IGC 2024 Plenary Meeting

Annex A Committee

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January 2024

2024 Report to the Plenary

Dear Delegates,

The 2023 edition of Annex A was published with an effective date of 1 September 2023 (in time for WGC2023 in Narromine). The latest publication of the handicaps document was 15 April 2021.

The significant changes were :

- Provision of paper charts by the Organisers no longer required.
- FR Calibration certificates optional.
- Restoration of 7.4.5b, "pre-start fix below a specified altitude," which was inadvertently deleted last year.
- The publication of a few local procedures (Contest site boundary, launch, release area, MoP, landing procedures) may now appear in the LP document, as usual, or elsewhere.

Also, note that the 2023 waiver that made 7.4.6 Energy Control at the Start optional has expired. The use of height and speed limits is now mandatory.

Minor changes and clarifications are published in the 2023 Changes to Annex A document.

In cooperation with the Championship Management Working Group, we continue to work on bringing Annex A into line with the other documents relevant to World and Continental Championships (Bid Form, Organiser Agreement, Bulletins, and Local Procedures).

At this Plenary, we expect three Year 2 proposals that may affect Annex A :

- Mandatory strobe light (Bureau)
- Modification of PEV penalties (NED)
- Cylinder Start (POL)

The last one, Cylinder Start, would require a significant rearrangement of the paragraphs of SC3A 7.4, Start Procedures. The rearrangement is needed to allow the classic start (now called the "Line Start" to exist side-by-side with the proposed new Cylinder Start. The rearrangement is presented as an appendix to the proposal from Poland.

The agenda has not been published at the time of this writing. We have had no contact from NAC's regarding this year's Year 1 proposals.

However, we have been alerted by the President that there may be a proposal regarding the Earth Model used in Annex A. The topic of Earth Models is remarkably nuanced. We have attached to this report an appendix that attempts to explain why this problem is hard.

I thank my colleagues Axel, Aldo, Reno, and Øjvind for their work on the rules in 2023, and we are looking forward to seeing everyone in Toulouse.

Rick Sheppe
Post Mills, USA

Attachment follows.

Conversations about Earth Models
IGC Annex A Committee
31 December 2023

Introduction

For analysis of sporting flights, accurate computation of bearing and distance is essential. Many people are surprised how complicated this can be on a spheroidal planet, such as our Earth. This paper undertakes to explain why this is so.

We imagine a pair of conversations.

Conversation 1, between a pilot and a mathematician

Suppose a pilot asks a mathematician to determine the distance and bearing from the Lasham Clubhouse to the Farnborough Airport.

This is a simple request, but the mathematician would need more information to begin working on the problem. He or she would have the following questions for the pilot:

1. What are the coordinates of the two places, exactly?

2. To what precision would you like the answer?

3. Which Earth Model should be used for the calculation?

With the answers to these questions, the mathematician would be able to solve the problem. Let’s call this “Problem 1:”

Problem 1
What is the distance (to the nearest meter) and bearing (to the nearest degree) from the Lasham Clubhouse (51º 11’ 22" N, 001º 01’ 54" W) to Farnborough Airport (51º 16’ 31" N, 000º 46’ 39” W), using <u>both</u> the FAI Sphere and the WGS-84 Ellipsoid Earth Models?

And the solution would be:

Solution to Problem 1			
Earth Model	**Distance (meters)**	**Bearing (degrees true)**	**Method used**
FAI Sphere	20106	62	Spherical Trigonometry
WGS-84 Ellipsoid	20168	62	Bowring

WGS-84 Ellipsoid	20158	62	Vincenty
WGS-84 Ellipsoid	20158	62	Karney
WGS-84 Ellipsoid	20158	62	Lambert

At this point Problem 1 is solved. But the pilot would still have some questions for the mathematician:

Pilot: I expected two answers, and you gave me five. Why are there four answers for the ellipsoid?

Mathematician: Problem 1 is an example of what is known in geodesy as "the inverse geodetic problem." This problem can be solved exactly on the sphere, but on the ellipsoid, there is no exact solution. The methods of Lambert[1], Vincenty[2], Bowring[3], and Karney[4], are the four most common mathematical approximations to the solution of the inverse geodetic problem on the ellipsoid. I used all four of them, so that they could be compared.

P: Is any judgment involved? In other words, if I gave Problem 1 to another mathematician, would I get the exact same answer?

M: Judgment is not involved, and yes, you would get the same answer from anyone. The five methods are completely deterministic.

P: I see that three of the answers are the same. Does this mean that the three methods are equivalent?

M: No. The three methods yield different answers, all of which, when rounded to the nearest meter, give the same distance. Problem 1 asks for the nearest meter.

P: Please rank the accuracy of the five methods.

M: If, by "accuracy," you mean proximity to the ideal solution on the surface in question, the ranking is:

Accuracy on the chosen surface		
Rank	**Method**	**Uncertainty (typical)**
1	Spherical Trigonometry	Zero (i.e. exact)
2	Karney	A few millimeters
3	Vincenty	A few centimeters
4	Lambert	±0.01%
5	Bowring	A few meters

P: OK, but that's not what I meant by accuracy. I would like to know the "closeness to the truth." If we were to measure the actual distance using a very long piece of string (and somehow preventing the string from being displaced vertically through hills and valleys), which method would agree most closely with the length of that string?

M: Karney.

P: And Spherical Trigonometry would presumably rank last?

M: Yes. The ellipsoid is a better approximation of the true shape of the Earth than the sphere. All of the methods on the ellipsoid would yield distances that are closer to the length of the string than trigonometry on the sphere.

Now suppose that the pilot has another question for the mathematician. The new question is "What is the distance and bearing from the Lasham Clubhouse to the Farnborough CTR?"

After being reminded by the mathematician that a geodesic is the shortest path between two points on a surface, the pilot agrees with the mathematician that the Farnborough CTR is a figure on the surface consisting of six vertices joined by six geodesics, specified and depicted as follows:

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AC D
AN FARNBOROUGH CTR
AF 133.440
AL SFC
AH 3500ALT
DP 51:21:12 N 000:42:47 W
V D=-
V X=51:28:12 N 000:27:13 W
DB 51:21:12 N 000:42:47 W, 51:21:03 N 000:42:36 W
DP 51:20:35 N 000:39:59 W
DP 51:15:20 N 000:36:39 W
DP 51:10:35 N 000:50:54 W
DP 51:17:05 N 000:55:08 W
DP 51:21:12 N 000:42:47 W
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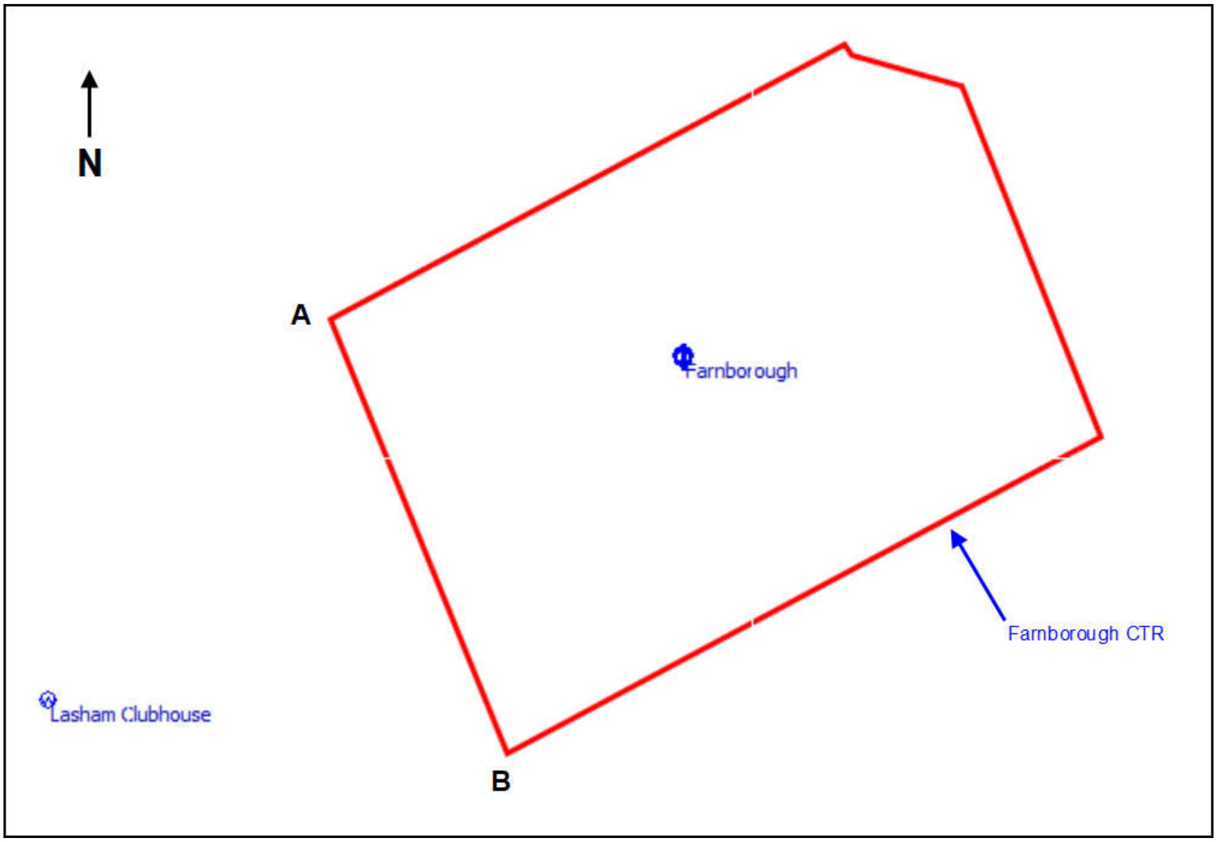
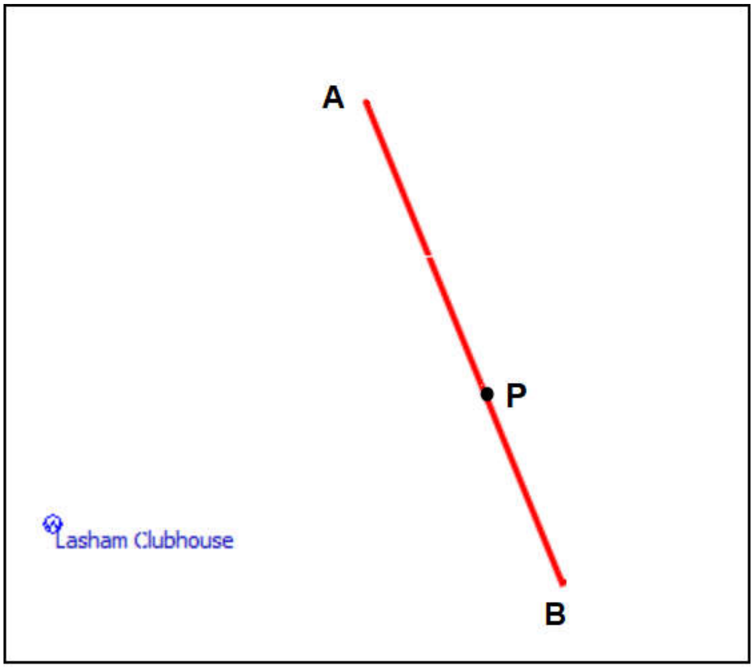


The pilot and the mathematician also agree that the only geodesic that matters in this new problem is the one nearest to the clubhouse, i.e. the geodesic that connects Point A and Point B in the illustration above.

Calculating the distance and bearing to that geodesic is Problem 2.

Problem 2

What is the distance (to the nearest meter) and bearing (to the nearest degree) from the Lasham Clubhouse (51º 11' 22" N, 001º 01' 54" W) to Point P, where Point P is the point on the geodesic connecting Point A (51º 17' 05" N, 000º 55' 08" W) and Point B (51º 10' 35" N, 000º 50' 54" W) that is closest to the clubhouse, using <u>both</u> the FAI Sphere and the WGS-84 Ellipsoid Earth Models?



A visualization of Problem 2

The mathematician would then provide this partial solution:

Solution to Problem 2			
Earth Model	**Distance (meters)**	**Bearing (degrees true)**	**Method used**
FAI Sphere	11279	68	Spherical Trigonometry
WGS-84 Ellipsoid	?	?	?

which would generate an obvious followup question:

P: Why are there no solutions on the ellipsoid?

M: This is a different problem from the inverse geodetic problem. Problem 2 is the “geodetic cross-track error problem.” The methods of Lambert, Vincenty, Bowring and Karney do not apply here. As far as I know, there are no published solutions to this problem. There is no way to calculate the coordinates of Point P.

P: Does this mean that the problem cannot be solved on the ellipsoid?

M: No it does not. You could solve it by numerical methods. But for that, you need to talk with a computer programmer, not a mathematician. Good luck.

Conversation 2, between the pilot and a computer programmer

In this conversation, the pilot asks a computer programmer to solve Problem 2.

The computer programmer does so, and provides this solution:

Solution to Problem 2			
Earth Model	**Distance (meters)**	**Bearing (degrees true)**	**Method used**
FAI Sphere	11279	68	Spherical Trigonometry
WGS-84 Ellipsoid	11311	68	Successive approximation

which leads to more questions, of course…

Pilot: What is "successive approximation?"

Computer Programmer: It is a numerical method that consists of a sequence of guesses that approach the answer. The computer program postulates a candidate Point P on the geodesic, tests it (using Vincenty in this case), and keeps track of whether the candidate point is closer to the clubhouse than the previous candidates. By monitoring trends in the calculations, it is possible to converge on the coordinates of Point P to the required precision.

P: What is the required precision?

CP: 1 meter, same as the precision required by the problem. It is necessary to locate Point P to within 1 meter in order to solve Problem 2.

P: Is any judgment involved? In other words, if I gave Problem 2 to another computer programmer, would I get the exact same answer?

CP: Judgment about which algorithm to use is required. The burden is on the programmer to prove that the solution converges properly. All programmers who provide that proof would get the same answer.

P: Is 11311 meters closer to the truth than 11279 meters?

CP: Yes, for the reason cited by the mathematician. The ellipsoid is closer to the true shape of the Earth than the sphere.

P: Are you familiar with the FAI Sporting Code, scoring programs, and glide computers?

CP: Yes to all three.

P: Under what circumstances do glide computers and scoring programs need to solve the geodetic cross-track error problem, (Problem 2)?

CP: “Problem 2” must be solved whenever a “line crossing” calculation is needed: start/finish lines, airspace boundaries, and some AAT boundaries.

P: Do glide computers and scoring programs that use the ellipsoidal Earth Model use successive approximation for “line crossing” calculations?

CP: The algorithms used by glide computers and scoring programs are proprietary, so this question cannot be answered for sure. However, it is unlikely that they use successive approximation, because numerical methods take too long to complete. Glide computers and scoring programs must perform thousands of geometric calculations per minute. It is impossible to do this while staying true to the ellipsoid.

P: How do they do it then?

CP: Probably by abandoning the ellipsoid and switching to a different Earth Model (either the FAI Sphere or the Flat Earth, which is based on the FAI Sphere).

P: Is using a combination of Earth Models valid?

CP: Yes. It is almost never important to stick with one Earth Model. It is completely appropriate to switch Earth Models depending on the context of what it being presented to the user. In competitions, if you don’t need unambiguous answers of ten meters or less, then switching Earth Models is expedient and harmless. This is true for scoring programs most of the time, and it is true for glide computers at all times.

P: When does the exception occur?

CP: When it is important to know the answer to within a few meters. The penalty for being on the wrong side of an airspace boundary, even by 1 meter, is harsh. If it’s close, we must be absolutely certain which Earth Model the flight evaluation software is using.

P: What is the real problem?

CP: In a competition, if the pilot and the Organisers use different Earth Models to calculate whether it was a near miss or an airspace violation, they may get conflicting answers. Without agreement about the Earth Model to use for that calculation, an unresolvable dispute may arise.

P: Can’t we just give the pilot the benefit of the doubt in these borderline cases?

CP: Only if all the other pilots agree not to protest.

P: Why is 1-meter resolution required? Why do competition pilots and Organisers care about 1-meter airspace incursions? Couldn’t we use approximations? Couldn't we add fuzziness to the airspace boundaries or to the fixes themselves?

CP: To get the answers to those questions, you need to talk with a policy maker, not a computer programmer. Good luck.

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[1] Lambert, W.D. "The distance between two widely separated points on the surface of the earth" *J. Washington Academy of Sciences* 32 (5): 126-130, 1942

[2] Vincenty, T. "Direct and Inverse Solutions of Geodesics on the Ellipsoid with application of nested equations" Survey Review 23 (176): 88-93, 1975

[3] Bowring, B.R. "The direct and inverse problems for short geodesics lines on the ellipsoid" *Surveying and Mapping* 41 (2): 135-141, 1981

[4] Karney, C. F. F. "Algorithms for geodesics" *Journal of Geodesy* 87 (1): 43-55, 2013