

GPS—THE EMPEROR'S NEW POSITION?

by Julian West

Since October of 1995, the IGC has agreed to accept GPS measurements for the verification of both badge and record flights. However, the GPS units used in gliders are only navigation aids with a quite remarkable, but somewhat less than perfect, accuracy. Only when operated with an external antenna and as differential GPS, which eliminates most sources of error, do they have the degree of accuracy required by the current sporting code. Standard GPS seems just as good only because nobody normally bothers to check its absolute accuracy. Although most of the time this accuracy is better than 110 yards, errors of several hundreds of yards have been observed by the author.

How GPS works.

A GPS set determines position and height by measuring the journey time, and hence distance, taken by signals broadcast from four or more GPS satellites. The orbiting satellites also regularly download an ephemeris of their own positions at any given time. Although a three dimensional position only requires three measurements, a fourth is necessary to calibrate the quartz clock in the set. It can give a horizontal position with only three satellites, but with less accuracy unless the correct height is set manually.

Lies, damned lies, and GPS?

Because of measurement errors, the co-ordinates displayed do not represent the true position. The problem is a statistical one, and an appropriate circle of confidence can be drawn around the apparent position to give the desired probability of the true position lying within it. The bigger the circle radius the higher that probability, and a radius of 1 drms (distance root mean square) gives a probability of 68%, while a radius of 2 drms increases this to 95%, as shown in Figure 1.

In practice, there are several error sources that combine to reduce the accuracy of the GPS position displayed. The best known of these is the deliberate degradation of the signal to give a random horizontal error (110 yards, 2 drms), which is now permanent. This means that, discounting other errors, there is a 95% probability of the GPS aerial being located within a circle of 110 yard radius centred upon the displayed position. To increase this probability to 99.9% would require a circle of 330 yards radius!

Other errors include instrument error (50 ft, 1 drms), abnormal atmospheric refraction (up to 100 ft), orbital data (ephemeris) errors, and satellite atomic clock drift. Taken altogether these errors lead to the oft quoted

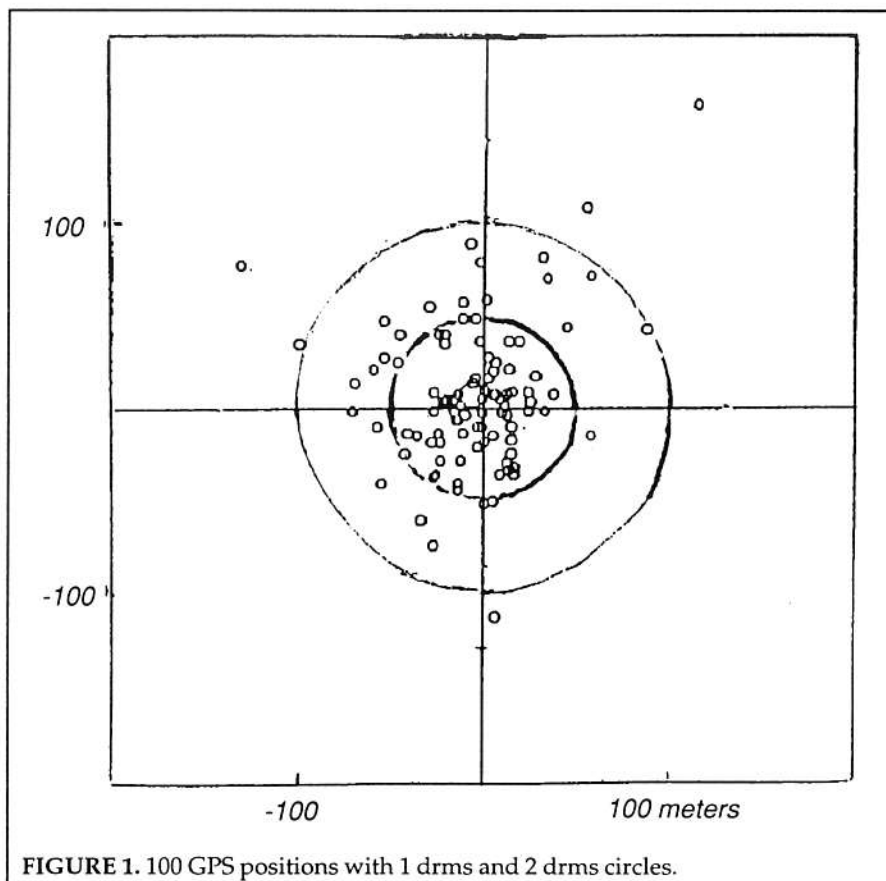


FIGURE 1. 100 GPS positions with 1 drms and 2 drms circles.

accuracy of 115 yards (1 drms). However, this figure does not take account of errors due to poor satellite geometry and weak signal strength. To cope with this particular problem the Garmin 55 calculates an estimated position error, based mainly on these two factors, and ceases to give a position if it exceeds 550 yards.

The position displayed is smoothed by a filter, whose time constant can be selected either automatically or by the user, and dynamic performance is further improved by including a dead-reckoning algorithm. Thus a GPS set does not show measured GPS positions but smoothed GPS positions in combination with a dead-reckoning correction. This only improves the accuracy if the set is stationary or moving steadily in a straight line. However, if the speed and/or direction are changed rapidly significant positional errors can occur. This makes it possible to "throw" a GPS position into the turn point sector by approaching it at high speed and then turning abruptly away shortly before getting there. This is made worse by cockpit mounted aerials that are prone to be cyclically shielded from satellites whilst circling.

Blind datum?

More of a problem abroad than in the United States is the error due to an incorrect map datum (up to 900 yards). The correct datum is that of the 1:50,000 maps used to determine the co-ordinates of the turn points. When flying at home this is the North American Datum of 1927, but what is the correct datum when flying

abroad? It should be marked on the 1:50,000 maps, which you probably haven't got, and may or may not be listed for your GPS. For example, there are two possible European datums, European 1950 and 1979. On 1:50,000 maps it simply states European datum, which means that it is the former. The difference between the worldwide WGS 84 datum and the European 50 datum is about 125 yards.

The rules of the game.

According to the sporting code, a turn point is not just a set of pre-declared co-ordinates but a well defined feature on the surface, which is precisely specified before take-off. Its position must be determined with sufficient precision for the task distance to be measured to at least an accuracy of 550 yards. If this rule were to be changed to allow pre-declared co-ordinates for flights recorded by GPS, this would at least enable the precise determination of task distance and eliminate the problem of an incorrect map datum. However, to attain the same accuracy for the distance actually flown around

three turn points, GPS would need to be accurate to 92 yards ($550/6$ yards) or less.

The observation zone is a quadrant on the ground with its apex at the turn point, and is rounded when the

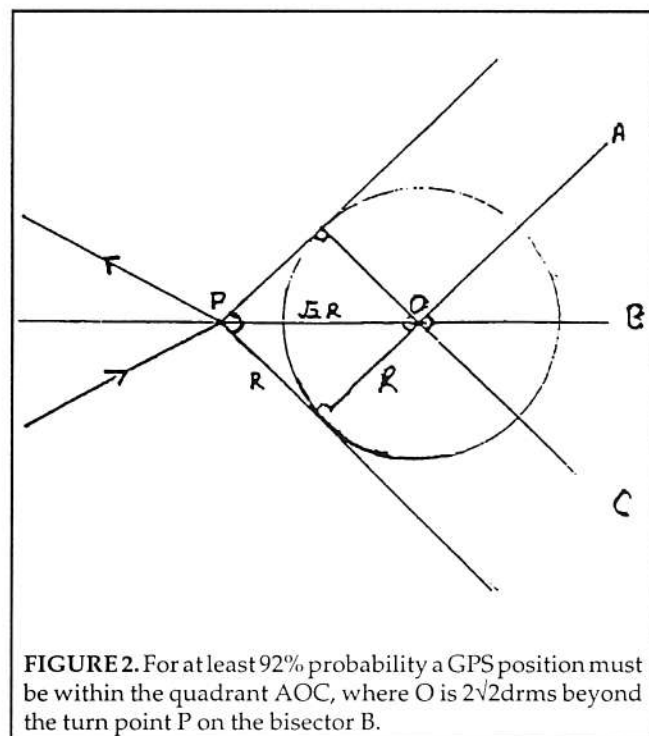


FIGURE 2. For at least 92% probability a GPS position must be within the quadrant AOC, where O is $2\sqrt{2}$ drms beyond the turn point P on the bisector B.

entire aircraft is proved to have been above the observation zone. This requirement of proof is the heart of the problem with GPS turn point verification. Whilst a turn point photograph can prove whether or not the entire aircraft was above the observation zone, a GPS measurement cannot. This is because, although it is remarkably good as a navigation aid, its absolute accuracy is always uncertain, unlike that of either a photographic or a geodetic measurement.

Rounding with confidence?

If GPS positions indicated that the bisector was crossed precisely at the turn point, then there would be only a 25% probability that the aircraft really had been within the observation zone. Similarly, if a GPS position was on the edge of the zone well away from the turn point, then this probability would still be only 50%. Thus, if standard GPS is to be used for turn point verification, the observation zone needs to be penetrated by a distance sufficient for there to be almost 100% probability that the entire aircraft was within the zone.

If, as shown in Figure 2, a circle of confidence with a radius R equal to 2 drms is drawn around a GPS position then, provided that the entire circle falls within the observation zone, the probability that the aircraft was within the zone is at least 97%. This is more than 95% because some positions outside the circle still fall within the zone. In practice, at least one logged GPS position needs to lie within the observation zone AOC of a pseudo turn point O , which lies on the bisector B at a distance $2 \sim \text{drms}$ beyond the actual turn point P . The degree of certainty should then be adequate for badge flights, but is still not good enough for records.

In view of the error sources described above, in absolutely ideal circumstances the radius R of a 2 drms circle of confidence is about 154 yards. But for a standard GPS set with a cockpit mounted aerial, R can be much

larger than this and may even exceed $5/8$ of a mile. This means that the bisector needs to be crossed at least $7/8$ of a mile beyond the turn point. Alternatively, the measured distance could be reduced by $1 \text{ } 3/4$ miles per turn point so as to allow for the inherent uncertainty in standard GPS positions. Anyone who thinks that this is unfair should take turn point photographs instead.

As a much higher standard of accuracy and proof is required for records, standard GPS positions should not be accepted for their verification. For the same reason, standard GPS sets should not be used on the ground, where their accuracy is worse than in the air, to determine turn point co-ordinates officially. A 1:50,000 map and, if necessary, an aerial turn point photograph always give more precise values for the co-ordinates.

GPS with a difference?

With differential GPS (DGPS) the differences between standard GPS and true positions are broadcast by a ground station, thereby eliminating almost all possible sources of error. This makes DGPS more accurate than even the military version. Thus, provided that signals were received at each turn point, the verification of both badges and records by DGPS might well be acceptable without restriction.

An economical alternative to DGPS would be to record the differential corrections at the take-off site, and then to correct the flight recorder data later during analysis. Provided the two sets of data are correctly synchronised this might even be more accurate than DGPS, as it eliminates the time delay inherent in transmitting differential data. Also, since the pilot does not know his exact position, he will need to round the turn point correctly. Because, at the end of the day, the official observer will know, within 115 ft (2 drms), where the sailplane has really been.