

How to deal with the 0.5% tolerance in paragliding and hang-gliding races

Jörg Ewald

1 Introduction

This article was written to help pilots optimize their flight routes in paragliding and hang-gliding races, considering the tolerance that is applied to the turnpoint cylinders. The information contained herein is currently only available to a small number of pilots, which leads to unfair situations where not all pilots have to fly the same distance. By making the information public, I aim to re-establishing fairness: All pilots will have the same information available, and all competitors in a race will therefore be able to optimize their flights accordingly.

2 Background

2.1 Earth models

Seen from far away, the earth is a sphere. When we look a bit more closely, this “sphere” is flattened at the poles, and a bit wider around the equator: a so-called ellipsoid. If we look even closer, the earth resembles an irregularly shaped potato, but that’s beyond the point right now.

Points on earth are defined by coordinates, usually given as latitude and longitude (e.g. N 47°1’16.7”, E 8°18’23.7” for Volirium’s offices). This works the same, no matter whether we assume earth to be a sphere or an ellipsoid. But when I want to calculate the distance between two points, then the earth model (sphere or ellipsoid) suddenly becomes important: The calculated distance differs between the two models. The difference even depends on where on earth the two points sit, and in which direction I have to move from one to the other. Direction north-south, the distance on the ellipsoid is smaller than the one on the sphere. Seems logical, since the ellipsoid is flattened in this direction. Direction east-west, on the other hand, the distance is bigger, since the ellipsoid is widened in this direction.

2.2 Race evaluation

Distance calculations are very important in races. Our instruments constantly calculate the distance to the next waypoint. Since we have to approach each waypoint up to a given distance (the cylinder radius), having this distance displayed correctly is important. Correct, in this context, means: If my instrument indicates that I have reached a cylinder, then the evaluation software, which is used to score my flight in the evening, must also conclude that I reached the cylinder.

Long before we started flying with GPS assistance, the FAI¹ determined that for airports, the sphere should be used as the earth model: The so-called FAI sphere, with a radius of 6371 km. This is sufficiently accurate for all our needs, and makes all necessary calculations relatively easy. Therefore, the evaluation software FS, which is used to score most paragliding and hang-gliding competitions (especially world and continental championships), uses the spherical model to determine whether the coordinates of a point in a pilot’s track are inside a turnpoint cylinder or not.

In theory, whether a cylinder is reached or not, is determined as follows:

¹ Federation d’Aviation Internationale, the international airports federation

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1. For enter cylinders: There must be one point in the flight recording for which the distance to the cylinder's centre is smaller than the cylinder radius.

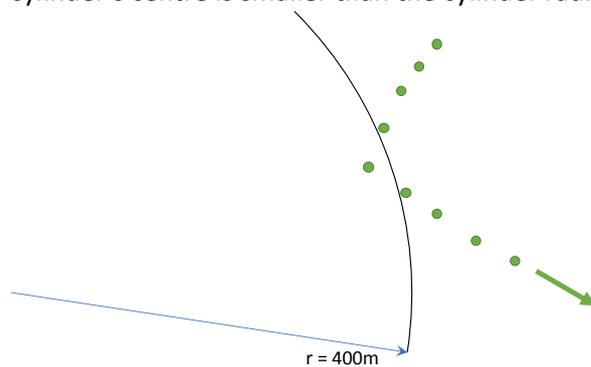


Figure 1: Validation of an enter cylinder in theory

2. For exit cylinders: There must be one point in the flight recording for which the distance to the cylinder's centre is bigger than the cylinder radius.

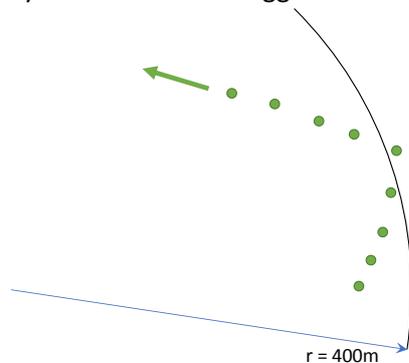


Figure 2: Validation of an exit cylinder in theory

2.3 The rest of the world

For ground-based navigation, the model of choice is not the sphere, but an ellipsoid, the so-called WGS84 ellipsoid. Its shape matches earth's shape much better, and therefore calculated distances match those actually driven or walked much better. On the other hand, calculating distances on the ellipsoid is more difficult, and there are things which simply can't be calculated on an ellipsoid, like for example the distance to an airspace that is defined by a straight line.

Until today, all GPS receivers, except those explicitly built for airports, base their distance calculations on the ellipsoid.

2.4 The original problem

In the early days of GPS use in our sports, the only available and useable GPS receivers were built for ground-based navigation, and therefore calculated distances on the ellipsoid. Especially devices by Garmin were used very frequently. This led quickly to problems, when pilots were absolutely sure they had flown inside a cylinder, that their GPS showed them a distance smaller than the cylinder radius, but the evaluation software still determined that they had missed the cylinder. The reason for this was of course the discrepancy between the GPS receiver (ellipsoid) and the evaluation software (sphere).

After a few years, vario manufacturers like Aircotec and Flytec developed their first varios with integrated GPS, and these calculated distances on the sphere, as required by the FAI. Here the

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displayed distances were the same as those in the evaluation software, but as long as many pilots still used Garmin receivers, the problem of different earth models had to be solved somehow.

2.5 The “solution”

To solve the problem, a tolerance was introduced: Pilots no longer needed to exactly approach a cylinder as described above, instead, during evaluation, a certain fuzziness was permitted. The tolerance was set to 0.5% of the cylinder radius. When this was introduced, cylinders had always a radius of 400m, so the tolerance was always +/- 2m.

Specifically, this means that the evaluation software rates a 400m enter cylinder as “reached” whenever there is a point in the tracklog from where the distance to the centre is less than 402m.

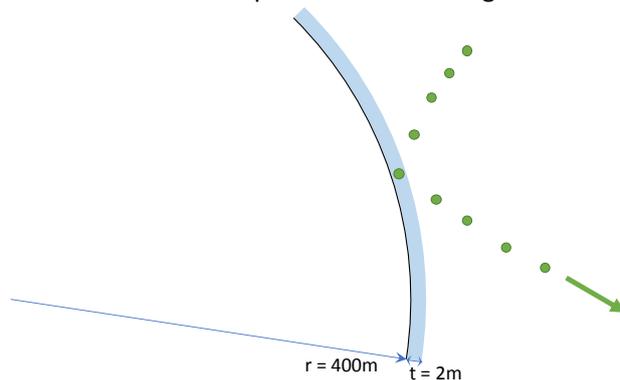


Figure 3: Actual validation of an enter cylinders of 400m

For a 400m exit cylinder, there must be a point whose distance to the centre is more than 398m.

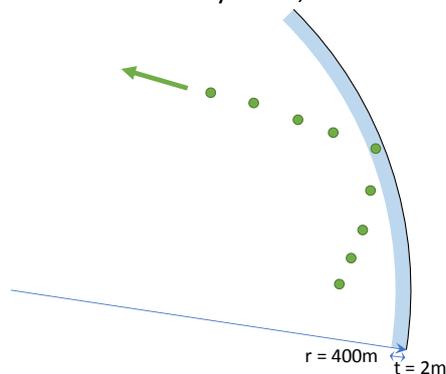


Figure 4: Actual validation of an exit cylinder of 400m

This fuzziness is bigger than the biggest possible discrepancy between distance calculations on the sphere and the ellipsoid. This ensures that pilots whose instrument indicates that they have reached a cylinder will always have this confirmed by the evaluation software.

2.6 The problem today

For a few years now, cylinders have been growing bigger and bigger, to offer more route variations to pilots. But along with the cylinder size, the tolerance grew as well, up to several hundred meters in extreme cases: For a cylinder of 52 km (e.g. task 3 at the 2016 paragliding European championships), 0.5% are equivalent to 260m. This means that if this an exit cylinder, I can turn around at 51.74 km, still have a point inside the tolerance zone, and fly a total of 520m less than those pilots who turn once they are at 52 km.

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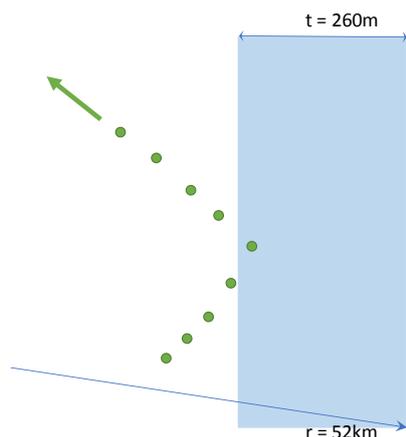


Figure 5: Actual validation of an exit cylinder of 52 km

CIVL² as well as the PWCA³ both are working on reducing the tolerance, by accepting only one earth model in the future. Until we get there, there is an opportunity to save on flown distance, by making use of the tolerance. In high level competitions, where the top pilots in goal are often separated by just a few seconds, this can make a big difference. Having as many pilots as possible be aware of this problem, and how to deal with it, is in my opinion crucial in order to have fair races.

3 Concrete procedure

3.1 Which earth model?

As a first step, each pilot must find out which earth model is used by his or her instruments and apps calculate distance.

Table 1: Earth models of varios and apps in use today

Vario / App	FAI sphere	WGS84 ellipsoid	Remark
Aircotec	✓		
Bräuniger	✓		
Compass	✓		
Flymaster	(✓)	✓	On older devices (e.g. B1 NAV) only the WGS84 ellipsoid model is available. On newer devices, the model can be selected: Settings > Navigation settings > Datum
Flytec	✓		
Naviter	✓	✓	Model can be selected in: Tools > Options > General
Skytraxx	✓		
Volirium	✓		
XC Soar		✓	
XCTrack	✓		

3.2 FAI sphere

If I fly with a device or an app that calculates distances on the sphere, using the tolerance is relatively easy:

² Commission Internationale de Vol Libre, FAI's commission for paragliding and hang-glidering

³ Paragliding World Cup Association, die organisation behind the Paragliding World Cup (PWC)

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1. Radius r is defined by the task setter
2. Tolerance $t = r * 0.5\%$ (easy way: $r / 100 / 2$)
3. Use calculated radius r' depending on cylinder type:
 - a. For enter cylinders: $r' = r + t$ (or the next smaller number that can be entered)
 - b. For exit cylinders: $r' = r - t$ (or the next bigger number that can be entered)

Example: Enter cylinder of 35 km: $r = 35$ km, $t = 175$ m, $r' = 35.175$ km. On a vario where cylinder sizes can be entered in steps of 50m, I set the Radius to 35.15 km.

3.3 WGS84 ellipsoid

On devices or apps that calculate distances on the ellipsoid, using the tolerance is a big more complicated, because the calculated distances depend on the latitude (distance from the equator) and the flying direction:

3.3.1 Preparation

Before we can start, we have to find out the specific deviation from the sphere for the flying area of a competition⁴. Here as an example Feltre, where the 2017 paragliding world championships will take place:

Table 2: Difference between earth models in the area of Feltre, Italy

Flight direction	FAI sphere [m]	WGS84 ellipsoid [m]	Difference [m]	Difference [%]
N-S	1000	999.63	0.37	0.04%
N-S	5000	4998.21	1.79	0.04%
N-S	10000	9996.43	3.57	0.04%
N-S	20000	19992.86	7.14	0.04%
N-S	50000	49985.81	14.19	0.03%
O-W	1000	1002.87	-2.87	-0.29%
O-W	5000	5014.33	-14.33	-0.29%
O-W	10000	10028.66	-28.66	-0.29%
O-W	20000	20057.31	-57.31	-0.29%
O-W	50000	50143.28	-143.28	-0.29%
NO-SW	1000	1001.25	-1.25	-0.12%
NO-SW	5000	5006.31	-6.31	-0.13%
NO-SW	10000	10012.63	-12.63	-0.13%
NO-SW	20000	20025.26	-25.26	-0.13%
NO-SW	50000	50066.82	-66.82	-0.13%

Points to note:

1. In north-south direction, the difference is relatively small (0.04%). The difference is positive, which means we have to fly closer towards a point in order to reach the required distance on the sphere.
2. In east-west direction, the difference is noticeably bigger (-0.29%). Here the difference is negative, which means that we do not need to go quite as far towards a point in order to reach the required distance on the sphere.

⁴ Useful for this: http://www.fai.org/distance_calculation/

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3. In northeast-southwest direction, the difference is almost exactly half of the difference we see in the other two directions above. But negative as well, we also have to fly less far towards a point to get the required distance on the sphere.
4. Since we will almost never approach a cylinder from exactly one of these directions, and to make sure that always really fly inside enter cylinders, or leave exit cylinders, we have to add a little safety margin.
5. The required calculations exceed what most people can do in their head, but shouldn't be a problem with the calculator on a mobile phone.

3.3.2 When entering a task

1. Radius r given by the task setter
2. Tolerance $t = r * 0.5\%$
3. Correction k , depending on direction in which we enter / leave the cylinder. **Important:** the percentages given here are based on the specific deviations in the Feltre area, as shown in table 2 above. For other locations, other values must be used.
 - a. When approaching from north or south: $k = r * 0.04\%$
 - b. When approaching from east or west: $k = r * 0.29\%$
 - c. When approaching from northeast, northwest, southeast or southwest: $k = r * 0.13\%$
 - d. When approaching from any other direction: Mean of direction values a. and b., or b. and c.
4. Safety margin $s = 2 \text{ m}$
5. Use calculated radius r' depending on cylinder type:
 - a. For enter cylinder: $r' = r + t + k - s$ (or the next smaller number that can be entered)
 - b. For exit cylinder: $r' = r - t - k + s$ (or the next bigger number that can be entered)

Example: Exit cylinder of 40 km, I expect to leave it roughly in the northeast: $r = 40 \text{ km}$, $t = 200 \text{ m}$, $k = 52 \text{ m}$, $s = 2 \text{ m}$, $r' = 39.75 \text{ km}$. On a vario where cylinder sizes can be entered in steps of 100m, I set the Radius to 39.8 km.

4 Conclusion and warning

With the method described above, a pilot can calculate an alternative size for each cylinder in a race route. Flying this alternative route will reduce the distance he needs to cover, but still result in a tracklog that will be considered valid by the evaluation software FS. All this is of course at the individual pilot's risk. Those who want to be safe will still enter the cylinder sizes as defined by the task setter, and fly the route that results from those cylinders. This is especially true for pilots whose instruments calculated distances on the WGS84 ellipsoid.

Author: Jörg Ewald is the general manager of Volirium, the swiss vario manufacturer that emerged from Flytec and Bräuniger. He is an active competition pilot in the Swiss paragliding league, and occasionally still in the world cup. Besides that, he acts as a technical adviser for national and international airports associations such as SHV, CIVL, PWCA, ACPA and FAI. Over the last few years, he was also mainly responsible for maintenance, bug-fixing and further development of CIVL's scoring software, FS.