics in mathematics may be useful in hydrography. The mathematical models we use represent the relationship in space and time of quantities referred to one or more coordinate systems *(analytical geometry).* Often these models are based on physical laws represented as *differential equations.* The geometrical quantities themselves involve curves and surfaces *(dif-*

ferential geometry). In order to apply adjustment calculus it is important that these models be either linear *(linear algebra)*, or linearizable *(calculus)*. Hydrographic information is often depicted on charts with conformal projections *(functions of complex variables).*

Adjustment calculus has traditionally played a role in the establishment of shore control for hydrography. Realization of the value of redundant observations for positioning at sea has recently led to the application of adjustment calculus in real time hydrographic survey positioning as well (Haugh, 1979). The topics from statistics that contribute to the development of the adjustment calculus include *probability theory, theory of random variables, probability distribution functions, point and interval estimation, multivariate statistics, error propagation,* and *statistical testing.*

The branches of computer science that are useful in hydrography include two which are a present-day necessity, *basic computer science* and *numerical methods,* and two which are growing in importance, *computer graphics* and *data base management.* Practical application of computers to hydrographic tasks requires that the hydrographer be familiar with topics from basic computer science such as *digital computer architecture,* and develop a fluency in *high level computer languages.* The most useful topic from numerical methods is the *computational methods of linear algebra,* for calculations involving linear (or linearized) mathematical models. Computer graphics is likely to play an ever increasing role in the manipulation, processing, and analysis of survey data, and eventually may become one method of displaying hydrographic information to users. As the volume of hydrographic data in digital form expands, the application of well-designed data base management techniques becomes more and more important.

All the topics considered so far are equally useful in other branches of surveying. However there are five aspects of hydrographic surveying that give rise to special mathematical background requirements for hydrographers [Thomson et al., 1979]. First, the long distances over which radiopositioning measurements are often made in hydrographic surveys make full familiarity with *ellipsoidal geometry* desirable. Second, hydrographic radiopositioning systems often provide range difference measurements, the understanding of which requires a knowledge of *hyperbolic geometry.* Third, since hydrography has no equivalent to aerial photo coverage in topographical surveying, the results of a hydrographic survey consist of sparse samples of data which do not provide a whole picture of the sea-bed. *Approximation* techniques are useful in generalizing this point and profile information into surficial representation. Fourth, the analysis of tides requires the application of *time series analysis* techniques. Fifth, the advent of computer-based automated real time hydrographic data acquisition systems requires a familiarity with *small computer architecture* (minicomputers and microprocessors).

Table 1 outlines a mathematical sciences syllabus for hydrographers based on the rationale presented above.

MATHEMATICAL SCIENCE FOR THE CATEGORY B HYDROGRAPHER

Two Canadian technology institutions which have hydrographic surveying programs are Humber College of Applied Arts and Technology in Rexdale, Ontario and the College of Trades and Technology of St. John's Newfoundland (CTT). Both programs are six semesters (three years) long.

The Humber program contains five courses in mathematical science:

Mathematics I
  (trigonometry, linear equations, etc.)
Mathematics II
  (algebra, nonlinear equations, etc.)
Mathematics III
  (matrix algebra)
Statistics
  (random variables, distribution functions, estimation, etc.)
BASIC Programming.

In addition, courses in Surveying Computations, Adjustments of Observations, and Geodesy, contain topics from mathematical science including probability theory, hypothesis testing, spherical and ellipsoidal geometry.

The CTT program contains seven courses in mathematical science:

Mathematics I
  (trigonometry, introduction to analytical geometry, etc.)
Mathematics II
  (analytical geometry, introduction to linear algebra, introduction to calculus)
Mathematics III
  (integral calculus, differential calculus, spherical trigonometry)
Mathematics IV
  (probability theory, least-squares, conformal mapping, coordinate transformations)
Computers I
  (computer architecture, FORTRAN programming)
Computers II
  (FORTRAN programming)
Computers III
  (network adjustment, block adjustment, satellite fix, etc.)

In addition, a course in Adjustments contains topics including probability theory, error propagation, etc.

The CHS Hydrography I program is taught to new employees during their first year of employment and consists of 10 weeks of lectures and 10 weeks of field training (IHB, 1980). These new employees normally have either a diploma in survey technology from a technology institution or a university degree in physical science or engineering. It is assumed that this background will have supplied much of the required mathematical science. However, the Hydrography I program contains courses in Survey Control, Electronic Positioning Systems, and Computer Familiarization, which cover topics such as spherical and ellipsoidal coordinates, hyperbolic geometry, small computer architecture, and programming languages.

According to (FIG/IHO, 1981), Category B hydrographers should have a *basic* knowledge of two-dimensional coordinate geometry, spherical trigonometry, programming languages and the use of computers, and a *practical* knowledge of computer architecture and other computer basics. Table 2 compares the branches of mathematical science dealt with in each of the three Canadian syllabuses against those specified in these standards, using the branch headings from Table 1. While a more detailed topic by topic comparison would be required, this Table indicates that the CHS Hydrography I program likely meets the FIG/IHO standard, while the Humber and CTT programs likely exceed it.

MATHEMATICAL SCIENCE FOR THE CATEGORY A HYDROGRAPHER

Three Canadian universities which offer Surveying Engineering or Survey Science degrees, with elective courses or optional programs in hydrographic surveying, are the University of New Brunswick (UNB), the University of Toronto (UT), and the University of Calgary (UC). Each program is four years long and consists of a number of core (mandatory) courses, plus elective courses.

The UNB Surveying Engineering core program contains eight half-year courses in mathematical science:

Introduction to Calculus I
Introduction to Calculus II
Linear algebra for surveyors
Advanced calculus for surveyors (including ordinary differential equations)
Differential geometry for surveyors (including analytical geometry and spherical trigonometry)
Partial differential equations and complex variables
Introduction to computer programming
Numerical methods I (including approximation and computational methods of linear algebra)

In addition, a sequence of three half-year core courses in adjustments cover the relevant topics from statistics. Two elective courses in digital mapping (including applications of computer graphics) and several electives from the UNB School of Computer Science (for example, data base management and computer graphics) are available.

The UT Survey Science core program contains the equivalent of six half-year courses in mathematical science:

Calculus (including analytical geometry and complex numbers) — full year
Probability and statistics — full year
Computer programming — half-year
Introduction to Survey Analysis (including linear algebra and computer techniques) — half-year

In addition, the core program includes two half-year courses in Survey Analysis (the application of statistics to surveying problems). The Hydrographic Surveying Option contains an elective full year course in Advanced Calculus (including ordinary differential equations), and a course in Data Management (which includes an introduction to interactive systems and data bases).

The UC Surveying Engineering core program contains seven half-year courses in mathematical science:

Mathematics for Engineers I
  (calculus, analytical geometry, differential geometry, etc.)
Mathematics for Engineers II
  (calculus, linear algebra, complex numbers, etc.)
  III
  (ordinary differential equations)
  IV
  (linear algebra, etc.)
Probability and statistics
Engineering computations
  (computer architecture, FORTRAN programming, etc.)
Numerical methods in engineering

In addition, the core program contains two half-year courses in adjustment and analysis of observed data. Elective courses in computer graphics and the structure of survey data bases are also available.

The CHS Hydrography II program is offered to employees with at least five years' hydrographic surveying experience, and consists of six weeks of lectures (IHB, 1980). There are no specifically mathematical courses offered, however courses in Radio Aids, Control Surveying, Geodesy, Map Projections and Cartography cover topics from probability and statistics, analytical geometry, linear algebra, conformal mapping, and the architecture and languages associated with the specific small computer systems in use with CHS.

Four of the examinations for Canada Lands Surveyors are in mathematical science:

Mathematics I
  (calculus, analytical geometry, etc.)
Mathematics II
  (linear algebra, differential geometry, spherical trignometry, complex numbers, etc.)
Statistics
  Computer Programming

According to FIG/IHO (l981), Category A hydrographers should have a *full* knowledge of basic computer science, a *practical* knowledge of linear algebra, analytical geometry, some aspects of calculus, complex variables, statistics, and other aspects of calculus. Table 3 repeats the comparison for Category A between the five Canadian syllabuses and the FIG-IHO standards, in terms of the branches of mathematical science dealt with in each. If we can assume that hydrographers taking the CHS Hydrography II course have an adequate background in calculus, then this Table indicates that both that and the CLS syllabus likely meet the FIG/IHO standard, while the three university syllabuses likely exceed it. As before, a more detailed study of course materials, sample examinations papers, etc. would be required to confirm this tentative assessment.

CONCLUSIONS

The syllabuses being developed in Canada for the training and certifications of Categories A and B hydrographers have mathematical science components which now appear tentatively to meet or exceed the international standards set by the FIG/IHO Standards of Competence for Hydrographic Surveyors. However this tentative conclusion must yet be confirmed by a more detailed study of each syllabus.

There are, however, several topics not required by the FIG/IHO standards, which should be considered for inclusion in those syllabuses in which they do not yet appear. In order of priority, these topics include the *numerical methods* topics of approximation and time series analysis, *differential geometry, differential equations, data base management* and *computer graphics.*

ACKNOWLEDGEMENT

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TABLE 1
Proposed Mathematical Sciences Syllabus for Hydrographers

- Linear Algebra
  - Vector Spaces
  - Matrix Algebra
  - Systems of Linear Equations
- Analytical Geometry
  - Cartesian Coordinate Systems
  - Spherical Coordinate Systems
  - Ellipsoidal Coordinate Systems
  - Hyperbolic Geometry
  - Coordinate Transformations
  - Spherical Trigonometry
- Differential Geometry
  - Geometry of Curves and Surfaces
- Real Analysis
  - Differential Calculus
  - Integral Calculus
- Complex Analysis
  - Functions of Complex Variables
- Differential Equations
  - Ordinary Differential Equations
  - Partial Differential Equations
- Statistics
  - Probability Theory
  - Random Variables
  - Distribution Functions
  - Point and Interval Estimation
  - Multivariate Statistics
  - Error Propagation
  - Hypothesis Testing
- Basic Computer Science
  - Small Computer Architecture
  - Fluency in High Level Language(s)
- Numerical Methods
  - Computation Methods of Linear Algebra
  - Approximation
  - Time Series Analysis
- Computer Graphics
- Data Base Management

TABLE 2
Category B Comparison Between Canadian Programs and FIG/IHO Standard

	HUMBER	CTT	CHS-I	FIG/IHO
Linear Algebra	•	•		
Analytical Geometry	•	•	•	•
Differential Geometry				
Real Analysis		•		
Complex Analysis		•		
Differential Equation				
Statistics	•	•		
Basic Computer Science	•	•	•	•
Numerical Methods				
Computer Graphics				
Data Base Management				

TABLE 3
Category A Comparison Between Canadian Programs and FIG/IHO Standard

	UNB	UT	UC	CHS-II	CLS	FIG/IHO
Linear Algebra	•	•	•	•	•	•
Analytical Geometry	•	•	•	•	•	•
Differential Geometry	•	•	•		•	
Real Analysis	•	•	•		•	•
Complex Analysis	•	•	•	•	•	•
Differential Equations	•	•	•		•	
Statistics	•	•	•	•	•	•
Basic Computer Science	•	•	•	•	•	•
Numerical Methods	•		•			
Computer Graphics	•		•			
Data Base Management	•	•	•			

NOTE: The CHS-I and CHS-II courses are in-house enhancement courses for employees of the Canadian Hydrographic Service who will normally have received training in surveying from a technology institute or university.

Book Review

Julian E. Goodyear

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Atlantic Region
Dartmouth, Nova Scotia

"Analysis and Adjustment of Survey Measurements" by Edward M. Mikhail and Gordon Gracie, published by Van Nostrand Reinhold, New York, 1981, 340 pages, cost $36.95.

This book was written in response to recommendations made at the Ninth Annual National Surveying Teacher's Conference, held in June, 1977 in Fredericton, New Brunswick.

If one were to research the availability of literature on the subject of analysis and adjustment of survey measurements, he would find that there is a wealth of information on the topic. However, it is in many forms and most of it unsuitable and not structured for the beginning surveying student or practicing surveyor.

The subject matter has been organized into ten chapters, beginning at an introductory level in Chapter 1, on errors and reliability in survey measurements. The use of field measurements in mathematical functions for computing quantities of interest is elaborated upon in Chapter 2. Hence, Chapter 2 contains sections on error propagation and the basis of linearization of a function.

Chapter 3 introduces the concept of adjustment and simple adjustment in Chapter 4. In Chapter 4 the reader is introduced to the concept of weights and the techniques of least squares adjustment of indirect observations and observations only. At this point, the reader who is unfamiliar with least squares adjustment should be prepared to spend quite an amount of time "digesting" the techniques used in Chapter 4.

Probability theory is the basis of Chapter 5. Topics covered include random events and probability, random variables, continuous probability distributions, normal distributions, expectation, measures of precision and accuracy, and covariance and correlation. Chapter 6, entitled Variance — Covariance Propagation, derives the propagation laws and applies variance — covariance propagation to the least squares solution of surveying problems.

The "powerful tool", of preanalysis, used in the design of surveying projects, is the subject matter of Chapter 7. This study provides the surveyor with the basic knowledge necessary for the selection of instruments and procedures to meet the specification of a project.

The material in Chapter 8 covers statistical analysis and introduces concepts such as chi-squart and t distributions, statistical estimation and testing, bivariate normal distribution and error ellipses.

Chapter 9 is a reinforcement of the techniques used in Chapter 4, treating a general approach to least squares adjustments and concluding with a summary of symbols and equations for quick reference when solving adjustment problems.

The concluding chapter discusses and illustrates least squares adjustment in a plane rectangular coordinate system. It includes formulation and linearization of distance, angle and azimuth equations, least squares position adjustment and transformation of coordinates from one rectangle system to another.

The text contains many worked problems as well as problem exercises at the end of each chapter. The book presupposes a knowledge of algebra, geometry, calculus and matrices, but provides an introduction to matrix algebra in Appendix A. Appendix B contains three tables used in statistical analysis.

The authors should be commended on the presentation of the concepts covered in the subject matter of this text. The information contained in this volume is well presented, mainly through interesting worked examples and the problem exercises. The book's greatest advantage over others covering the same material is that it is strongly oriented toward the solution of practical surveying problems.

Julian E. Goodyear

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Ottawa, February 19, 1953 **List 2325**

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CHA/CHS News

Atlantic Region

Personals
Dick Lelievre retired in July after 33 years with the Canadian Hydrographic Service. In March, he was honoured with a dance, buffet, many speeches and gifts at the Dartmouth Inn.

Congratulations to Nick Stuifbergen and Julian Goodyear who graduated with degrees in Survey Engineering from U.N.B. Three other hydrographers involved in the university training program are Walter Burke, Hank Boudreau, and Rick Mehlman. We wish them the best of luck in their studies.

Atlantic Region has two new cartographers — welcome to Patsy Meisner and Nick Palmer.

Congratulations to Marcel Chenier who won the checker competition.

Three people departed for new horizons: Ross Tracy is now with Occidental Petroleum spending alternate months in Libya and at home in Hantsport; Dave Holt is trying to live off the land in the wilds around Greenfield but so far the salmon haven't been cooperating. He's also working on a novel and generally having a good time; Jane MacLeod left us to take up another vocation and we wish her all the best.

Welcome to Paul Bellemare, from Quebec Region, who has joined us for 2 years. He has mainly been involved in aerial hydrography.

Adam Kerr sailed the Atlantic accompanied by Jim Bruce, and two others and arrived in Britain safely.

Congratulations to Paul and Joanne McCarthy on the birth of their son; Adam and Judith Kerr on the birth of their son Timothy; and to Gary and Cynthia Landry who were married in February.

Welcome to Bev McNeil, who joined the Hydrographic Service in October.

Congratulations go to all those who received their CLS Commissions: Adam Kerr, Burt Smith, Hank Boudreau, Gary Henderson, Steve Grant.

Central Region

Personals
Ab Rogers retired September 18, 1981, after serving 31 years in the Hydrographic Service.

The Regional Tidal Officer's position vacated by Brian Tait was filled by Dennis St. Jacques.

Bruce Richards and Sean Hinds joined the rank and file of field Hydrographers. Bruce is not new to the ways of Hydrography, having come from the Cartographic Section of C.H.S.

Over the summer, Dick MacDougall, John Medendorp, Denis Pigeon and Steve Bockmaster increased their income tax deductions by new additions to their families.

Craig Fisher and Brent Beale, both of Cartography, got married this summer.

Events
This spring, four adventuresome, overweight C.H.A. members participated in the annual Burlington Road Race. Calling themselves the "C.H.A. Ship-Heads" Danny (bum leg) Mahaffy, Brian (will) Power, Dennis (tidal bore) St. Jacques and Brad (big foot) Tinney completed the 15 mile relay in a personal record time of 1 hr., 52 min. 18 secs., placing 132 in a field of 244 teams.

Ottawa Branch

Personals
Congratulations to Jake Kean and John O'Shea who have received their CLS commissions this year. Other members of the Ottawa Branch are working towards theirs.

Bob Steele has returned from education leave, he graduated from Ottawa U. with a B.Sc. in Computing Science.

John Cookson of the Cartographic Training Section has just completed a major project with the recent release of the CHS Drafting Standards. Pete Richards of Hydrographic Training assisted in organizing a week-long seminar conducted in Burlington this past summer for six delegates from the Sri Lanka, Papua, New Guinea, Guyana, Malaysia, Jamaica, and Singapore.

Ray Thomas retired July 3rd.

Ron Parker of the Cartographic Systems Section has resigned from the Government.

Ron Gauthier, after 10 years with the Geoscience Mapping Section has accepted a position with the Inland Waters Directorate of D.O.E.

Ray Petit has joined the staff at Russell Road as a Sailing Directions Officer.

Sue Dahms has joined the Cartographic Systems Section as a programmer.

Don Vachon and Gary Kosowan were both married this past summer.

Jim Bruce returned from French language training just in time to join Adam Kerr on another trans-Atlantic sailing trip.

Dusty Degrasse, recently retired from Central Region, has moved to Ottawa.

Many members of the Headquarter's staff were on temporary assignment away from the office for part of the spring or summer:

- Lung Ku (Tides, Currents, and Water Levels) spent July and August at Patricia Bay working on a numerical model for Parry Channel.
- Gunther Schutzenmeier, (Training) was on the Maxwell for three months in the Strait of Belle Isle.
- Pete Richards spent a week in the Bruce Peninsula assigned to the Aerial Hydrography Project.
- Jake Kean (Planning) spent the month of September on the Labrador in Foxe Basin.
- Dave Gray (Nautical Geodesy) spent three weeks in June along the Gaspe Coast calibrating Loran-C lattices.
- Three members of the Geoscience Mapping Section — Diana Pantalone, Paul MacMillan and George Medynski each spent a month aboard the Dawson in Davis Strait.

Events

The Ottawa Branch organized a trip in June to the MOT buoy tending depot in Prescott. The 25 members (including one non-CHS member) were given a tour of both the shore facilities and of the MOT vessel the Alexander Henry. Poor weather conditions prevented the vessel from sailing and taking the CHA members to Brockville Narrows and back as had been planned.

The Branch also organized one luncheon with a guest speaker and one other lecture.

General News

Some new equipment has been acquired at CHS Headquarters. A new Kongsberg plotter has been installed in the Chart Production area and the Nautical Geodesy section has purchased 2 JMR Satellite Receivers and one Internav 123 Loran C Receiver.

Pacific Region

Personals

Tracy Collins is ably replacing Mona Mikkelsen as Technical Records Clerk while Mona is on maternity leave. Ann Morrey has joined the Chart Production Staff as part-time Secretary/Typist.

Chart Production hosted three COSEP students this summer, two of whom spent time in Chart Production, Chart Correction and Chart Distribution. The other undertook a Market Analysis Survey in Pacific Region for Chart Distribution.

Ron Korhonen completed an Acting Term Assignment in Navigational Aids and Al Schofield is presently fulfilling an Acting Term Assignment in photomech while Brian Watt is attending a course in Belgium.

The month of July saw the departure of two cartographic staff. Grant Chan resigned his position to accept employment with the B.C. Government and Malcolm Brown was successful in his bid for employment with the Government of Manitoba. Staffing action is presently underway to fill these vacancies.

In field hydrography, there are two new recruits: Maurice Bastarche and Knut Lynberg, both graduates of the B.C. Institute of Technology. Brian Wood has joined as a term employee.

Robin Tamasi resigned after thirteen years service and has gone to join Alberta Power Ltd. in Edmonton.

Congratulations to the successful candidates in the February CLS Examinations: Mike Bolton, Vern Crowley, Barry Lusk, Tony Mortimer, and Tony O'Connor.

Tony O'Connor, National President of CHA, has been elected a Councillor at large in CIS and Chairman of the CIS Hydrographic Technical Committee.

Events

On the social scene, our Annual Golf Tournament was held on August 21 and Mike Foreman duplicated his performance of 1979 by taking top honours in this 'battle of the duffers'. This prestigious event was followed the next day by a BBQ and dance at the Institute where the recipients of their respective prizes were treated to a video-tape of their languid performance on the links.

Both I.O.S. Mariners softball teams have wrapped up another 'tavern-haunting' season competing in numerous tournaments throughout the city. Regarding the success of this past season, suffice to say, our trophy case is endowed with no more hardware than at this time last year.

General News

A Market Analysis Project funded by Canadian Hydrographic Service, Pacific Region to examine Nautical Chart and Publication Distribution Systems has been completed. The study, conducted by COSEP student Janice Runacres, sought to identify the retail users of C.H.S. products, their future requirements for navigational products produced by the C.H.S., gather input and suggestions regarding charts and our distribution system from Authorized Agents, and to evaluate the effectiveness of our advertising programs. In-depth personal interviews of both chart users and chart agents were conducted and each agent was mailed a questionnaire form. The results of this analysis are presently being reviewed.

Quebec Region

Avis personnels
Cet été, l'équipe de Jean-Marie Gervais a été affectée a des levés hydrographiqies en Gaspésie tandis que celle de Peter Kielland a terminé le levé du Lac Saint-Jean pour ensuite continuer sur la Rivière Richelieu. Jean-Marie Gervais a aussi participé avec Dave Gray à la calibration du réseau Loran-C dans le Golfe Saint-Laurent.

Au début du mois de septembre, Peter Kielland a entrepris un cours en Géodésie d'une durée de quatre ans à l'Université Laval. Kent Malone le remplacera sur le terrain. Russ Melanson a remplacé Ken Williams durant le mois de septembre alors que ce dernier poursuivait son cours de "Perfectionnement des cadres supérieurs" au centre de perfectionnement de Touraine.

Du côté de la cartographie, René Lepage et Alain Gagnon ont effectué une envolée d'hélicoptère le long de la Côte Nord du Québec. Claude Chantigny s'est mérité le poste de surveillant (DD05) lors d'un récent concours. Deux étudiants ont été embauchés durant l'été, soit Michelle Grenier et Denis Caron. Ils ont été d'un aide précieuse en cartographie.

En attendant le retour des hydrographes, Richard Sanfaçon s'occupe des préparatifs en vue des ateliers de travail qui auront lieu à Québec au début du mois de février 1982. Les premiers pas ont été faits en vue de la production de cartes spéciales à l'occasion des célébrations du 350ième anniversaire de l'arrivée de Cartier au Québec (1534-1984). Une course de voiliers venus de tous les coins du monde aura lieu à cette occasion

A tous les employés du Service hydrographique, et les membres de l'A.C.H. nous réitérons notre invitation, en espérant vous voir en grand nombre à Québec en février '82.

On vous salue et à bientôt!

Personals
This summer, the team of Jean-Marie Gervais surveyed in the Gaspé while that of Peter Kielland finished the survey of Lac Saint-Jean and then continued on the Richelieu River. Jean-Marie Gervais also participated with Dave Gray in the calibration of the Loran-C network in the Gulf of St. Lawrence.

At the beginning of September, Peter Kielland started a course in Geodesy which will last four years at Laval University. Kent Malone will replace him in the field. Russ Melanson replaced Ken Williams during the month of September while he continued his course of "Improvement of Upper Management" at the Touraine improvement centre.

In cartography, René Lepage and Alain Gagnon flew by helicopter along the North Shore of Quebec. Claude Chantigny won the position of supervisor (DD05) in a recent competition. Two students were hired during the summer, Michelle Grenier and Denis Caron. They were a great help in cartography.

While waiting for the return of the hydrographers, Richard Sanfaçon is making preparations for the workshop which will take place in Québec in the beginning of February 1982. The first steps are made in the preparation of special charts on the occasion of the celebration of the 350th anniversary of Cartier's arrival at Quebec (1534-1984). A race, with sailboats coming from all over the world, will be held on that occasion.

To all the employees of the Hydrographic Service, and CHA members, we send our invitation to the workshop, and hope to see a great number of you in Quebec in February '82.

We salute you and hope to see you soon.

Evenements
La region de Québec a organisée un concour pour le dessin d'un écusson pour l'atelier de travail. Plus de quinze écussons furent soumises et Richard Sanfaçon gagna le prix, un abonnement d'un an au National Geographic, pour son dessin unique. Félicitation Richard!

Events
Quebec Region organized a contest for the design of a workshop crest. More than fifteen crests were submitted and Richard Sanfaçon won the prize, a one year subscription to National Geographic, for his unique design. Congratulations, Richard!

We would like to hear some news from all our non-CHS members.
If you have anything to contribute to our NEWS column, please write to:

The Editor, 'Lighthouse',
The Canadian Hydrographer's Association
Bedford Institute of Oceanography, P.O. Box 1006,
Dartmouth, Nova Scotia, Canada B2Y 4A2

Notes

On August 18, CSS Acadia moved to her permanent berth at the Maritime Museum of the Atlantic as a national historic site (see 'The Acadia Goes to the Nova Scotia Maritime Museum', R.M. Eaton, Lighthouse, Edition No. 21, April, 1980). She will be opened to the public in the summer of 1982.

Dick Lelievre Retires

Mr. Dick LeLievre recently retired from the Canadian Hydrographic Service, Atlantic Region. Dick joined CHS in May of 1948. It didn't take Dick long to work his way up to HIC on various ships, such as the Theron, Acadia, Algerine, Baffin, Kapuskasing, and Minna.

Dick originally comes from the rocky shores of Inverness, Cape Breton. He and his wife Theresa now reside in Bedford, Nova Scotia.

Dick was one of the first graduates of the Nova Scotia Land Survey School in Lawrencetown, under the direction of Major J.A.H. Church. Actually, Dick has had many 'firsts'. He was HIC on one of the first HI—FIX surveys (Chaleur Bay 1963); and he was on board the Labrador on her first trip through the Northwest Passage.

Dick has been busy painting and generally having a good time since his retirement. We wish Dick all the best in his new endeavours.

A.R. Rogers Retires

Ab Rogers, Hydrographer, Central Region, retired on September 18 of this year after a long and distinguished career with the Canadian Hydrographic Service.

Ab joined CHS in June, 1950, participating in a variety of surveys encompassing the Eastern Arctic, East Coast of Canada, MacKenzie River, N.W.T., Alberta and Ontario.

During this time Ab served on the C.S.S. Kapuskasing, C.D. Howe, C.S.S Acadia, M.V. Theron, ships familiar to his colleagues, certainly names that excite memories of past adventures in far away places.

In 1952, shortly after Ab joined the C.H.S., he was put in charge of the C.D. Howe carrying out reconnaisance surveys in the Eastern Arctic and Hudson Bay area. For the next eleven years this was a part of Canada Ab was to become very familiar with. In 1967 Ab left the salt water behind and started the job of charting the fresh waters of the Ottawa River.

In 1970 Ab moved from Ottawa with the establishment of Central Region, currently referred to as Bayfield Laboratory for Marine Science and Surveys, and made his home in Burlington. It was shortly thereafter Ab assumed his present position as O.I.C. of Marine Information Centre and Field Sheet Inspection while still acting as H.I.C. on local surveys. The high quality of field work can be credited in part to Ab's severe attention to detail and accuracy while inspecting field sheets.

A C.H.S. party in Ab's honour was held on November 6 at a local Golf and Country Club.

Ab will be missed by those associated with him. His dedication and hard work towards maintaining high standards in the Canadian Hydrographic Service will be an inspiration to all that follow.

News from Industry

Klein Associates, Inc.

Klein Associates announces the appointment of George W. Skuse as Manufacturing Manager. George brings 20 years of high technology electronic manufacturing experience to Klein's staff and he is a senior member of the Society of Manufacturing Engineers and the Boston Chapter of the American Production and Inventory Control Society.

NITELINE

Klein Nightime Inquiry Telephone Emergency Line is now in effect. Worldwide clients of HYDROSCAN Side Scan Sonar and Sub-Bottom Profiler may now reach key Klein Technical and Sales Personnel on nights, weekends, and holidays by dialing (603) 893-6131.

EG&G CANADA LTD.

Exploranium/Geometrics is introducing a new Marine Search Magnetometer the G-866, for most search applications. The instrument has 0.1 gamma sensitivity and can operate with cable lengths up to 1000 feet. The Magnetometer console is fully weatherproofed and runs off any power source from 11 to 30 V DC.

Features are push button controls and a built-in chart recorder with a dual sensitivity chart and printed values of time and magnetic field. The console weighs only 13 lbs. and is 7 ½ x 9 x 16 inches.

N.B.A. (CONTROLS) LTD.

N.B.A (Controls) Ltd. have produced a new wave profiling buoy —WAVECREST — designed to perform long term, unattended, accurate wave measurement in any marine environment.

WAVECREST transmits the acquired data via a 27 MHz band radio link to a receiver which may be located on shore, ship, or offshore platforms. The sensor which measures the movement of the waves is an accelerator housed in the lower of two cylindrical buoyancy units which form a compound pendulum. The main shell itself is manufactured from lightweight polyethylene to provide high impact resistance, is ultra-violet stabilized and non-corrodible. By simply disconnecting the shell's top panel, one gains immediate access to the sensor unit, electronic module and battery packs. In the event of severe damage to the shell, the entire system can be removed and simply remounted in a new shell.

MARINAV CORPORATION

Marinav offers, from Del Norte Technology of Euless, Texas, a new Trisponder Rho/Theta System. The system has been designed specifically to provide the hydrographic surveyor with highly accurate positional data where poor geometry precludes using standard microwave positioning equipment.

On shore, a digitizing theodolite feeds angles to 0.01 degree accuracy into the Trisponder Remote Unit, as the hydrographer tracks the vessel. The angles are transmitted to the Distance Measuring Unit in the vessel when the theodolite operator on shore presses his foot switch.

The Trisponder is normal in other respects and can operate range-range when fix geometry permits.

CANADIAN APPLIED TECHNOLOGY

CAT are active in setting up data collection services for water survey and resource management which can be accessed by local terminal or central computers, for example, for daily flood forecasting. Such systems are being used on Lake Winnipeg, around London, Toronto, and elsewhere.

MESOTECH

Mesotech's two latest releases are the miniature acoustic Model ART 525, and the compact electro-mechanical Model 586.

The acoustic release transponder (ART) is claimed to be the world's smallest at 76 mm diameter x 475 mm long (3 in. x 18.7 in.) and it can release loads up to 450 kg. (1000 lbs.). Its 32 unique release codes ensure reliable operation and complete rejection of interfering signals and noise. As a transponder, a single unit may be used to range to a point location, or up to 4 may be used with Mesotech's 411/412P navigation system for area navigation.

Model 586 releases loads up to 2300 kg. (5000 lbs) from depths to 1000 m (3000 ft.) or 2000 m (6000 ft.). It is 173 mm diameter x 533 mm long (6.8 in. x 21 in.) and weighs 9.3 kg. (20.5 lbs.) in air.

Mesotech has announced the development of an interesting new survey tool, the Model 965 profile sonar. Microprocessor controlled over 2 orthogonal axes, the sonar can examine with high resolution, any surface or object within a 100 metre diameter hemisphere.

A monitor CRT provides 1% resolution of true ranges and depths, while an R5-232-C interface at 9600 baud can address a host computer.

Anticipated uses for this sonar are: dredging in tough strata; positioning caissons, mats or drilling templates; short range navigation; and harbour surveys.

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APPLIED MICROSYSTEMS LTD. has moved to:

2035 Mills Road
Sydney, B.C. Canada
V8L 3S1

Although AML offers a comprehensive product line of tide gauges, current meters, CTD's and temperature profilers it has also designed two retrofit electronic systems of interest to geodyne current meter users and Ott chart recording water level gauge users. These are on IBM compatible nine track recorder with 250 Megabit capacity for the geodyne and a precision quartz clock stepping motor drive for the Ott recorder.

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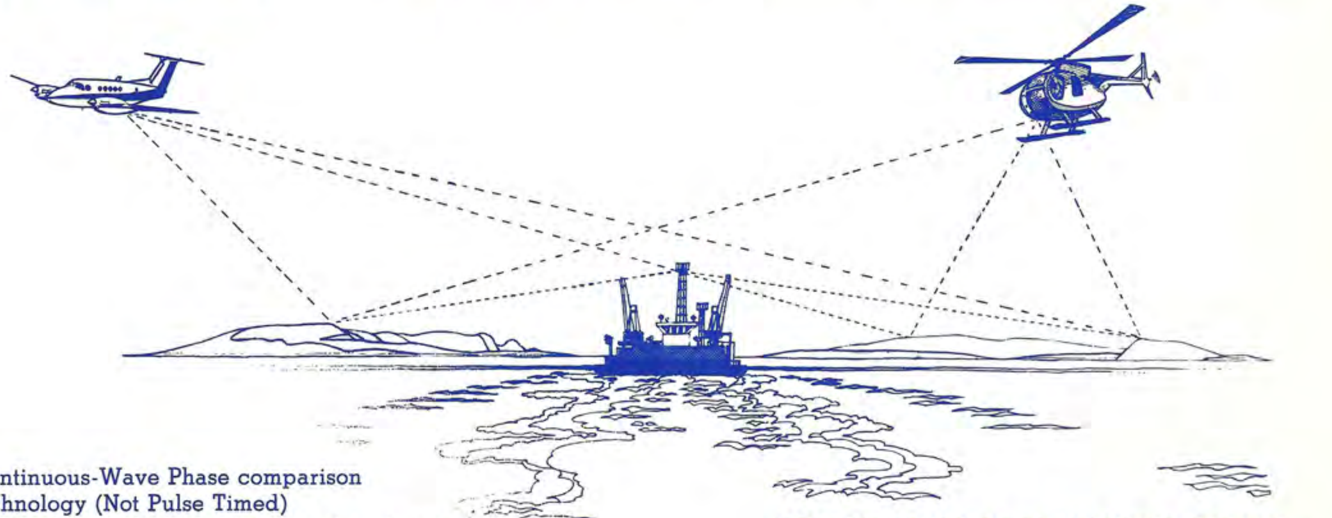

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