Position Paper on Periodic Pressure Altitude Calibration of FR

Published in support of 2023 proposal 6.1.1 on 2023-02-22, version 2.3

This is not a Position Paper on Periodic Pressure Altitude Calibration of FR.

This is a paper on why the above is not needed.

This document will not contain a technical discussion of if, how, why and when the accuracy of pressure sensors in Flight Recorders possibly deviates and whether it then varies with absolute altitude, calendar age, frequency of use or some other variable.

We will not present statistical evidence for either occurrence or non-occurrence of "drifting" of pressure readings. Nobody has these data anyway.

What we will do in this document is to deliberate why we in our sport measure altitude to begin with and what the “good enough” level of accuracy is. From there we will examine how this can be achieved in FAI's legal framework and address possible needs for adjustment of the Sporting Code, if necessary at all.

Spoiler alert: the conclusion will be that unlike regularly visiting a dentist, periodically having to calibrate the pressure sensor in your Flight Recorder is not actually good for you. It is at best an expensive nuisance and if we can get by without this recurring hassle then we all are off for the better.

Why do we measure altitude?

Because we want to evaluate and verify a sporting performance – be it a result in a gliding competition or a claim for a badge, diploma or record. In all of these cases altitude is either the subject of the claim itself or a limit that must not be crossed, like Minimum Finish Altitude, Maximum Starting Altitude or Maximum Loss of Height.

This is why we measure altitude and for these purposes our Flight Recorders need to have a “good enough” level of accuracy. Others may want us to measure and record altitude at much higher accuracy in order to follow up whether we have entered forbidden airspace. This is not our main concern and we will come back to this later in this paper. For now it suffices to state that our requirements on the level of accuracy of altitude measurements performed by the devices we carry with us in our gliders for sporting purposes cannot possibly be driven by someone else’s desire to detect and punish airspace violations for legal reasons. For us the sporting requirements are those that count – these need to be met with a “good enough” level of accuracy according to our specifications.

How do we measure altitude?

To begin with: we don't. What we do measure are other variables that can be put into an equation for calculating an altitude value. For technical details we refer the reader to this nice summary [1] which also elaborates on the accuracy of both ways of measuring altitude. Let’s nevertheless look into this ever so briefly:

We can measure barometric air pressure and assuming a perfect standard atmosphere we can calculate an altitude value from the measurement data [2]. Unfortunately we seldom experience these perfect standard atmospheric conditions in real life, they vary all the time and often we don't exactly know how. We correct for this in various ways, for example by entering a certain QNH value issued by some local or national authority. We then fly with these settings all day and pretend they don't change with location and time of day. Which they do. But we don't care, because this is "good enough". (And if only the pressure altitude [3] is of interest and everyone else makes the same rough assumptions then it doesn't matter anyway.)

Altitude can also be measured indirectly using GNSS signals. Doing so seems to be frowned upon by some but we want to remind the reader that the Sporting Code 3D [4] already today allows this for Position Recorders (PR) and Flight Recorders (FR) without valid calibration. Section 2.4.3.c reads: "If PR barometric data is not available or the FR calibration period has lapsed, GPS height data may be used for Silver and Gold claims, provided that a 100 metre error margin is applied to all pressure height requirements of the Code (example: the gain of height is at least 1100 metres for Silver altitude)."

In other words: we have already accepted in our official rules that an altitude measurement can be performed with less accuracy and specified how it can still render a valid sporting performance. In principle this is nothing new, we are used to this.

How do we make sure to measure altitude correctly?

Measuring anything correctly is very difficult and quickly gets one into philosophical questions like what the true value of anything really is.

The technical minded reader can find some more details in a series of infoboxes throughout this chapter, but it suffices to state that all measurements are prone to errors of various types and from various sources. Calibration can help to cope with part of the error stemming from the measuring instrument itself.

Infobox: Errors

If we talk about sources and types of measurement errors then this webpage [5] as well as this one [6] give a good summary. Also, let's not confuse precision and accuracy, which this webpage [7] explains nicely: "Accuracy refers to how close a measurement is to the true or accepted value. Precision refers to how close measurements of the same item are to each other."

Infobox: Accepted accuracy

For our Flight Recorders we find the requirement in the Sporting Code 3D Annex B [8] section 2.1.3:
- ±1 hPa (ca. 8 m) at sea level
- ±3 hPa (ca. 25 m) up to 2000m
- ±1 % above 2000 m (ca. 8.0 hPa = ca. 80 m at 2000, ca. 2.6 hPa = ca. 67 m at 10000 m)
  (Unclear if the third section relates to the pressure value or the altitude value. Upon asking for clarification GFAC confirmed the latter.)

EASA defines the accuracy of a "serviceable altimeter" in airplanes and helicopters in Annex VII to ED Decision 2022/012/R [10] section AMC1 NCO.OP.101(a) as:
- ± 60 ft (ca 18 m)

ICAO defines the accuracy of a "serviceable altimeter" in the PANS-OPS (Doc 8168), Volume 1 as:
- ±20 m or 60 ft for altimeters with a test range of 0 to 9 000 m (0 to 30 000 ft)
- ±25 m or 80 ft for altimeters with a test range of 0 to 15 000 m (0 to 50 000 ft)

FAA defines in the US Code of Federal Regulations, Title 14, Chapter I, Subchapter C, Part 43(d), Appendix E [12] in Table I acceptable tolerances for altimeters. The table is comprehensive, here just a few samples:
- ±20 ft (ca. 6 m) at sea level
- ±80 ft (ca. 24 m) at 10000 ft (ca. 3050 m) altitude
- ±130 ft (ca. 40 m) at 20000 ft (ca. 6100 m) altitude

Infobox: Calibration

In order to cope with a part of the instrumental error, namely a static offset many FR manufacturers perform a factory calibration, i.e. they expose the device to a series of pressure levels and compare the pressure reading of the FR to the true value of the pressure. The differences for each pressure level are handed to you as your individual calibration chart.

Anecdotal evidence exists that some manufacturers also (used to) store a set of correction values internally in the device and apply these on the raw measurement value. Anything that is displayed and written to an IGC file has then already been corrected once. For additional correction they still provide a calibration chart, nevertheless.

Modern pressure sensors produce a temperature-compensated digital output. Each chip is individually calibrated by the chip manufacturer, thus no need for the FR manufacturer to perform an internal correction as described above.

This initial factory calibration of the pressure sensor in Flight Recorders is not affected by the proposal to remove the demand for periodic calibration. Any newly produced FR shall still be pressure-tested as usual and shall still be delivered together with a usual calibration chart.

Infobox: "Periodic calibration", a semantic clarification

There is today no formal requirement for a "periodic" calibration in the sense of a legal requirement to perform calibration in regular time intervals, i.e. according to calendar date, whether the device is used or not. Rather, the requirement comes indirectly from that we regularly want to use our FR's and that for each flight that is to be evidenced a calibration period exists, which starts 5 years prior and ends 2 months after the date of the flight.

Does this fine distinction of "periodic calibration" and "calibration period" matter in practice? No. We all send our respective FR's for calibration every 5th year because we use them regularly to give proof of various flights performed – for which a current calibration chart is required. It is thus true that while *de jure* no requirement to periodically calibrate your FR exists, it does so *de facto* because otherwise our FR's would be useless for the purpose we purchased them (unless we use them as position recorders according to Sproting Code 3D section 2.4.3.c). To keep things simple let's continue to call it "periodic calibration" but keep in mind where it comes from.

Who watches the watchmen?

Here comes the elephant in the room: who says that any of the calibrations after sale of the FR are actually accurate? There may be several systematic errors that skew the result of such a calibration.

To begin with, how do we know that the pressure chambers used actually generate the correct pressure level? We know of some service providers who use left-over equipment from the military. Are those pressure chambers periodically checked and approved by some authority? IGC has no requirements of that sort. Sporting Code 3D Annex B [8] provides in section 2.1 some guidance on how to perform an altitude calibration but list no requirements on the calibration equipment employed. Seemingly anyone can thus provide their own calibration services without official oversight, potentially using tools unfit for the purpose. For example, instrumental and environmental errors might produce faulty pressure levels in the test chamber and then the pressure sensor in the FR is blamed for a supposedly faulty measurement reading.

(Update: in the latest edition of Technical Specification for FR, published on 1 February 2023 [9] we find a recent addition by GFAC in chapter 4: "The duration of validity of a calibration is 5 years, whether carried out by a manufacturer or another facility approved by an NAC". No further elaboration on what this entails in practice.)

Apart from the question of official approval of a calibration service provider, how do we know that the pressure level generated by the pressure chamber is at the right value? Even with perfectly functioning equipment human error can possibly be introduced. For example, an analogue pressure gauge displaying the pressure in the test chamber can lead to estimation error (wrong reading of the output) while even a digital display can still lead to transcriptional error (writing down the actual value incorrectly).

Transcriptional human error can also be introduced when writing down the altitude reading from the FR during calibration.

Furthermore, procedural error can exist, for example we have heard of one calibration service provider determining the "true" value of the pressure inside the test chamber by means of an old Volkslogger! In this case during such a "calibration" a FR is really just compared to another FR of dubious and in any case uncertain accuracy.

Conclusion

Given everything stated above, there is a certain likelihood that part of the supposed "drifting" of pressure sensors inside our Flight Recorders are due to systematic errors on behalf of the calibration service provider, rather than the device itself. Any such periodic "calibration" would then just give us the warm feeling of accuracy without actually providing it.

But let's for a moment assume that this isn't the case. Let's assume that no error whatsoever is introduced during calibration. With periodic calibration as the only means of securing "correct" altitude readings we still have the issue that right after a calibration a Flight Recorder might get damaged and produce faulty altitude readings but would nevertheless be considered trustworthy until the next calibration is performed. Again a warm feeling of accuracy without it actually existing.

Thus the value of periodic calibration is uncertain at best.

How can we make sure to measure altitude correctly, for real?

We can't. But we can keep altitude measurement errors on an acceptable, "good enough" level for our sporting purposes. These are results in a gliding competition and claims for a badge, diploma or record.

Competitions

Already today software like SeeYou Competition [13] performs a simple value correction (we call it "surface pressure altitude correction" or "SPAC") that reaches the "good enough" level of accuracy: before launch when standing on an airfield the software will compare the altitude reading of the FR with the known elevation of the airfield in question. The difference will be correctively applied to all pressure altitude measurement values of that flight.

One might counter that in addition to a constant error component (an "offset error") there might also be present "gain error", i.e. an error component that varies with altitude (or another variable like temperature, humidity etc.) – which is true. However, we need to remember the sporting purposes of these altitude measurements. In a gliding competition we want to ensure that limits like Minimum Finish Altitude, Maximum Start Altitude and Contest Area Altitude Limit are not violated. All of these are typically sufficiently close to the ground level that any error component varying with altitude in a reasonable way will not have a significant impact.

Thus: the simple SPAC correction already done is "good enough" for use in competitions.

Badges, diplomas and records

Here we are interested in determining the value of Altitude Gain or Loss of Height. For the latter the same reasoning applies as for Minimum Finish Altitude in competitions: the altitude values concerned are sufficiently close to ground level in order to just use the simple SPAC correction again. Furthermore, the LoH value (typically 1000 m) is the difference between start and finish altitude. Here the constant offset (error) in the altitude measurement is predominant and cancels mostly out.

For measuring Altitude Gains we have to acknowledge that the possibility of an error component varying with altitude exists. However, let's remember again that our official rules already handle Position Recorders without barometric pressure sensors and Flight Recorders with lapsed calibration period. Those are allowed for use up to and including the Gold badge. We as IGC can at any time make the political decision to widen the scope and allow the use of such devices also for the Diamond height. (For Diamond distance and Diamond goal as well as for distance diplomas and distance/speed records we again talk about giving evidence for Loss of Height, which has already been discussed above.)

Which leaves us with the question of how to handle altitude records. The international altitude record is already at a level that requires a High Altitude Flight Recorder (HAFR). Sporting Code 3D [4] section 3.3.3 already handles this. For continental and national records, however a conventional FR might still suffice. As IGC we have at least three options:

1. make the political decision to allow the simple SPAC correction
2. include a safety margin, like the extra 100 m for Silver/Gold badge claims with PR
3. keep today's rule that allows for a calibration up to two months afterwards, see section 2.4.6

Infobox: Managing uncertainty through analysis

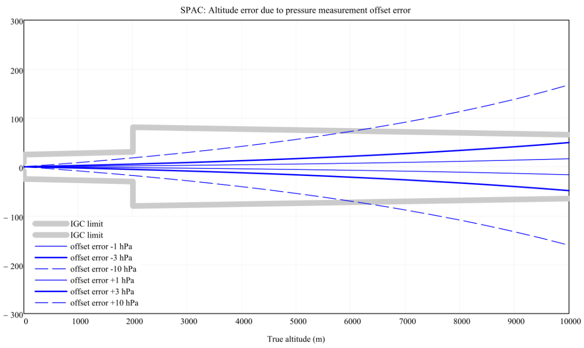
The statements and reasoning above have basis in an analysis made in support of the proposal. Anecdotal evidence is no evidence, and nobody, IGC included has the data to make a sound statistical analysis. Therefore, at this point turning the question around and asking how great an error can be to still result in acceptable accuracy is the best we can do.

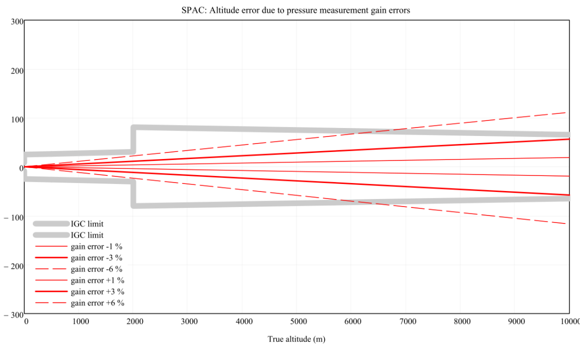
Using the Barometric formula [2] we can assess the impact of the two principle types of measurement errors we mentioned previously: offset errors (all pressure data are wrong by a constant delta, i.e. a difference) and gain errors (all pressure data are wrong by a constant percentage, i.e. a factor).

Let's remember that the Sporting Code 3D Annex B [8] gives in section 2.1.3 values for acceptable errors that do not necessitate any value correction such as the one we propose above:

- ±1 hPa (ca. 8 m) at sea level (i.e. an offset error)
- ±3 hPa (ca. 25 m) up to 2000m (i.e. an offset error)
- ±1 % above 2000 m (i.e. a gain error)

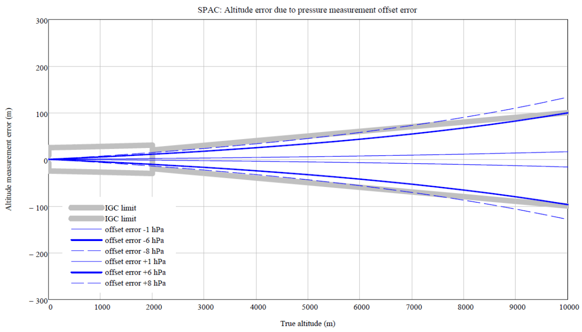
The charts below visualise these acceptable errors together with the impact of hypothetical offset/gain errors of different size after simple SPAC correction:

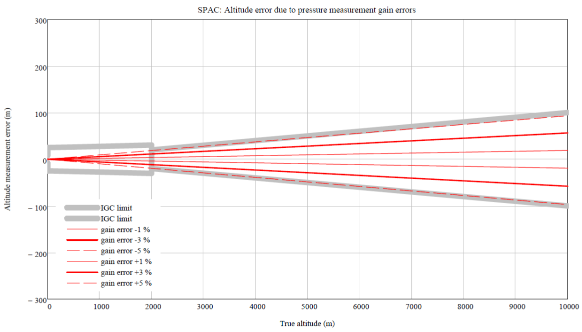




Some observations from the charts above:
- The error limits stated in Annex B form a sharp-edged envelope with abrupt changes, which seems impractical.
- A pure offset error of 3 hPa is within limits beyond 10000 m
- A pure offset error of 10 hPa is within limits up to 6000 m
- A pure gain error of 3% is within limits beyond 10000 m
- A pure gain error of 6% is within limits up to 6000 m

Update 2023-02-26: A different interpretation of the third section of the accuracy envelope defined in Annex B yields the charts below:





Some observations from these updated charts above:
- The error limits still form a sharp-edged envelope with abrupt changes, which seems impractical.
- A pure offset error of 6 hPa is within limits beyond 10000 m
- A pure offset error of 8 hPa is within limits up to 6000 m
- A pure gain error of 5% is within limits beyond 10000 m

To set all these values into perspective: reference [14] is a data sheet for a modern, known to be reliable pressure sensor, used in several trusted FR's in our sport. The manufacturer of this sensor guarantees an offset error over the whole altitude and temperature range of ±2.5 hPa (and does not specify any gain error, presumably because none exists).

Conclusion

Looking at the various types of gliding performances for which a Flight Recorder is used we find that for almost all flights a simple SPAC correction is sufficient. For altitude records, however, we acknowledge the demand for higher accuracy.

Do others require us to measure altitude correctly for legal reasons?

No. There is no need for pre-emptive obedience. No authority requires us to have highly-accurate pressure sensors in our Flight Recorders. The only real requirement on the accuracy of altitude measurements is to be "good enough" for our sporting purposes.

Infobox: Altitude in controlled airspace

We certainly have to obey by the national and international laws governing of aviation, which includes controlled airspace. But there are no laws requiring us to carry highly-accurate altitude measuring devices with a recording function in order to proof our innocence regarding a suspected entry into forbidden airspace.

If an infringement is detected by external means then the authorities concerned can and will engage the individual pilot and then perhaps the FR in question will be examined as potential evidence in the investigation. The pilots who want to be safe can always voluntarily calibrate their FR's and bring the calibration charts with them to any competition or free flight (suppressing all the doubts concerning the actual value of a periodic calibration, which we know from the reasoning above is uncertain at best).

Summary and conclusion

After purchase of a Flight Recorder there is no need to perform any addition calibration at certain time intervals. The actual value of such periodic calibrations is uncertain at best.

There will be no significant impact on the validity of sporting performances. A simple value correction (“surface pressure altitude correction”, SPAC) suffices for all performances but altitude records.

The requirement of a periodic calibration of the barometric pressure sensor in Flight Recorders can therefore be removed from our sporting rules.

The possible exception may be a few specific first-generation Flight Recorders of significant age. After removal of periodic calibration in general a group of experts should be tasked with analysing PA drift figures of these devices and investigating whether specific FRs that are shown to be less pressure-stable should be subjected to follow-ups at regular time intervals. This, however, shall not delay removal of the requirement for periodic calibration in general.

References

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