GFAC paper on Pressure Altitude Calibration

update 24 February with Annex D

References

A 2022-3 Plenary Agenda item 6.1.3 from Denmark and France:
www.fai.org/sites/default/files/6_1_3_2022_v2_sc3_2_4_6_den_fra_-_remove_periodic_calibration_of_flight_recorders.pdf

B Table of Current IGC-approved Flight Recorders: **www.fai.org/page/igc-approved-flight-recorders**

1. Reference A is the proposal from Denmark and France for the removal of periodic pressure altitude calibrations of IGC-approved Flight Recorders, published in the papers for the March 2022 IGC Plenary. As at the 2022 Plenary, this proposal continues to be strongly opposed by the GNSS Flight Recorder Approval Committee (GFAC), and is opposed by the Sporting Code Committee and members of the ANDS Committee.

2. Reasons for Opposition. Pressure Altitude (PA) is used as the Sporting Code altitude measurement for altitude performances below 15km*. It is also used for compliance with airspace rules, and is the International Standard for the altitude of Controlled Airspace. Accurate PA measurement is therefore essential for the accuracy and integrity of sporting gliding awards and competition scoring. The France/Denmark proposal would apply to all IGC-approved flight recorders (FRs) of which there are 59 different types from 21 different manufacturers (table, Annex A), many of which were designed many years ago and some manufacturers are no longer active. Annex B gives examples of changes in PA calibration figures for some IGC-approved recorders and shows that even recent FR designs exhibit PA drift. Annex C gives more detail on the causes of PA calibration changes, and Annex D is comment from the Sporting Code Committee.

** For altitude records above 15km a specially designed IGC-approved High Altitude Flight Recorder (HAFR) is required*

3. Stability of Pressure Sensors. The sensors used in current FRs are low cost devices, and many have proven drift over time. Those with drift require periodic calibration so that errors in PA values that are used to certify IGC performances do not develop without being detected. Some manufacturers of pressure sensors used in current IGC-approved FRs have said:

3.1 "All pressure transducers - no matter what they are made of, how expensive they are, or how accurate, are susceptible to sensor drift over time. Pressure sensor drift is a gradual degradation of the sensor and other components that can make readings differ from the original calibrated state." Reference:
www.solinst.com/products/dataloggers-and-telemetry/3001-levelogger-series/technical-bulletins/understanding-pressure-sensor-drift.pdf

3.2 "Despite all care, long-term stability and accuracy is physically impossible" and "The laws of physics place certain limits on a sensor's long-term stability". Reference: **www.stssensors.com/blog/2020/06/30/the-long-term-stability-of-pressure-sensors**

4. Applying a ground level offset correction. Reference A claims that a correction to the take off pressure altitude would mean that there is no need for periodic calibration, since the altitude at take-off is known and can be compared to the PA recorded in the IGC file. However, PA errors have two distinct components, Zero Errors and Slope Errors. Over time, drift occurs in both Zero and Slope errors. Errors at takeoff may be corrected using the known takeoff altitude, but the slope of the sensor response with altitude cannot be corrected with a simple zero shift.

5. Calibration errors cannot be corrected using GPS data. Measurement at known altitudes on mountains show that pressure altitude varies by hundreds of metres compared to GPS altitudes. Therefore, GPS Altitude at takeoff cannot be used to accurately convert to pressure altitudes and accurate pressures on mountains relevant to a glider flight are not available.
Reference: **www.cohp.org/ak/notes/pressure_altitude_v6.html**

6. Consequences of removing regular calibrations. In IGC Competitions, entry into Controlled Airspace (CAS) attracts major penalties. This is scored as landing at the point of entry, even if the entry is only a few metres. If pressure altitude is not accurately recorded, such a penalty could be applied even though the glider was clear of CAS. Conversely, entry into CAS might not be detected and escape a penalty that would be applied if the recorded pressure was more accurate.

7. Summary. Since Pressure Altitude (PA) sensors have been shown to exhibit drift with time, periodic calibration is necessary to ensure that PA is available to the accuracy required by the Sporting Code. If calibration intervals are simply deleted, GFAC will have to consider removing Approvals of types of flight recorder which are known to have PA drift, and to monitor other FR types to ensure that they maintain PA accuracy.

8. Conclusion. Pressure Altitude (PA) drift has been found in IGC files from many of the 59 different IGC-approved types in Annex A, of which several were designed over 20 years ago, so periodic PA calibration must not be removed from all IGC-approved Flight Recorders. However, GFAC should be tasked with analysing PA drift figures in more detail to see whether FRs that are more pressure-stable could have an increased calibration period. A suggestion is in the following sub-para.

8.1 At a PA calibration check after 5 years since the last calibration, if the correction figures do not differ by more than 1 HPa/mB up to an altitude of 5 km (Diamond Height) since the last calibration, no more calibration checks on that FR would be required in the future unless a hardware or firmware change is made that could affect the PA calibration figures.

Ian Strachan
Chairman, IGC GFA Committee

Annex A: Approval Data for 59 Types of Current FRs
Annex B: Analysis of IGC File Pressure Altitude Variation
Annex C : IGC file Pressure Altitude errors
Annex D: Sporting Code Committee paper

Note on Calibration: In this document the word "Calibration" refers to the process of checking the Pressure Altitude output of a Flight Recorder with respect to the ICAO pressure altitude, and producing a correction table.

The table includes 59 main types of IG-approved FR. 14 variations on the main type are listed, making a total of 73 FR types and sub-types.

s/n	Original Approval Date	Manufacturer	FR Type	IGC approval level
1	1996-1-16	Cambridge	CAI10	3 (Badges up to Diamonds)
2	1996-11-10	Zander	GP940	3 (Badges up to Diamonds)
3	1997-7-16	Cambridge	CAI 20 / 25	3 (Badges up to Diamonds)
4	1998-4-15	Garrecht	Volkslogger VL1.0	2 (Badges & Distance Diplomas)
5	1998-5-19	LX Navigation	DX50 (ex-Filser)	3 (Badges up to Diamonds)
6	1998-6-30	LX Navigation	LX5000 (ex-Filser)	3 (Badges up to Diamonds)
7	1996-8-12	LX Navigation	LX20/21 (ex-Filser)	3 (Badges up to Diamonds)
8	1998-8-31	LX Navigation	Colibri V1, V4 & V4F	3 (Badges up to Diamonds)
9	1998-8-31	LX Navigation	Colibri V8	2 (Badges & Distance Diplomas)
10	1998-6-30	LX Navigation	LX5000 (Filser)	3 (Badges up to Diamonds)
11	1999-3-8	SDI	PosiGraph V1.0	3 (Badges up to Diamonds)
12	2001-10-30	Cambridge	CAI 302 / 302A	2 (Badges & Distanc Diplomas)
13	2001-10-30	Zander/SDI	GP941	3 (Badges up to Diamonds)
14	2002-10-31	Scheffel	Themi T3.0	3 (Badges up to Diamonds)
15	2002-2-12	SDI	PosiGraph V2	3 (Badges up to Diamonds)
16	2003-3-14	LX Navigation	LX7000	1 (All Flights)
17	2005-7-20	LX Navigation	LX7007 / 7007F	1 (All Flights)
18	2005-8-8	New Tech	NTE Matchbox	2 (Badges & Distance Diplomas)
19	2006-5-30	Aircotec	XC PROFI	2 (Badges & Distance Diplomas)
20	2006-6-10	EW	microRecorder	2 (Badges & Distance Diplomas)
21	2007-1-10	New Tech	NTE EASY	2 (Badges & Distance Diplomas)
22	2008-3-10	FLARM	Flarm-IGC	3 (Badges up to Diamonds)
23	2008-3-10	FLARM	PowerFlarm-IGC	3 (Badges up to Diamonds)
24	2008-4-12	DSX	7110 / 8010	2 (Badges & Distance Diplomas)
25	2008-4-25	LXNAV	LX80-00, -30, -40, -80	1 (All Flights)
26	2008-6-10	IMI	Erixx V1.0	2 (Badges & Distance Diplomas)
27	2008-6-14	EDIATec	ECW100F	3 (Badges up to Diamonds)
28	2008-8-31	LX Navigation	LXN Mini Box Flarm	3 (Badges up to Diamonds)
29	2008-8-31	LX Navigation	LXN Red Box Flarm	3 (Badges up to Diamonds)
30	2009-2-14	Triadis	Altair RU1	1 (All Flights)
31	2009-5-25	ClearNav	CN-IGC	2 (Badges & Distance Diplomas)
32	2010-6-14	LXNAV	LX9000 & 9000F	1 (All Flights)
33	2010-6-14	LXNAV	LX9050 & 9050F	1 (All Flights)
34	2010-6-14	LXNAV	LX9070 & 9070F	1 (All Flights)
35	2010-8-31	LXNAV	Nano 1	1 (All Flights)
36	2011-9-15	DSX	SaFly	3 (Badges up to Diamonds)
37	2011-11-20	LX Navigation	Colibri II	1 (All Flights)
38	2013-5-5	Triadis	Triadis RU2	2 (Badges & Distance Diplomas)
39	2013-3-31	Triadis	Triadis RU3	1 (All Flights)
40	2013-7-31	LXNAV	FlarmMouseIGC	3 (Badges up to Diamonds)
41	2013-7-31	LXNAV	Flarm PowerMouse	3 (Badges up to Diamonds)
42	2013-7-31	LXNAV	Nano 3	1 (All Flights)
43	2014-3-20	Naviter	Oudie-IGC	1 (All Flights)
44	2014-4-10	ClearNav	CNV-IGC	1 (All Flights)
45	2014-11-26	LX Navigation	LX Eos & Eos 80	1 (All Flights)
46	2014-11-26	LX Navigation	LX Era 57 & Era 80	1 (All Flights)
47	2014-11-26	LX Navigation	LX 10000	1 (All Flights)
48	2015-3-10	ClearNav	CN II	1 (All Flights)
49	2015-4-20	PressFinish	GCA-IGC	1 (All Flights)
50	2015-11-22	Logstream	FR1	1 (All Flights)
51	2016-4-25	LXNAV	S-10	1 (All Flights)
52	2016-4-25	LXNAV2	S-100	1 (All Flights)
53	2016-8-3	LXNAV	LX9000HAFR	1 (All Flights)
54	2016-11-16	LX Navigation	LX MOP IGC	1 (All Flights)
55	2017-2-12	LXNAV	Nano 4	1 (All Flights)
56	2018-8-31	LX Navigation	Colibri X	1 (All Flights)
57	2018-11-15	LX Navigation	LXN Flarm Eagle + Mobile	3 (Badges up to Diamonds)
58	2021-4-20	RC Electronics	Fenix & FenixN	1 (All Flights)
59	2022-7-12	Naviter	Oudie-N-IGC	1 (All Flights)

This includes inputs from GFAC Technical Advisor Dickie Feakes (DF). He has been a Pressure Altitude calibrator for the last 40 years and has calibrated over 2500 FRs.

B1. IGC approved flight recorders (FR) require initial calibration of their Pressure Altitude (PA) figures to ensure that they comply with the IGC minimum accuracy requirements. PA figures are subject to two specific types of error. The International Standard Atmosphere (ISA) altitude of zero is defined as a pressure of 1013.25 HectoPascals (or milliBars) (HPa/mB), and any difference of the recorded PA in an IGC file at this altitude is called the "offset error" or "zero error". IGC specifications require this error at FR manufacture to be within +/- 1 HPa (27ft/8.23m). There is also the difference between the altitude in the IGC file and the corresponding ISA altitude at varying atmospheric pressures - sometimes referred to as the "gain error" or the "slope error". The IGC specification requires this to be +/- 3 HPa up to 2000 metres and 1% of altitude above. These errors are recorded for each FR on a calibration chart at manufacture (except Flarm, see later). Later re-calibrations are carried out at not more than 5 year intervals either by a Calibrator approved by the relevant National Aero Club (NAC) or by the FR manufacturer if this service is offered.

B2. GFAC Technical Advisor Dickie Feakes has carried out calibrations on some 2500 different FRs ranging from the early Cambridge GPS10 to the latest LX NAV instruments. Some of the Cambridge FRs show errors of over 1300ft at 30,000ft (396m at 9144m) and a calibration chart is available (**Reference 1**). Some 150 LXNAV and LX Navigation FRs have been calibrated and about 10% had significant error figures. **Reference 2** gives figures for an LX9000 with a zero error of 110 ft (36 m) and larger errors as height is increased.

B2.1. Of the nine models of the LX Navigation Colibri II that have been calibrated, all are outside the IGC specification at ISA zero and only marginally inside at 30,000ft/9144m. An example is at **Reference 3** which is a calibration of a Colibri II in April 2017 and **Reference 4** is for the same unit 5 years later.

B2.2. NAC-approved Calibrators do not normally have access to the original manufacturer's calibration and it is difficult to say how much calibration figures have changed since initial sale. Since world sales are estimated to be at least 10 times the number I have calibrated, this indicates that there may be quite a few FRs with calibrations that are outside IGC limits. However, for an LXN EOS unit I can provide more information. The original manufacturers calibration chart (dated 2015/2) is at **Reference 5** and this FR performed satisfactorily until the owner upgraded the firmware, when he noticed that the 1013.25 datum height was now in error byabout 4 HPa. This FR was given to me for calibration and I confirmed the error, the new calibration chart being attached at **Reference 6**. A week later the owner made a diamond height climb with this FR and the corrected heights from my calibration chart were compared with a calibrated Flarm unit carried on the same flight. The FLARM calibration chart is attached at **Reference 7**. Analysis attached at **Reference 8** shows a very close agreement between the EOS and FLARM figures once the corrections are applied. This confirms that my calibration of the EOS was accurate and the unit had shown marked drift since the original manufacturer's calibration.

B2.3. I have calibrations for 36 Flarm FRs. It should be noted that Flarm is the only manufacturer which does not provide a calibration on initial purchase (an agreement with IGC many years ago to bring them into our Approval system), which then has to be done after delivery by an NAC-approved Calibrator.

References - Calibration Details - available in ZIP file **via this link**.

Reference 1 - Cambridge GPS25 Serial/No 0C5
Reference 2 - LX9000 Serial/No 7GH
Reference 3 - Colibri II Serial/No N5N 2017/4
Reference 4 - Colibri II Serial/No N5N 2022/2
Reference 5 - LX Navigation EOS Serial/No Q9J at initial sale 2015/2
Reference 6 - LX Navigation EOS Serial/No Q9J 2021/11
Reference 7 - Flarm Serial/No 6IX
Reference 8 - Analysis of Diamond Height Claim

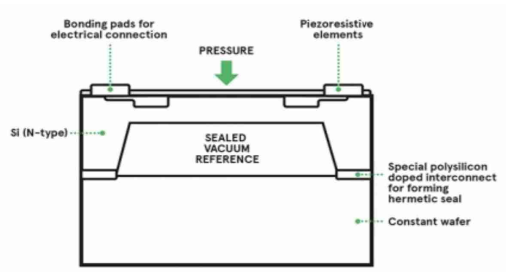
C1 Absolute Pressure Measurement System. The response of a measurement system can be modelled by a polynomial equation of the general form:

$$F(p) = K0 + K1p + K2p^2 + K3p^3 + K4p^4 \ldots$$

The coefficients of the polynomial are determined by mathematical curve fitting. In the case of the direct output of a silicon pressure gauge of the type used in Flight Recorders, the output is sufficiently linear that the constant K0 can be referred to as the “Zero” and K1 as the scale, and higher order terms ignored. Both the dimensions of the sensing diaphragm (and hence the deflection under changing pressure), and the embedded sensing strain gauge are affected by temperature. To compensate for this, the pressure sensor also incorporates a temperature sensor on the diaphragm, and the coefficients and higher order ones are dynamically modified within the sensor to give a digital output that is a measurement of absolute pressure only, already temperature compensated. The absolute pressure signal is then converted to ISA Altitude by software in the Flight Recorder firmware.

C2 IGC Pressure Altitude recording. The linear digital pressure signal from the sensor output is converted to an International Standard Atmosphere Pressure Altitude. Any inaccuracy in the pressure sensor output will appear as a Pressure Altitude error. An IGC Flight Recorder is supplied with a ‘Calibration Chart’ which indicates the correction which should be applied to correct the recorded pressure to that required for flight verification. The Sporting Code (SC3b para. 2.1.3) requires that in all FRs before or immediately after initial sale, on set-up and on calibration of their pressure altitude system, the sea level setting should correspond to 1013.25 hPa within 1.0 hPa/mb, within 3.0 hPa/mb up an altitude of 2000 metres, and within 1% of altitudes above 2000 metres. The accuracy of these corrections depends on the pressure sensor being unchanging with time (“zero drift”). The sensor manufacturers quoted in para 3 of the main paper show that these do drift over time, and so periodic calibration is required to remain accurate.

C3. Causes of drift in silicon pressure sensors. Fig. 1 shows a cross section through a typical absolute pressure sensor. The reference pressure is normally a sealed vacuum, since this does not change with volume or temperature. This means that the sensor is subject to forces due to atmospheric pressure, and this is one cause of drift as creep within the silicon diaphragm which resists the pressure, and changes in the sensing elements under stress undergo minute changes at a molecular level. Silicon crystals are used in the sensing elements for their long term stability, but long-term measurable changes can be detected. These changes are accelerated by shock and vibration, such as occurs when landing a glider on a rough surface, or transporting it in a trailer with the instrument panel fitted.



C4. Summary. The only way to ascertain whether changes in the accuracy of the Pressure Altitude sensor output have caused the accuracy in IGC file Pressure Altitude to fall outside limits required by the Sporting Code, is to carry out periodic Pressure Altitude calibration.

Regarding the proposal to remove the need for periodical calibration of flight recorders

This proposal was first presented to the 2021 Plenary under the category "Other Proposals". Our committee argued against the proposal as did GFAC; however, their and our arguments were ignored. The proposal has been submitted again as a Year-2 proposal.

GFAC has the responsibility to control the technical requirements of IGC Flight Recorders, and the Plenary should follow their expertise. The Sporting Code committee fully supports the GFAC position on future Pressure Altitude calibrations. Much of the reasoning in the original Danish/French proposal had no evidence to support it. This has not changed in the current version.

Consider the reasoning in the proposal *(quoted in italic lines below starting with an askerisk *)* :

• *A less than 5-year-old calibration certificate is now required even for a simple badge.*
The term "simple badge" is not defined by the proposers but, assuming Silver & Gold are intended, this statement is **NOT TRUE**. Refer to SC3-2.4.3c: 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.

• *It is very difficult to get such a proper document.*
This statement is **NOT TRUE** - it is not difficult at all. Most FR manufacturers are located within the European Union and it is easy to send an FR to them from within the EU - including the countries of the proposers. There are also private pressure altitude calibration labs in Germany (Akaflieg Stuttgart), in the UK, USA, Canada, and Australia.

• *It leads to many side effects: Fewer badges or records submitted.*
No evidence is given for this - in contrast, the Claims Officer for the DAeC sees no shortage in recent years of claims for FAI & national records being submitted; all with valid calibration certificates.

• *Calibration certificate with a variable or untrusted precision, etc.*
No evidence is given for this. Calibration facilities must be approved by the responsible NAC.
If a NAC has evidence that a calibration facility is unreliable, it should take appropriate action.

• *Moreover, the data in the calibration certificates are rarely used even in a WGC.*
For badges, see SC3-2.4.3a: The pressure altitude evidence is to be corrected using the calibration chart data when the precise altitude is critical to the claim.
Germany. Within the DAeC (arguably the largest NAC) calibration data is used to correct the pressure altitude when analysing all FAI and national claims for Diamonds, Diplomas, and Records. This is straightforward when using Claim Check (**www.badgeflight.com**) for the analysis (written by a member of the Sporting Code Committee).
UK. The same procedure is followed in the UK where competition rules require pilots to provide a calibration certificate; these are routinely used when the scoring program indicates a possible airspace infringement.
Poland. The Claims Officer for Poland confirms that the situation there is similar.
If other scoring software do not make use of the calibration data, then this should be corrected!

• *Last but not least, manufacturers having a long-term experience report that the pressure sensors do not drift. If they work, they work fine.*
This statement cannot be supported as GFAC has evidence that drift certainly does occur over time. For example, as shown by the GFAC submission to the 2022 Plenary, of a sample of 150 flight recorders from the LX Companies (probably the manufacturers of most Flight Recorders currently in use) over 10%, when calibrated after a 5-year period, showed drift exceeding the IGC FR Specified limits.

Need for accurate altitude data
Altitude data plays an important role in the Loss-of-Height (LoH) rule and its associated penalties. The Sporting Code Committee has always been careful not to "devalue" existing achievements by changes to the Code. Claims Officers also wish to avoid wrongly awarding or wrongly denying a claim due to a pressure sensor having drifted. Furthermore, for example, pilots attempting the 100 km triangle speed record take particular advantage of the allowed 1000 metre Loss of Height - where inaccurate altitude data can lead to a false acceptance or denial of the claim. Additionally, as has been suggested as being sufficient, the application of only a localized QNH correction to an altitude profile does not consider flights being conducted in at high er altitudes in wave.

Conclusion
The Sporting Code Committee strongly opposes removal of periodic FR calibration.

24 February 2023