Five Centuries of Dead Reckoning

E. G. R. Taylor

THE term 'dead reckoning', so the *Admiralty Navigation Manual* (1938) says, is a corruption of the old '*ded*-uced reckoning' or 'position by account', and is used to cover all positions that are obtained from 'the course the ship steers and her speed through the water, *and from no other factors*.' (The last italics are ours.) Had Master William Borough, Chief Pilot of the Muscovy Company, and presently to be appointed to Queen Elizabeth's Navy Board, come across this definition, he would have picked a two-fold quarrel with their present Lordships at Whitehall. For his use and explanation of the term is the earliest of which we have knowledge, although it does not appear even then to have been new. 'And in keeping your dead reckoning', he wrote in 1580 (having certainly never heard any nonsense about *ded*-uced reckoning) 'it is very necessary that you do note at the end of every four glasses' (i.e. every half-watch) 'what way the ship has made, by your best proofs to be used, and how her way hath been through the water considering the sagge of the sea to leewards, according as you shall find it growen: and also to note . . . the wind, upon what point you find it then, and of what force and strength it be, and what sailes you bear'. Borough was addressing two experienced ship-masters, and for the old-time pilot there was certainly no quite separate 'estimated position' to be arrived at (according to the *Manual*) when the D.R. position is adjusted for the estimated effects of winds, currents and tidal streams. And the reason for this was a very good one, namely that the speed of the ship through the water was itself still a matter of estimate and not of measurement. The log line had indeed very recently been invented but, as we shall presently see, it was known only to a few, and even when known was (like all novelties) viewed by sailors with suspicion. Most English seamen, and all foreign pilots, still determined the ship's way by 'pondering withall what space she was able to make with such a winde and such direction' as a young English Jesuit named Stevens put it, when trying to explain to his father how the Portuguese ship in which he was travelling to Goa in 1579 was navigated. Landlubbers aboard ship are, of course, a useful source of information about sea-practice, because they describe all those things that sailors themselves take for granted, although very likely they misinterpret what they see.

Such an observer was the German monk, Felix Faber, who in 1483 went on a pilgrimage to the Holy Land, as a passenger in a three-masted Mediterranean galley. The pilot was a man skilled in the paths of the sea, he says, but he had with him other experienced men, astrologers and augurs (or so Felix imagined them to be) who considered the signs of the

stars and the sky, formed a judgment as to the winds, and so directed the pilot. All alike were expert in the art of judging from the look of the sky whether it would be stormy or fair weather, taking into account also the colour of the sea, the behaviour and movements of dolphins and flying fish, the way that smoke rose, the lights that played on the masthead at night, and the scintillations from the oars as they were dipped into the water. At night, too, they could tell the hour simply by inspection of the stars. They kept a mariner's compass set always against the mast, besides another on the poop by which a lantern burned at night; and when at sea they never took their eyes off the latter; there was always someone watching it, and from time to time he sang out sweetly and melodiously, an indication that the voyage was going prosperously, while by this self-same song the man at the helm was directed how to steer. Nor did the helmsman ever move the rudder unless by his order who, up above, was watching the compass; for it was he who discerned whether the ship was proceeding in a straight line, on a curve or sideways. This last is not a very seaman-like way of stating what went on, but we understand what Brother Felix meant. And he continues with the information that besides the 'Stella Maris' as they called the mariner's needle, naming it from the star toward which it turned, they had other aids or instruments by which to judge the courses of the stars and the blowing of the wind, whereby they picked out those narrow paths of the sea (*semitae maritimae*) which must be followed. These aids, no doubt, were a useful supplement to the astrologers and soothsayers (if such they were, and not just the master's mate and the bo's'un), for they included a chart carrying a scale and criss-crossed with 'thousands and thousands' of lines (as it seemed to the landsman)—in fact a Mediterranean plain chart or portulan, on which were painted sixteen or more wind-roses, with the rhumb lines ruled out in different colours. Every day (says the Brother) the pilot and his assistants hung over this chart, conferring together, for from it they could tell where they were, even when no land was visible, and clouds hid the stars, and from it, too, they learned what course to follow, from point to point along the 'lines'. Such in short was navigation by dead reckoning in 1483 as observed by a tyro awed and mystified, as all plain men then were, by the pilot's boast that he could set course for an unseen destination, and avoid hidden dangers 'without sight of sun, moon, or stars', helped only by a compass no broader than the palm of his hand and a piece of painted parchment.

But to set a course was not to follow that course. The galley could not sail close to the wind, but must tack to and fro, or 'traverse' as it was then called, so that it was necessary to keep a traverse board or traverse book in the steerage, and the course made good had to be worked out from this each day and entered in the Journal. This meant that something in the nature of a traverse table was required, and in fact a far-off ancestor of Inman's tables, going back more than five hundred years, has survived in the sailing directions which form part of Andrea Bianco's Atlas of

1436.* And the mention of a similar table in a Genoese inventory of 1390 carries the date back farther still. Nor need such a table have even then been a novelty, for the properties of the right-angled triangle, and in particular the fact that the ratios which we term the sine, cosine and tangent of any angle were constant no matter what the dimensions of the triangle, had been familiar since the propositions of Euclid were once more studied in the twelfth century. Bianco's table or *Toleta de Marteloeo*, as it was termed, is a graphically determined set of values for the northing (southing) and easting (westing) corresponding to a run of fixed length (100 miles) along each of the eight quarters, points, or rhumbs of the wind, from $11\frac{1}{4}°$, $22\frac{1}{2}°$, $33\frac{3}{4}°$, &c., up to 90°, which makes up a quadrant of the compass. As the charts of those days were ruled in rhumbs and showed no latitudes (which were not then observed in navigation) the term 'd. lat.' does not appear, the columns being headed *alargar*, *avancar*. According to the Toleta a ship sailing 100 miles along the sixth point from North ($67\frac{1}{2}°$), for example, would make 92 miles easting and 38 miles northing, and so for other distances in proportion, which could be worked out by proportion, using the Rule of Three or Golden Rule.

Even simple arithmetic was however a stumbling block to the majority, and Bianco's Atlas also contains a scheme or diagram, constructed on the principle of the sinical quadrant, from which a graphical solution of the traverse could be obtained. The basis of the diagram was a large square accurately subdivided into eight rows of eight small squares. From the top left-hand corner were drawn the sixteen half-points and points (beginning at $5\frac{5}{8}°$) in a quadrant. The whole was surrounded by a circle showing the principal points of the compass. To indicate how the diagram was to be used, a naked cherub runs along the top of the large square, stepping off distances with a pair of dividers nearly as tall as himself, and opened to the width of a small square. Presumably the diagram was intended to be drawn to the same scale as the chart and any distance pricked off on the one could then be transferred to the other. The northing and easting were, of course, measured directly from the 'scheme' and no arithmetic was required. With the Great Age of Discovery, initiated by the Portuguese, long ocean voyages were begun which required observations of latitude to check the D.R. position, and latitudes began to be marked in the margin of the portulan chart. Corresponding tables were eventually prepared by the Jewish mathematicians responsible for working out new navigational methods, among them the *Table of Leagues*, which set out the distances to be sailed along each rhumb in order to raise or depress the pole one degree, together with the corresponding easting or westing (departure). The degree of the meridian was taken as $17\frac{1}{2}$ leagues of 4 miles, and as an example we can extract the following figures from the table as set out in the oldest surviving Portuguese navigating manual: 'Item per 6 quartas releva per grao 46 legoas e mea, at afastaras da lynha direyta 42 legoas per grao et

* It is reproduced in Fontoura da Costa's *A Marinharia do Descobrimentos* (1933).

mea.' That is to say that sailing along the 6th rhumb the distance required to raise a degree is 46½ leagues, and the corresponding easting 42½ leagues. The later Spanish Manuals substituted 16 and two-thirds leagues as the measure of a degree, and the still later English manuals 60 miles, the value used by cartographers.

As this brief review shows, seamen of four or five centuries ago would find no difficulty in working out the daily course made good and the position reached, provided they could make a correct estimate of the distance sailed along each leg of the traverse. But this involved knowing the speed of the ship, and right down to the mid-eighteenth century it was still usual to rely on the master's or the pilot's judgment. He knew his ship, and what she could do carrying such and such sail, under a fresh or a light breeze, with the wind on the poop or on the quarter, and so on. He had a rule of thumb for estimating leeway, and would help himself at most by noting the movement of foam alongside, or by throwing a chip overboard and timing its passage between two bolt-heads on the ship's side. As to the log line, Richard Norwood, when discussing it in his *Seaman's Practice* in 1637 declared that many sailors were either so cocksure of their judgment that they disdained to use it, or were shamed out of doing so because they feared to proclaim themselves 'young seamen', that is to say inexperienced pilots.

Who invented the log line we do not know, except that he was certainly an Englishman. The device makes its first appearance very unobtrusively in William Bourne's *Regiment of the Sea* written about 1573. The author himself was a gunner and therefore not a directly interested party, but living at Gravesend and being interested in 'inventions and devices' of a mechanical sort he noticed what was going on. It is he who tells us that Humfrey Cole, the famous contemporary instrument maker, had invented a gadget to record the ship's way. But this was not a log, it was a sort of 'way-wiser' which actually clocked up the mileage when trailed in the water behind the ship. As for the true log, 'to know the ship's way', Bourne says, 'some doo use this, which as I take it is very good. They have a piece of wood, and a line to veere out overboorde, with a small line of a great lengthe which they make fast at one ende, and at the other end and middle they have a piece of lyne which they make fast with a small thred to stand lyke unto a crowfoote, for this purpose that it should drive asterne as fast as the shippe doth go away from it, always having the line so ready that it goeth out as fast as the ship goeth. In the like manner they have either a minute of an hour glasse, or else a knowne part of an houre by some number of woordes, or such other lyke, so that the lyne being veered out and stopped just with that tyme that the glasse is out, or the number of words spoken which done they hale in the logge or piece of wood again, and looke how many fathoms the ship hath gone in that time.' So far there was no question of knotting the line, and the speed had to be worked out arithmetically, but it appears that the publicity that Bourne gave to the

log caused more sailors to try it; and not always satisfactorily, for in a later edition of the Regiment he adds some practical hints, in particular that the mark on the line at which counting begins should be two or three fathoms from the billet (later it was much more than this), so that the log floated well clear of the dead water or eddies at the stern. He observes that the use of a form of words is preferable to the minute glass, and should be repeated two or three times if the ship is moving slowly. No doubt the first minute (and later half-minute) glasses were not accurately made, for such small divisions of time had hitherto hardly been considered. Several materials besides fine sand began to be used, including ground-up shells and particles of metal, which were thought to run more smoothly; and Emery Molyneux, the compass and globe maker, gained a reputation for making reliable glasses.

In 1599, the 1587 edition of Bourne's book was translated into Dutch and so our neighbours learned to use the log, but Fournier in his great work on hydrography (which included navigation) published in 1643 still speaks of it as a specifically English instrument. By his day the line had been knotted in such a way as to eliminate arithmetical calculation and this improvement probably took place by the turn of the century, for when Edmund Gunter, the mathematician, and Richard Norwood, a prominent teacher of navigation, came to discuss the matter twenty or thirty years later the stereotyped practice was to knot the line every 7 fathoms and run it out for 30 seconds. In this way every knot run represented approximately a mile an hour and the unit of speed became known as the knot. The two writers mentioned were concerned, however, with the interpretation of the ship's run in terms of latitude and longitude. It was commonly accepted that 5000 feet made a mile (7 fathoms in 30 seconds gave 5040 ft. an hour), and 60 miles or 300,000 ft. made a degree. But by the seventeenth century it was becoming more and more apparent that the true degree was much more than 300,000 ft. Gunter, studying the results of recent surveys accepted it as 352,000 ft., while Norwood made his own determination and arrived at the very nearly correct figure of 367,200 ft. Neither of them wished to sacrifice the standard '60 miles to a degree' which gave the useful relation of one mile to a minute of arc, and both proposed re-knotting the log line so that 'a mile an hour' actually corresponded to a minute of arc an hour, the mile necessarily containing a greater number of feet. Gunter's method of effecting this was to introduce a new unit, the centesme, which measured one hundredth part of the degree of 352,000 ft., that is to say 0′·6 or 36 sec. of the arc. A little calculation will show that a line knotted at 44 ft. intervals and run out for 45 sec. would give the equivalent of 1 knot = 1 centesme an hour. Ten knots would be equivalent to 6 minutes of arc an hour, 5 knots to 3 minutes and so on: thus runs could be worked directly in degrees and minutes of lat. and long. (By this date charts on Mercator's projection were available.) But Gunter as a landsman did not appreciate what he was doing in throwing over the fathom and the

30 sec. glass, as well as introducing the still new-fangled decimal system. It is true that he said that if the half-minute glass was retained, the line could be knotted at 29¼ in., and that all results could be worked out mechanically by the scales on his elaborate Sector, but he seems to have had only one practical disciple. This was Captain Thomas James who equipped himself with 'Gunter' sand-glasses and log-lines when he sailed in search of the North West Passage in 1631.

Norwood's degree, it will be remembered, was 367,200 ft., and he proposed to 'cast away' the odd 7,200 ft. both because it left him with a minute of arc of 6000 ft. and because, as he said, it was safer to have a method of reckoning which showed the ship to be nearer the land than was actually the case rather than one which showed her farther away. He retained the 30 sec. glass, but the interval between the knots was 50 ft. and not a round number of fathoms, so sailors did not like it. Nevertheless to Gunter and to Norwood belongs the credit of introducing the sea mile, a unit independent of the statute mile and the older Italian mile (of 5000 ft.), and dependent only upon an increasingly refined measure of the degree.

Intelligent teachers of navigation like Captain Charles Saltonstall advocated Norwood's line, and intelligent instrument makers like John Seller put it on sale. The fact that it gave better results than the traditional line must have been borne in upon sailors, but not all were convinced, as we learn from the Revd. John Harris (Secretary to the Royal Society) and his disciple William Jones, both of whom wrote on navigation and taught its principles in the days of Queen Anne. After detailing how the log line is run out from a reel attached to the gallery of the ship ('though this at best be but a precarious way, 'tis however the most exact of any in use') Harris gives an account of Norwood's measure of 'the true Sea Mile' of 6000 ft., and his 50 ft. knot interval, and then goes on: 'From hence plainly appears the gross Error of having but 42 feet or 7 Fathom between Knot and Knot, which is the common Division of the log-line at Sea. Indeed, being sensible their Divisions are too short, they lessen their Half-minute Glass proportionably, as having that made of only 24 or 25 seconds. But this is nothing but correcting one Blunder or Error by another, and shows plainly that the common Sailors will not go out of their way, tho' they are sure they are in the wrong.' But the eighteenth century was to see changes in all that; nautical training improved, time became precise, D.R. assumed its modern shape.