

# FORUM

## The Accuracy of Dead Reckoning in the Air

*from*

Squadron Leader D. F. H. Grocott, A.F.C., R.A.F.

I AM of the opinion that the figures in Mr. Durst's paper\* have been obtained primarily from the main civil operators and that the results are not necessarily valid for military aircraft. Before accepting Mr. Durst's paper as a reference work for all aircraft it would be necessary to know the answers to the following questions:

(a) Were the navigating officers of each aircraft experienced practising navigators or were they perhaps 'third officers' occupying the seat to obtain navigational experience?

(b) Were the aircraft equipped with and did the navigators use Loran equipment? If so, were the operators adept at using sky-wave signals?

(c) Were the aircraft fitted with air mileage units and air position indicators?

(d) Were the aircraft fitted with remote indicating compasses with performance characteristics equal to those of the G3 and G4B (CL2)?

(e) Were the radio compasses swung at regular intervals?

When I was a member of the Transport Command Examining Unit (1949-51) one of my tasks was to assess logs and charts of experienced navigators flying the main trunk route from the United Kingdom to Australia. I can say quite confidently that as far as the 200 kt. aircraft are concerned a D.R. error of 8 n.m. per hour proved to be an excellent working approximation. Seldom did circles or ellipses of errors around fixes and D.R. positions not intersect or give a 'sensible' wind.

I should like to offer the following comments on the specific points raised by Mr. Parker.

(1) *Track Keeping*. In this portion of the world (the Malayan area) the most accurate method of keeping fairly close to a predetermined track is still the old faithful of observing the drift at frequent intervals and obtaining a fix or M.P.P. every 30 minutes. I do not think that an increase in the fixing rate is justified or necessary.

(2) *Safety Heights*. I agree in principle with sectors of error, the sector increasing as a function of time, but surely it must be left to the navigator on the spot to decide the reliability of the information and hence the size of the sector. By all means give the navigator a guide as to the size of the sector—perhaps some idea of the 50 per cent and 95 per cent sectors—but never tell him to draw a circle of specified radius around a fix or D.R. position.

(3) *Search and Rescue*. A thorny problem, but does a knowledge of the D.R. figure really help when you are not certain when the last fix was obtained, the exact time of ditching or the flight direction of the aircraft after the last transmission. I would suggest that if only one aircraft is available for searching then

\* Durst, C. S. (1955). The accuracy of dead reckoning in the air. *This Journal*, 8, 91.

Parker, J. B. (1955). The navigational implications of Mr. Durst's paper. *This Journal*, 8, 113.

this aircraft will proceed to the position in the distress message and will carry out a square search until P.L.E. If more than one aircraft is available, I suggest that regardless of the D.R. error the pattern of search laid on by the rescue organization for the first 24 hours will be a creeping line along the estimated track—the length of the legs being decided by endurance considerations rather than by D.R. accuracy.

(4) *Finding the Island*. Please do not abandon this technique. I had cause to use this historic procedure when I flew to Ascension Island (no aids at the island) and also when I flew from Reykjavik to 90° North and then on to Alaska. In the latter case, it was a modified technique to guarantee flying over the north pole; I took a series of position lines and used the next track as the leading line. In both cases the procedures were successful.

(5) *Most Probable Positions*. In this part of the world accurate navigation and the intelligent use of M.P.P.s go hand in hand. Seldom can a good fix be obtained on the long sea crossings, yet by the intelligent use of drifts, astro position lines and at times loop bearings, it is possible to obtain 'accurate' M.P.P.s. I have discussed this point many times with 'dyed in the wool' long-distance navigators and invariably they agree that M.P.P.s are just the thing.

(6) *Fixing rate*. I think that for straight-line A to B flying over a distance of about 1500 n.m. a constant fixing rate is acceptable for all aircraft. But as soon as 'dog legs' are included then the fixing rate will be a function of the speed of the aircraft.

(7) *Wind Utilization*. The experienced navigator, despite the figures produced by Mr. Durst, will always weigh the found wind and the Met. wind. The amount of weighing will depend on the navigator's estimate of the accuracy of the M.P.P. or fix.

*Mr. C. S. Durst comments:*

Sqn. Ldr. Grocott asks for the particulars of the types of equipment used in aircraft on which the statistics given in my paper were based, and of the experience of the navigators. I cannot give precise particulars but can only say that the aircraft flying over the Atlantic were those of the main civil operators, and though no doubt they were using somewhat different navigational procedures, according to individual practice, the statistical comparison which I employed gives a figure which applies broadly to civil aircraft operating under those conditions. The aircraft flying in circuits were military aircraft presumably being navigated with skill and care. The standard errors in both the civil and the military aircraft came out at about the same magnitude. The figures I give were never intended to be accepted blindly for all aircraft under all conditions. I endeavoured to make this clear by showing, for instance, comparative figures for wind errors over the North Atlantic and over Central Africa. I daresay a D.R. error of 8 n.m. per hour run was an excellent rule for 200 kt. aircraft on the U.K.—Australia route, where in general winds are much less variable than over the Atlantic (but I would hazard a guess that it was not so satisfactory over the Mediterranean in winter). For aircraft of higher speed flying at greater height over the more stormy routes across the Northern Atlantic or Northern Pacific it would not be applicable.

In regard to Sqn. Ldr. Grocott's last paragraph, my point, and it is I believe an important point, is that with aircraft of 300 or 400 kt. or more the value of a found wind is very much less than with aircraft of 200 kt. because the

faster aircraft has left the found wind so much further astern than the slower aircraft.

*from J. D. Proctor*

THE methods I use to navigate Vikings (TAS 170 kt.) at 2000–12,000 ft. in Europe, the Mediterranean and Africa are these:

(a) 'Beacon Crawling' on airways where legs are shorter than threequarters of an hour: When over a 'facility', I alter the flight-plan time for the next leg almost according to the minutes lost or gained on the last leg in proportion to the lengths of the legs, but a little closer to the flight plan time than that. Flight plan course (mag) is mentally modified similarly. Thus navigation is based mainly on experienced wind and slightly on forecast wind.

(b) Otherwise, when good pin points will certainly be available every hour and at turning points: TMG, distance made good, track required and distance-to-go are measured between P.P.s, with dividers and protractor, or with dividers and the 1 in 57 rule; if course has been altered not more than 20° between P.P.s, I find the mean course made good arithmetically. Hence drift made good and g/s. Generally I find a wind only when strong or very different from the forecast or at a major turning point. The wind I use, actually or by implication, lies about 1/3 of the way from the last found-wind towards the forecast wind, unless the forecast is quite wrong and discarded. Unless mountain ranges, large valleys, centres of depressions or fronts are present, I generally assume the next wind will conform quantitatively to the trend observed in the winds found. I regard D.R. on the first leg as most inaccurate and try to obtain positional information after the first 20 minutes.

(c) Under other conditions I generally keep an air plot (because it copes so well with changes of course, and of TAS and of estimated wind). To try to attain a safety factor of 100,000 as much as for expediency, I always get a fix if available or a drift every 3/4–1 hour, more frequently the stronger the wind. I find an M.P.P. roughly by J. B. Parker's methods and figures and find a wind between the last M.P.P. and the last-but-two M.P.P.; I use a wind about half-way between this and the forecast wind. The longer the period of the found wind or the longer the next leg, the closer is the wind to use to the forecast wind; the more reliable the M.P.P.s, the closer is the wind to use to the found wind.

I expect the direction of light winds to vary considerably. Occasionally I suspect the accuracy of the compass and then I use the trend of forecast wind rather than the forecast wind itself. I treat hunches with great reserve.

When high ground, airways or prohibited areas are close to track, or when airways have to be joined at a specified altitude or when fuel is short, I consider not only the most probable position, most probable E.T.A. and most probable wind, but also very approximately their 50 per cent errors, and alter course or altitude and adjust climb or descent accordingly.

I hesitate to criticise Mr. Durst's valuable paper, but I think fixing is generally less accurate than he supposes (also time keeping), due to scarcity and inaccuracy of d.f. stations in many areas. Also wind forecasts given by many European and African meteorologists often seem less accurate than the British forecasts analysed by Mr. Durst; often they seem to be out of date actuals not forecasts. For instance, during the morning of 29.10.55 Athens forecast NW./35 kt. at 10,000 ft. over E. Alps for the afternoon, and one hour before we were over E. Alps Treviso forecast the same wind; yet we found E./10 kt.

I think transmission of more wind reports by aircraft and their fast dissemination would perhaps improve wind forecasts. Therefore I personally consider D.R. and wind finding more accurate and more important to transport aviation than apparently does Mr. Durst.

*Mr. Durst comments :*

Captain Proctor's note is extremely interesting to me in that it shows precisely how the wind forecasts are used in the air—as against their use for flight planning on the ground before take-off. I wonder what other practices pilots have in the use of forecasts. It is most intriguing to find that Captain Proctor does in fact use a regression equation on his latest found wind and the forecast wind giving weight according to his knowledge of the circumstances.

I hoped I had not given the impression that I belittle the value of aircraft found winds. They can be exceedingly useful to the forecaster particularly over the Atlantic. A difficulty in their routine use on the forecast chart is the uncertainty as to whether an observation will arrive which refers to the point on the synoptic map where information is vitally needed; but I believe experience shows that aircraft found winds are exceedingly helpful.

*from E. Palmer*

MR. PARKER requests me to give the flaws in his reasoning\*. As I see it, he is drawing conclusions from data that is both insufficient and highly selective. Indeed, he admits the latter charge when he says that 'Only two particular areas of the world, the North Atlantic and Central Africa, were considered'. The claim that these two areas can be considered representative is unacceptable, as I will endeavour to show.

In Central Africa winds are almost invariably light and largely seasonal. Consequently, there is a relatively small margin for error and therefore the forecast wind bears comparison with the found wind. Radio fixing aids are not of a high order and map accuracy leaves something to be desired. The North Atlantic area is exceptionally well observed meteorologically, both from the ground and from the air. Communications are comparatively good and upper-air charts are drawn at frequent intervals. Found winds tend to suffer due to the inaccuracies of Loran—the major fixing aid—at night.

I suggest that, had Mr. Durst examined some other areas, different conclusions might well have been arrived at. For example, the Mediterranean area, the Sahara, Northern India and the Hong Kong-Tokyo route. In the Mediterranean, all practical navigators must have experienced, at one time or other, some really odd forecasting. Naturally, I do not normally keep records but a case from my last service in this region is a typical example.

Benina-Rome : 10.12.55	WIND (kt.) AT 14,500 FT.	
	<i>Forecast</i>	<i>Found</i>
Benina-Top of climb	290/25	034/19
T.O.C.-Caraffa	310/25	358/6
Caraffa-Capri	330/25	321/11

This resulted in 19 minutes approximately clipped off the flight plan in a flight of about 3 hours 50 minutes.

\* Parker, J. B., *This Journal (Forum)*, 8, 371.

I should point out that fixes were obtained visually in two cases and by reasonably good radio bearings, obtained under good conditions in the third. The forecast was issued by Cairo, no forecast being obtainable at Benina.

The reason for the poor forecasting in this region I attribute to:

- (a) Insufficient and perhaps not always accurate observations.
- (b) The time lag between the time for which the forecast is issued and the time of the chart from which it was compiled.
- (c) Failure to take note of, or sometimes even believe, aircraft reports.

In the case of the Sahara I cannot believe any Met. officer would claim that his forecast winds are more accurate than those found. It is difficult to see how they could be. Here, the Met. officers do pay attention to our results and it is one of the few areas where we are still requested to transmit our found winds in flight.

There is a case from my last service:

<p><i>Kano-Tripoli</i> : 29.12.55          Lat. North          12-14          14-17          17-20          20-25          25-28          28-30</p>	<p>WIND (kt.) AT 13,000 FT.  <i>Forecast</i>          Var. 12 kt.          300/20          330/30          360/45          360/45          360/45</p>	<p><i>Found</i>          Var. under 10 kt.          297/14          329/13          353/9          340/26          026/10</p>
	<p>Flight plan time: 7 hours 11 mins.          Actual on course time: 6 hours 23 mins.          Difference: 48 mins.</p>	

Here I have no criticism of the Met. officers; it is probably lack of information that causes inaccuracies of this magnitude. On this subject I believe it is impossible to generalize, as I feel both Mr. Durst and Mr. Parker have done. Each case must be considered separately.

A remark that no navigator can accept, at least as far as air navigation is concerned, is that 'practical experience can be a misleading guide'. Most emphatically, my friends and I would not claim that our astro sights are 'practically all within 5 n.m.'. If this were so we would not bother with 3-, 4-, and sometimes 5-star fixes, but be content with 2! My practice is to use 3 stars under the best conditions, 4 or more under not so good conditions and to repeat any sight which, for any reason, does not satisfy me. The point is, that experience does give us a strong indication as to when a particular sight is not to be relied upon.

In the light of experience we all seem to be agreed that the old methods of arriving at a D.R. position or M.P.P. are not satisfactory. As I see it, we would do better to use a 'most probable wind' compounded not mathematically (it could hardly be done satisfactorily I should think) but, as Mr. Parker says, subjectively, laid off from the air position, to give the best estimated position.

Finally, I fully support Mr. Parker in hoping that other navigators—and meteorologists—will give us all the benefit of their views.

#### *Mr. Durst comments:*

Mr. Palmer takes me to task for using data which was insufficient and highly selective. For wind errors I have taken two extreme cases, the North Atlantic where winds are strong and variable and an equatorial region where winds are

comparatively light. Most regions of the world lie between these extremes so they give a bracket to the general accuracy, and to that extent my data are fairly representative of the general problem.

Fixing errors vary greatly with the facilities available. I have nowhere been able to find any suitable figures of what the errors are in different circumstances and different places. It would be most valuable if some such data were available for the various routes and times of day.

Navigational error is a matter which needs investigation to determine how far an aeroplane is in fact an accurate instrument for observing its own motion relative to the air. Into this comes not only compass-error and airspeed error but also the side-slip error mentioned by Mr. Fox. What I endeavoured to do in my paper was to split up the D.R. error into these components. Though data may be insufficient on one item, that deficiency does not vitiate the conclusions on the others.

*Mr. J. B. Parker comments :*

Mr. Palmer says that the data are both too few and too highly selective for any generalizations to be made. Though there are areas where good fixing services and relatively poor meteorological facilities swing the balance against the forecast wind, the general picture obtained from considering only the North Atlantic and Central African areas is not unrepresentative, as Mr. Durst points out. The actual amount of data accumulated is large enough to justify the results of Table I of my article to within 5 n.m.; that these are figures aggregated over many variables is freely admitted and is made clear in the text.

I cannot agree with Mr. Palmer's generalization that no navigator will accept that his practical experience can on occasions be a misleading guide. While nothing can be a substitute for experience, there are some of us who are humble enough to examine, from time to time, our ideas based on experience to see if they are really free from odd hunches and prejudices. Summarizing, experience with 200 kt. aircraft appears to show that found winds are generally superior to Met. winds. It will be interesting to find out whether practical results on faster aircraft will confirm the theory that there comes a point when the reverse is true.

The trend of the very stimulating reactions to the articles by Mr. Durst and myself (*Journal*, April 1955) is that the case for preferring the Met. wind to the found wind is not substantiated in operations. On the other hand there is broad agreement that a subjective wind estimation, based on the weighting of forecast and observed winds, is the best operational procedure.

Judged by Mr. Durst's data, it is when the aircraft's speed is greater than about 250 knots that the superiority of the Met. wind begins to assert itself. On Squadron Leader Grocott's assumptions (speed 200 knots) the case for existing techniques appears to be firm, though there is a large discrepancy between the 8 n.m. per hour figure for D.R. error and that found by Mr. Durst. Captain Proctor's interesting note, based on aircraft in the same speed region, confirms this. His consideration of the probable errors of M.P.P.s and most probable winds is most interesting, and it may well be that by such thoughtful handling of all the available data dead reckoning errors can be reduced below the level referred to in our papers.