Appendices to Report to IGC by GFAC Chairman

Appendix Numbers: 1. Sporting Code - considerations on COTS GNSS units
2. Engine recording in IGC files

Appendix 1 - Sporting Code matters

This adds to proposals by the Sporting Code committee on the possible use of Commercial Off the Shelf (COTS) GPS units to replace camera position evidence for Silver and Gold badge flights. What follows shows some of the implications if IGC were to accept this concept.

Considerations on the possible use of evidence from COTS GPS units for verification of Silver and Gold badge performances

1 **Existing IGC Procedures for Diamonds and Above**. IGC procedures and standards for GNSS recorders have been in place for over 10 years. They are embedded in the Sporting Code for Gliding (SC3) and its annexes, particularly Annex B to the Code and also in the stand-alone document "Technical Specification for IGC-approved GNSS Flight Recorders" that also contains the protocols for the IGC data file format. These standards involve a number of levels of security, procedures and rules that apply to the validation of flights in the IGC environment. The lowest level of IGC-approval is for badge flights up to and including the three diamonds and the highest is for all flights including for World Records. It is proposed that these existing and well-proven rules and procedures should not be altered by introducing different standards of security, procedures, accuracy and integrity of altitude and position data into the types of flights already covered by the IGC-approval system. It follows that such COTS units could be considered for evidence for flights below the three Diamonds, that is, for Silver and Gold flights. For the reasons given in para 6, pressure altitude to the ICAO ISA must also be available for the flight. In principle, the COTS GNSS unit would replace the camera for evidence of horizontal position.

1.1 Status of GNSS Units. Any COTS GNSS unit used for evidence of Silver and Gold flights must not be regarded as an IGC-approved unit, for which the more rigorous IGC Specification applies. Such COTS units are not part of the existing IGC-approval system. The use of IGC-approved recorders for flights for Diamond legs up to World Records should continue under the existing system and any new procedures for COTS GPS units should apply only to evidence for flights below Diamond level, that is, for Silver and Gold badge legs. Some known features present in some COTS units must be taken into account so that the fix data that is used in evidence is both accurate and to a consistent datum in both latitude, longitude and GNSS altitude.

1.2 Pressure Altitude. Independent of the COTS GNSS unit, pressure altitude data to normal IGC standards is needed for the purposes below:

1.2.1 Measurement. For accurate gain-of-height and altitude loss calculations in accordance with IGC Sporting Code rules and procedures that have been in place for many decades.

1.2.2 Comparison. So that the altitude profile of the flight from the GNSS unit can be compared to data from the independent pressure altitude source as a check on the integrity of the overall COTS GNSS data. It should be recognised that GNSS altitude and Pressure altitude data use different zero datums and different altitude scales, but the general shapes of the altitude graph with time should be very similar.

2 **Evidence of Position**. If IGC decide, for Silver and Gold flights, evidence of horizontal position (Latitude and Longitude) from the internal Track Records of a COTS GPS unit downloaded after flight, could be accepted instead of camera evidence of position. However, there must be procedures for control and Official Observation of such recorders in a similar way to cameras. Also, it must be ensured that the Lat/Long figures that are downloaded are derived from GNSS position lines (rather than predictions) and that all data uses the same Earth Model (Geodetic Datum).

2.1 Predicted Data and Averaging. Any GNSS unit that can produce lat/long fixes that are not derived directly from real-time GNSS satellite lines-of-position, must be prohibited. This includes predicted data based on past fixes, often used in units designed for ground use when signal is temporarily lost due to ground obstructions, and units with excessive "averaging" that results in alteration of precise lat/long positions.

2.2 Changes of Earth Model. It is preferred that the GNSS unit will not allow the Earth Model (Geodetic Datum) to be changed when the unit is operating in flight, but can only be changed during the initial set-up process. However, if a GNSS unit permits change of the Earth Model in flight, such units must either be positioned out of reach of the crew in flight, or must be sealed by an OO before flight in such a way that the Earth Model cannot be changed in flight.

3. **Downloading from the COTS unit**. So that one of the existing analysis programs can be used, the downloaded data must be converted to the IGC format for post-flight analysis, as far as possible (allowing for the limitations of data available from the unit concerned). Additional data required by the Sporting Code would be manually recorded by the OO and pilot in the usual way. The program used for downloading and conversion to IGC format must include a system such that any unauthorised changes to the electronic data, can be detected later. This is a similar principle to the IGC Validation system but applies to the data after downloading rather than being integral with the recorder system itself.

4. **Supervision**. Such COTS GNSS units and procedures associated with them should be supervised by the NAC and their OOs in accordance with the provisions of the Sporting Code. Such supervisors should be aware that the security of the unit itself and of the data initially downloaded from it does not conform to IGC standards for flights other than Silver and Gold and that COTS units do not have the physical or electronic security that is built in to IGC-approved GNSS recorders. GNSS recorders with IGC-approvals apply to higher badges, diplomas, records, and Championships that use Sporting Code Annex A rules. Their characteristics are covered in the Technical Specification for IGC-approved GNSS Flight Recorders.

5. **NAC approval for types of COTS unit and Download Software**. Before a type and make of COTS GNSS unit and the type of software used for downloading and conversion to IGC format (para 3) can be used for evidence for Silver and Gold flights, the type of recorder and the download software must have been tested and approved by three NACs that are current IGC members. *(This was a system used in the past for the use of Electronic Barographs).* Details of such NAC tests and approvals should be passed to the Chairman of GFAC *(or other person acceptable to IGC)* who will ensure that the types of GNSS Units and Software are listed on the IGC GNSS web site.

6 **Altitude Evidence**. In the Sporting Code for Gliding (FAI SC3), where accurate measurement of altitude is concerned, pressure altitude has always been required. Such pressure altitude figures must be calibrated to the International Standard Atmosphere of the International Civil Aviation Organisation (the ICAO ISA). Any change to this long-term IGC policy would require major amendments in many places in the Sporting Code and its three annexes. For the reasons given below, such a change cannot be justified. Every IGC-approved Flight Recorder has a pressure transducer system, calibrated to the ICAO ISA, in accordance with the IGC Specification for such recorders. Electronic pressure transducers fitted to IGC-approved recorders, typically by Intersema (Switzerland) and Semsyn (USA), are more accurate and stable with time than the older aneroid-based barographs that record on a drum or a roll of paper. Such pressure altitude figures are an integral part of all fixes recorded in an IGC flight data file and have been considered reliable enough that the Sporting Code requires re-calibrations at longer intervals than aneroid barographs.

6.1 Pressure Altitude and Controlled Airspace. Worldwide, the vertical boundaries of controlled airspace are defined to a pressure altitude datum. This includes airways bases and control zone levels.

6.2 GPS altitude. Pressure Altitude and GPS altitude are to different scales. GPS altitude is vertical height above the ellipsoidal world model (Geodetic Datum) that is used for the Latitude and Longitude figures. This is not the same as the ICAO ISA. In many GPS units, a conversion is available that gives an approximate altitude above local sea level. However, heights Above Sea Level (ASL) on maps are often taken from a single Mean Sea Level (MSL) datum which is a good average for the area in question, and this may not correspond to exact MSL at any given point. For the WGS84 system, an approximate local sea level figure can be obtained through the use of look-up tables that convert between the WGS84 ellipsoid and the WGS84 Geoid, an equipotential surface approximately equivalent to local sea level. Such look-up tables can be stored in the GNSS unit in electronic form and often form the basis of ASL selections mentioned in equipment manuals. GPS altitude figures can be converted to pressure altitude to the ICAO ISA but this is not easy and requires a knowledge of the actual atmospheric temperature and pressure structure at the altitudes and positions of the glider concerned during the flight. For accurate conversions, these need meteorological "soundings" derived from radio-sonde ascents or observations from aircraft with appropriate instruments.

6.2.1 Anomalies in IGC fileGPS Altitude. Even if the above was practical, errors in GPS altitude need to be considered. In ideal conditions, GPS altitude errors should be about twice those of lat/long due to the geometry of the position lines. Unfortunately, analysis of many hundreds of IGC files has shown a significant number of cases where GPS altitude figures show examples of electronic noise, that is, random variations of GPS altitude with time. They also show occasional more major anomalies including obvious GPS-altitude errors and altitude unlocks. Examples include GPS altitude overshoots over pressure altitude at high points and undershoots at low points, giving an exaggerated gain-of-height. These anomalies are not a feature of the GPS system itself but of the way raw GPS altitude fixes are processed within the low-cost GPS boards concerned. Fortunately, GPS lat/long figures are processed separately using different algorithms, for instance using noise reduction techniques, and are not subject to the same anomalies as GPS altitude. In comparison, pressure altitude figures in IGC files have been shown to be very reliable and free of electronic noise. However, it must be borne in mind that most IGC-approved recorders are vented to the surrounding air ("cockpit static") which, although the difference is generally small, is not quite the same as the calibrated static used in flight instruments.

6.3 Conclusion on Altitude Figures. For the above reasons, it cannot be recommended to IGC that GPS altitude should replace pressure altitude in the Sporting Code for accurate altitude measurement. However, there is no difficulty with the existing use of GPS altitude to prove continuity of flight if pressure altitude recording fails because for this purpose, accuracy is not as important as continuity.

6.4 Altitude in COTS GPS units. Some COTS GPS units record GPS altitude with each lat/long fix in their track records. However, such GPS altitude figures are subject to the different scale and the errors that are described above and should not be used for accurate altitude measurement.

6.4.1 Pressure Altitude. A few COTS units include a pressure altitude capability that may or may not be recorded in the track record. It may not be possible to calibrate this pressure altitude to the ICAO ISA because some units are designed to re-set the pressure datum automatically with time in an effort to obtain an continuous approximate "above sea level" reading. Such pressure altitude figures, if recorded in the track record, will not be to the ICAO ISA and therefore not to the IGC measurement standard.

7. **Changes to the Sporting Code**. In accordance with the above, the following amendments to Sporting Code Section 3 could follow, subject to IGC agreement and final adjustments by the Sporting Code, ANDS and GFA Committees:

SC3 para **Amendment**

In all parts of the code the term "Flight Recorder" to be changed to "IGC-approved Flight Recorder" where applicable, to distinguish between Recorders that are tested by GFAC and approved and those that are not.

4.6.4 A revised para 4.6.4 and its sub-paras to read as follows.

4.6.4 **GNSS Flight Recorder position and other evidence**

4.6.4.1 IGC-approved Flight Recorders for Diamonds and above. Types of FAI/IGC-approved recorder for which an official IGC-approval document is posted on the IGC GNSS web site may be used for the validation of the types of flights that are described in the approval document. See Annex B para 1.1.3.3 for the different approval levels for various types of flight. For validation of a flight using evidence from an IGC-approved recorder, the conditions and procedures in the IGC-approval must be followed . OOs involved shall familiarise themselves with the terms of the IGC-approval. The approval document will specify procedures to be used, advice to pilots, to OOs and NACs and any limitations (see Annex B Chapter 1).

4.6.4.2 Silver and Gold badge flights - Position and Altitude Evidence. GNSS receiver units that are not IGC-approved in accordance with 4.6.4.1 but after flight are capable of producing a track record of the flight in both lat/long and GPS altitude, may be used for evidence of horizontal position (Latitude and longitude) for Silver and Gold badge flights only. The track record must be capable of being downloaded after flight and converted to the IGC data file format for analysis. The type of GNSS unit must have the approval of at least three NACs for this purpose and such types will be listed on the IGC GNSS web site. Official Observer supervision of the unit concerned is required before and after flight. A record of pressure altitude to the ICAO ISA to the normal IGC rules and procedures for pressure altitude is also required for the flight, such as by the use of a separate barograph or recorder. This is to comply with IGC standards of altitude measurement for any gain of height, start and finish altitudes and for comparison with any nearby controlled airspace. The pressure altitude record must also be compared with GPS altitude recorded on the same flight and must show a similar general shape of altitude against time for the flight. This is an integrity check on the data in the IGC file that is not as secure as that from IGC-approved recorders.

4.6.4.3 General Procedures for all GNSS Flight Recorders

4.6.4.3.1 Geodetic Datum (Earth model). The WGS84 Geodetic Datum shall be used for all Lat/Long data that is recorded and used after flight for analysis. It must be shown that the downloaded lat/long data was fixed on the WGS84 datum for the whole flight. A recorder must be used in which the recorded data: either is permanently fixed on the WGS84 Datum, or it must not be possible to change the datum from WGS84 in flight, or if such a change is made the change must be recorded on the IGC file (although if a change from WGS84 is shown, the flight data shall be invalid for IGC purposes).

4.6.4.3.2 Presence of the recorder in the Glider. There must be incontrovertible evidence, independent of the Recorder data, that the Recorder from which the data was taken was in the glider flown by the pilot during the claimed soaring performance. This is particularly important with small and portable types of Recorder that can easily be transferred between gliders.

4.6.4.3.3. Before the flight. For recorders capable of storing a pre-flight declaration to IGC standards, this shall be stored electronically in the flight recorder (1.3.2) together with the time of declaration, or, where a written pre-flight declaration is allowed, the OO shall sign it. The flight recorder system shall be placed, configured or sealed in such a way that it will be impossible to operate any controls or connect other devices other than those specifically allowed for use in flight, for instance in accordance with the IGC approval for the equipment.

4.6.4.3.4 Takeoff and landing evidence independent of the Recorder. An OO shall ensure that there is separate evidence for the times and points of takeoff and landing, pilot(s) names, glider type and registration, and the type and serial number of the Recorder used for the flight evidence. This evidence shall be independent of the data produced by the Recorder. This is used as an independent integrity check on the flight recorder data which can then be used for more detailed analysis (Annex C para 11.3).

4.6.4.3.5 After flight. As soon as possible after landing, The OO shall check any seals that were applied before the flight and the flight data shall be transferred under OO observation from the Recorder to standard storage media via a PC or other device. The program used for downloading must include a conversion to the IGC format for post-flight analysis (as far as possible, allowing for the limitations of data available from the type of unit concerned). The program used for downloading and conversion to IGC format must include a system such that any unauthorised changes to the electronic data, can be detected later. The flight data shall then be sent either by email or by sending the storage device, to a person approved by the NAC to make the analysis.

4.6.4.3.5.1 COTS recorders. The above applies, but in the case of downloading after flight, the system used is similar in principle to the IGC Validation system but applies to the data after downloading rather than being integral with the recorder system itself. Such programs for downloading COTS recorders must have the approval of at least three NACs for this purpose and such programs will be listed on the IGC GNSS web site. Additional data required shall be manually recorded by the OO and pilot in the usual way.

4.6.4.4 Data Analysis. Analysis of the flight data shall be performed by a qualified person approved by the NAC, whose duty is to ensure that the appropriate evidence is present to verify the reaching of way points, heights, times and position, as required. The GPS altitude record with time must approximately match the pressure altitude record in terms of general shape. Detailed guidelines for analysis are in Annex C. Where there is more than one Recorder in the glider, the one holding the last pre-flight declaration shall normally be used for analysis. However, in the case of a failure or partial failure of this Recorder, data from another may be used provided it is approved for the type of flight performance claimed. If the soaring performance qualifies for a badge or record, the following shall be forwarded to the NAC:

4.6.4.4.1 Original Data. The download process from the Recorder immediately after landing must include the production of data in the IGC file format. If the type of recorder downloads into an intermediate format such as manufacturer's binary, the file in this format must be kept as well as the IGC format to which it has been converted and sent for analysis together with the IGC format file. Storage of data between download and analysis of flight data may be on any standard media such as diskette, hard disk or memory stick but such media must be protected from the possibility of data corruption or interference.

4.5.4.4.2 Claim form. The appropriate claim form(s) must include evidence of times and exact locations of events (such as takeoff and landing) independent of Recorder data. This must agree with the data from the Recorder to give confidence that the rest of the detailed recorder data can be used as evidence for the flight.
4.6.4.4.3 Free (not pre-declared) Flights. For free record flights, the achieved way points shall be determined after flight from valid fixes in the flight recorder evidence.

4.6.4.4.4 Other Data. This includes any other measured data and/or ancillary material required by a NAC to support the mandatory evidence (examples, Annex B, Appendix 1).

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Appendix 2. Engine recording in IGC files
For either Annex B to the Code or the IGC Technical Specification for Flight Recorders

Engine Noise Level (ENL) recording in IGC-approved Recorders

Introduction. An IGC-approved recorder with the ENL facility has a microphone inside the sealed recorder. This is used, combined with signal processing inside the recorder, to put three numbers between 000 and 999 that reflect the acoustic noise at the microphone, into each fix record in the IGC file. The ENL system is intended to show that the engine has not been run under forward thrust during the part of the flight that is claimed for the glide performance. With many types of internal combustion engines, this system has proved reliable since it was developed by Dr David Ellis, the previous owner of Cambridge Aero Instruments, in about 1994. Because it is all inside the sealed recorder, an ENL system is easier to deal with, compared, for instance, with microswitch-based or other systems requiring a sensor connection to the recorder. It is also superior to vibration-based systems because the recorder does not need any special mounting in the cockpit or OO checks before and after flight.

1. ENL System Design - General. An ENL system must be designed to differentiate between any engine running that generates forward thrust, and any flight condition encountered in normal soaring flight without such use of engine. The key word is "differentiate". The critical engine-on case with all motor gliders (in terms of "differentiating") is not when the engine is run at high power. Nor is the critical engine-off case a quiet glide with a well-sealed cockpit. These cases are expanded below.

2. High Engine Power. A combination of engine and propellor noise at high power are expected to give ENL figures over 800 out of the maximum ENL in the IGC file of 999. Most two-stroke systems give over 900 and some ENL systems give the maximum of 999. Four stroke and Wankel rotary engines give lower figures but still enough to differentiate between power-on and power-off. Electric engines at high power have also been shown to give reasonably high ENL (much is propellor noise), but high power is not the critical case in terms of differentiating between power-on and power-off flight, see 3.1 below.

3. Critical Noise-level Recording Cases

3.1 Power-on. The critical power-on case that is used for testing ENL differentiation is power for low-speed cruise, that is, just sufficient power for level flight in still air. At this condition, recorded ENL must be high enough to differentiate from the Power-Off cases below. A more critical condition is where engine could be used to extend glide angle rather than fly level or climb, but it is considered not practical to use this case in IGC tests because it is more difficult to test than the "level flight" case.

3.2 Power-off. The critical ENL power-off case is not a quiet, well-sealed cockpit. It is a noisy cockpit, typically thermalling with air vents and cockpit panels open. This can produce ENL figures up to 300, more if sideslip is present and 400 has been seen on some recorders. Another noisy case is high speed flight with the cockpit panel(s) open, but this is not as realistic as thermalling with panels open because in the latter case the glider will be climbing.

3.3 ENL numbers. The three ENL numbers as recorded in IGC files must therefore differentiate between the "quiet engine" and the "noisy cockpit" cases. This is done by carefully selecting the frequency and gain at which the ENL system is most sensitive. The ENL system is then tested by GFAC in a range of motor gliders, gliders and powered aircraft. Experience has shown that peak sensitivity at frequencies between about 70 and 100Hz gives good (high) response to engine and propeller noise and less response to cockpit noises.

4. Low noise Motor Gliders. Where the engine system produces low ENL values that are difficult to differentiate between power-on and power-off flight, an additional system shall be provided in the motor glider concerned that produces a signal that can be used in the IGC file as an indication of forward thrust generated by the engine system (the RPM three-letter code in the Technical Specification). This will be subject to GFAC evaluation and decision on the type of motor glider concerned.
