'The Metrication of Navigation'

from R. Turner

Mr. Sadler rightly emphasizes one aspect of time: that is to say time is one coordinate of a space-time set of coordinates that locate an event. The other aspect is that of time interval and it is this that the S.I. second defines. Thus if S.I. units are used the time interval between two events is measured in S.I. seconds; the orbital period of the Earth on its axis (referred to a specified frame of reference) is a certain number of S.I. seconds and, in this context, unless this happens to be $86{,}400^s$ it is surely incorrect to call this interval a day.

Charles Cotter says my note is controversial. I do not think this is so. The controversy lay in the decision to adopt S.I. units. My purpose was to indicate the implications of this decision. The S.I. unit of plane angle is the radian and hence the argument for the retention of a unit of distance related to the minute of arc is not relevant. The problem involved in adapting rhumb-line sailing to S.I. units is not difficult and has already been dealt with with great clarity.[1] The advantages of a single universal coherent system cannot be over-emphasized and it is to be hoped that difficulties will not be prolonged by isolated areas of resistance.

REFERENCE

1 Sadler, D. H. (1956). Spheroidal sailing and middle latitude. This *Journal*, **9**, 371.

Mr. D. H. Sadler writes:

I am not sure that I fully understand Mr. Turner's point (this *Journal*, **21**, 81) about what should, or should not, be called a day; but the unit is the second and the point is academic.

However, I would like to make an important reservation to his statement, undoubtedly correct in the context, that the S.I. second defines time-interval. This reservation, which has a rather remote navigational connection, arises because the unit of time-interval in the official IAU (International Astronomical Union) System of Astronomical Constants is the second of ephemeris time, which differs *fundamentally* from the S.I. second. As is recognized by the Comité Internationale des Poids et Mesures, it is not possible to use the S.I. second as the unit of time-interval in celestial mechanics, or in the precise ephemerides of the Sun, Moon and planets (the navigational ephemerides in terms of G.M.T. are only approximate—though amply good enough for their purpose).

from A. D. Horscroft

Mr. Turner's article under the above heading appears to me to contain several mis-statements that I feel need correcting and I should like to make the following comments on it.

1. The units used in navigation do have a systematic relationship, as can be seen from the following:

(a) 1000 fathoms = 10 cables = 1 nautical mile. (The correct figure for the fathom, 6·08 statute feet is so near to 6·00 statute feet that many

authorities, including the Admiralty, give the latter figure as correct, thus upsetting the relationship.)

(b) The nautical mile has any of the following definitions, any of which is correct according to the context in which it is used:

(i) A nautical mile at any place is the length of an arc of the meridian subtending an angle of 1′ at the centre of curvature at that place.

(ii) A nautical mile is the 21,600th part of the Earth's circumference, measured along a great circle passing through both poles.

(iii) A nautical mile is a length equal to 6080 statute feet.

(iv) A nautical mile is a length equal to 1852 metres.

Definition (i) gives a nautical mile varying with latitude, i.e. $6077{\cdot}1 - 30{\cdot}7 \cos 2\phi$ statute feet, where ϕ is the geographical latitude. Definition (ii) gives a mean length for this and is a constant, definitions (iii) and (iv) provide convenient approximations to this, expressed in terms of standard land measures.

2. The full story of the derivation of the statute foot from the nautical mile, though tortuous and very involved, can be read in either *Men and Measures* or *Historical Metrology*, which may be consulted at many public libraries.

3. For seamen, at least, the degree of approximation between the various nautical miles is so good that very few navigators ever take the trouble to distinguish between them, for there is negligible need to do so. For the non-seamen, who really needs to distinguish between the miles, a little thought should be sufficient to show which, if any, of the units is being used.

4. I heartily agree that a change, if a change be made, should be as quick as possible. Preferably, all ships using B.A. charts should be supplied with the new charts before changeover day, and throw away the existing charts on that day. Anything less, a gradual changeover, should be firmly resisted by seafarers and shipowners. Under no circumstances should a seaman be put in the position of changing from fathoms on one chart, to metres on the next, and back again. Indeed, I put forward for argument the possibility that a shipowner might be hard put to make good a claim to limit his liability should he supply his Masters with charts in such a manner, and stranding occur as a result of this change between successive charts.

5. I can see no logical reason for changing from degrees to radians for measurement of angle at sea. The radian is a mathematical concept, and, while it would not be impossible to graduate sextants in radians, it would be no easier than the present method. Definition: A radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle. But the Earth's radius is not constant. We then have to devise methods for avoiding this. Is the Earth to be considered a perfect sphere with constant radius? We are back to the difference between definitions (i) and (ii) for the nautical mile—and we can add the problems of geocentric and geographical latitude as well.

If decimalization of angular measure be required, then the correct unit is the grade. 400 grades equal 360°, 100 grades equal 90° and, for all practical purposes at sea, an arc of 100 kilometres subtends an angle of one grade at the centre of the Earth. (It should be remembered that the original definition of the metre was the ten-millionth part of the distance from the pole to the equator; compare definition (ii). The latitude scale on charts may then subdivide the grade into 100 nautical kilometres, each of which subtends an angle of 0·01 grades at the centre of curvature at that place.

6. The navigator assumes the Earth to be a sphere for great-circle calculations, but not so for rhumb-line calculations. Indeed, meridional parts for the sphere are no longer given in *Norie's Tables*. A little thought will show that great circle distances are given in terms of the angle subtended by the given distance at the centre of the sphere. This is so near the sum of the angles subtended at successive centres of curvature by each successive nautical mile, and when taken in minutes of arc, both are so near the distance in nautical miles of 6080 statute feet, that the practical navigator assumes them all to be the same.

7. Together with the change from degrees and minutes to grades and nautical kilometres should come the corresponding change in time measure, similar to the original proposals of the French Academy. The day would then be 10 hours long, or perhaps 40 hours long. The latter would be preferable since time and hour angle would then be measured in the same system of units. This would give one day equals forty hours, one hour equals 10 grades, equals 1000 kilometres, equals 1,000,000 metres. Instead of 86,400 seconds to the day we would have 400,000 hectometres.

1 hectometre (time)	=	0·216 seconds	
1 kilometre ,,	=	2·16 ,,	
1 grade ,,	=	216 ,,	or 3 m. 36 sec.
1 hour (decimal)	=	36 minutes	

8. What seaman now takes notice of orbital periods or the rotation of the Earth as measures of time? What we use is a clock, adjusted to run at approximately the correct rate, corrected at frequent intervals from a chronometer, whose rate and error are known and are up-dated by radio time signals derived from universal time. True, the astronomers adjust the time signals to adjust to their ideas, but that does not concern us at sea. If they left the time signals on universal time for a century, the difference would be barely noticeable. We don't worry about the Sun as a timekeeper, nor the Mean Sun, and the Equation of Time is only retained in the *Nautical Almanac* as a historical curiosity. Whatever units we work in, the various 'Years', 'Days' and 'Times' will still be used by those who need them and by nobody else.

Conclusion: It will be seen that I am led to somewhat different conclusions to Mr. Turner. Partial adoption of the metric system will make things more difficult and will mean that a changeover will be repeated again and again, till we have absorbed it all. Slow and gradual adoption will be downright bad and dangerous. For a full adoption, not only must the metre be used for heights and depths, but the nautical kilometre and metre for distances, the grade and kilometre for angles and the metric hour, grade and kilometre for time. In short, I think it better that we do not change to the metric system, but if we do, it must be instantaneous, and complete, in length, height, depth, angle and time.

from L. W. J. Fifield

Turner has said, 'The proliferation of units can and does cause confusion and unnecessarily increases the demands made on the newcomer to navigation . . .'.[1] It is probable that more trouble arises from the ambiguities present in navigation—trouble which is not confined to the newcomer, as can be verified in any student class of Master Mariners, all of whom have had several years' navigating experience.

Since the Admiralty Chart is undergoing changes which many of us would have thought drastic only a few years ago, it should not seem impossible now to consider more changes touching the navigator, the astronomer and the geographer. For example, might longitude, with advantage, be measured unambiguously to the westward from 0° to 360°, so simplifying change of date at 180°, and the conversion of G.H.A. to L.H.A.? Could marine clocks and chronometers be graduated from 0 to 24 hours, obviating the half-day ambiguity we now suffer? Again, should latitude and declination be measured from 0° to 180° from the north pole to give a more logical and unique description of terrestrial position and of the navigational triangle? And should bubble and marine sextants be graduated to read from the local vertical, giving a direct read-out of zenith distance? (A problem arises here, of course, in the use of the marine sextant for measuring horizontal angles.)

Those of us who might profess to be knowledgeable may well dismiss such questions as trivial—perhaps subconsciously hoping to preserve something of the mystique of the craft. The practising navigator of today is hardly in a position to judge dispassionately the merits of changes whose object is not necessarily to ease the burden of those currently navigating but to present a more logical system consistent with other disciplines—as in the adoption of the S.I. units. The changes interrogated here are not original proposals: they have been mooted wherever navigators meet for years past. But it seems that there is now a climate of change and we have seen the relatively painless adjustment made by marine navigators at the introduction of the G.H.A. Almanac. The views of navigators, cartographers, geographers, astronomers and computer mathematicians are needed to ensure that geographical and celestial position are uniquely and unambiguously defined in a framework which is eminently logical so that the practical man may observe and describe and, presumably, leave to a machine the tedious business of computation.

In America, Dunlap has asked '. . . where does the navigator stand today?', and has answered, 'For the great majority, still on the bridge, sextant in hand, waiting for the stars and horizon both to be visible.'[2] Nevertheless, this navigator should surely be waiting with concepts which will readily translate to the heralded computer age.

REFERENCES

1 Turner, R. (1968). The metrication of navigation. This *Journal*, **21**, 81.

2 Dunlap, G. D. (1968). Marine navigation: Where we stand—what needs to be done. *Navigation*, U.S.A., **14**, 357.

The Improvement of Navigation Lights and Signals

Douglas J. Lindsay

The Forum comments about small craft lights by Bernard Hayman[1] clearly shows up a shortcoming in the original argument put forward.[2] In relegating the