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FROM EPHEMERIS TO EPETIS *

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Geographic positioning invariably implies solving " triangles of position ". On the celestial sphere, the angles of a triangle are the celestial pole, the observer's zenith and the zenith of either a terrestrial mark or a celestial point. I do not propose to elaborate on this fact since it is one well known to navigators and geodesists, but only to point out the singularity of the situation.

In astronomic positioning the celestial point (**) has by definition the corresponding star's hourly angle at the meridian of origin as Longitude and the star's declination as Latitude. The distance and bearing of this point are deduced from the star's height and azimuth. No difficulties are posed by the fact that this point is mobile, provided the hourly coordinates of the star at the time of the observation can be determined.

THE DEVELOPMENT OF POCKET CALCULATORS

The hourly coordinates of moving bodies and the vernal point (Aries) are given for each day in tables called Ephemeris (by reason of this daily characteristic). When they are drawn up to the degree of accuracy necessary for ship positioning they are known as Nautical Ephemeris, or the Nautical Almanac. The triangles of position are solved by arithmetical means, for their dimensions are generally large in relation to the terrestrial radius. There is a profusion of tables of various kinds: in general they supply solutions which approximate the triangle to be solved. How-

(*) This is a newly coined word, chosen for its analogy with the word Ephemeris.
(**) On the terrestrial sphere this point is called the sub-stellar point.

ever, none has definitively supplanted the logarithmic tables to which we invariably return after following a new fashion or satisfying our curiosity regarding a new or unusual approach.

For the geodesist, mechanical calculators have for a long time enabled preference to be given to the table of natural values for trigonometric lines over the logarithmic tables. However, we must wait until mini-calculators of pocket size can produce the values of trigonometric functions directly, so that navigators and geodesists may be able to relegate the said tables to use only in an emergency. To go through such a table is a relatively long job, and thus inconvenient both on the bridge and in the field. Interpolation, which remains a necessity, is scarcely simplified by using an auxiliary table or a pocket calculator with only the capacity to carry out the four arithmetical operations.

We need to progress — to be able to dispense (both in time and place) with the requirement for tables of hourly coordinates. In order to do this the pocket calculator must produce these coordinates directly. Several models, designed especially for nautical computations, have already come on the market. Thanks to their " read only " memory capacity and a fixed programmation, these calculators permit solution of triangles of position for epochs far into the future — some even right up to the end of the century, although this is more an argument to appeal to a simpleton than a real advantage. These specialized pocket calculators will remain costly, chiefly because they will not have a very wide market, and due to their low efficiency to cost ratio resulting from the very fact that they are specialized products.

Comparable results can be obtained equally quickly using an all-purpose programmable calculator (with either magnetic card or plug-in module data/program storage facility) at far lower cost for equal performances and infinitely larger efficiency to cost ratio. It thus suffices to give the lucky possessor of one of these little marvels the means of drawing up his data cards — awaiting the time that cards for each make of calculator become available through commercial channels. Moreover, the programmation scheduled for one of these pocket calculators can also be utilized on either a desk-top calculator or a computer carried on board for reasons other than that of positioning the vessel.

The problem — and it is identical to that confronting the designers of special-purpose pocket calculators — is to evolve a method of representing the hourly coordinates (which are functions of time) that takes up only little space and is easily exploitable. It has been demonstrated that Tchebychev's polynomial development, which is valid for the whole period between two consecutive rechargings of the data cards, is the most suitable representation (*). For a given celestial body, the number of terms in the development — and thus the length and difficulty of its exploitation — is a direct function of the length of the above-mentioned period and the accuracy we wish to obtain. As to the length of this period,

(*) See « *Un projet d'Ephémérides nautiques pour calculateur de poche* », by P. MANNEVY, Vol. XXVII, No. 106, April 1979, page 220.

it appears reasonable to make this not less than a month, and to go beyond a year seems unnecessary. In marine positioning the accuracy required is to a tenth of a sexagesimal minute, which is what the Nautical Almanac supplies.

The pocket calculators to be currently found on the market can exploit one month periods, and the models expected to be available in the near future will allow a yearly period to be used. Thus, the Nautical Almanac can truly be relegated to use in an emergency, as one of the reglementary secondary aids which all ships must carry, for they will be replaced on the bridge first by the " Epimenis " and then by the " Epetis ".

In reality, these new documents differ fundamentally from the earlier ones. Firstly, they are only used once a month in the case of the former and once a year in the case of the latter, and the work can be done at leisure in the calm of the office. Secondly, the data has merely to be copied onto the keyboard of the pocket calculator in order to set up data cards. Alternatively the cards may be completed by recopying by automatic means those of a friendly navigator, unless of course they are issued by the manufacturer already completed.

NAUTICAL EPIMENIS

Aware that this means that new facilities can be put at the disposal of the navigator (*) the French Hydrographic Service will be issuing " Nautical Epimenis " from 1980 onwards (**), and later will be editing " Nautical Epetis ". The new publication is composed of six sheets in a transparent folder, so arranged that the outer pages (read through the pochette) contain all the information required on the bridge, i.e. :

— data for correcting observed altitudes;
— right ascensions and declinations for some fifty of the most frequently used stars;
— a space reserved for the insertion of the operating procedure either by hand or by means of a " sticker " (not the programmes themselves, which are mentioned later in this paper).

The four inner sheets contain the information necessary for writing the computation program and for loading the data for moving bodies (the Moon excepted) and for Aries. These pages are consulted only once — when the pocket calculator is first received — in order to enter the programs, and thereafter only once each month at leisure in order to enter the coefficients for the development. Also contained in the folder are the Directions for Use (to be stuck on one of the outer sheets) and the programs

(*) The marine and the air navigator alike – the astronomer, too, when his instruments can give him no better than a tenth of a sexagesimal minute.

(**) *IHB note :* The 1980 edition of "Epiménides nautiques" is available in either an English or French version from Etablissement Principal du Service Hydrographique et Océanographique de la Marine, 13, rue du Chatellier, B.P. 426, 29275 Brest Cedex, France, or from sales agents for their nautical publications.

for the pocket calculators used in the French Navy (at present the TI 59 and the HP 67).

The publication thus consists of a permanent part and an annual part renewable every year at an extremely low cost.

Since the programmes will be either supplied by the manufacturers or appended to the " Epimenis " it is considered that preparation of the cards each month should take less than a quarter of an hour. On the bridge itself, personnel without a knowledge of mathematics or astronomy should be able to solve triangles of position within a minute — and this includes keying in the observation's epoch and the coordinates for the estimated position. If it is also necessary to identify an observed but unknown star then the operation would take two minutes.

LASTING VALUE OF INDEPENDENT POSITIONING

Anyone with a rational understanding of the various radiopositioning systems in use today has a natural interest in astronomic positioning.

Incontestably, the services rendered by Omega, Loran-C and Trident are considerable (to mention only the most reputed in its category of coverage — world, regional or local) and this is also the case for radio-positioning by means of a terrestrial satellite of known orbit. Certainly the precisions claimed by manufacturers rely on the operator's particular experience and care. Even when degraded by a coarser procedure, this precision still satisfies the navigator's needs. There is, however, less talk of the variations in accuracy, or of the more easily perceived malfunctioning of equipment which should serve to shake a prudent user's sense of security. It is true that the high degree of automation arising from the ingenuity of our electronic and computer experts is not likely to lead us to suspect the figures displayed on a receiver or introduced into an integrated navigation computer.

The navigator, with responsibility for the safety of the ship, should not however neglect to carry out a check by independent means—he should position by sounding wherever possible, or by stars whenever possible, since both are methods where he can ascertain directly the degree of precision and accuracy. It is true that these checks can be less frequent and more circumstantial than hitherto, as the predetermined route is today often maintained by radioelectric fixes and sometimes by an inertial navigation system.

This recourse to independent methods is all the more necessary in times of conflict (*), when they may even become the only possible methods. At such a time it would be vain to rely on the availability of shared radiolocation systems (or even on the regular dissemination of time radiosignals).

(*) Conflict between "military sophisticated" adversaries – not police action.

Although systems that are local and short-lived or circumstantial (*) might form the exception, their organization and structure would need to be hardened (against jamming) and the onboard systems would have to conform to the endurance standards for military equipment.

The training of naval forces thus includes their training in astronomic positioning and requires that this positioning routine be carried out more frequently than is necessary for peacetime navigation. It will thus be well worthwhile to lighten the process of calculation which is a tedious but essential part of the operation.

It will also be worthwhile to attempt to render observations of the celestial bodies easier and more certain, for this is the noble part of the art of navigation.

(*) For in the "onboard interrogation" mode they would be most indiscreet.

CHANGING STANDARDS

"The world's continental shelf area is about equal in size to the earth's land mass and this can be mapped and charted only by traditional methods of painstaking coverage by expensive and relatively slow-moving ships.

The task has always been too vast for the resources of manpower and ships available, and generations of highly dedicated and zealous hydrographic surveyors of many nations have struggled to keep one step ahead of the requirements of their customers — the naval and mercantile fleets of the world. They have done this remarkably well by concentrating their limited resources on those areas where depths appeared likely to be critical to the largest concentration of marine traffic of the deepest draughts.

Thus, in the 19th century — when the largest vessels afloat, or deemed likely, drew about 27 feet (9 m) — the surveyors concentrated on areas where there seemed likely to be dangers with less than 36 feet (12 m) of water. Once they found depths generally more than 36 feet, the surveyors carried out their search in less detail. This is clearly demonstrated by the mid–19th century surveys in the Irish Sea; close inshore these were very detailed, with the lead-line being dropped frequently along lines run some 200 yards apart; further offshore, when depths of some 40 feet were being obtained consistently, the spot depths obtained by the lead-line were along lines three quarters of a mile apart. During a survey started in 1977, using modern sidescan sonars, a bank was found lying between the lines of the 1843 survey; this bank is some 600 yards across, with depths of around 21 metres (69 feet). The surveyors working to Admiral Beaufort's instructions 135 years ago were quite right not to have wasted the efforts of their seasoned leadsmen in trying to find such a bank which would not have bothered any ship using that area until the introduction of the modern VLCC. But is it right for modern VLCCs to be routed through areas last surveyed to 19th century standards ?"

From a paper by Rear Admiral D.W. HASLAM presented at the Nautical Institute's Conference on International Shipping, London, February 1979, reproduced by kind permission of the organizers.