FAI Sporting Code

Section 2 – Annex 4

Requirements for Equipment used for Flight Validation

2018 Edition
Approved by the FAI General Aviation Commission (GAC)
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NOTE: The General Section and Section 2 combined make up the Complete Sporting Code for Powered Aerodynes: Aeroplanes, Jetlift Aircraft, Tilt-Wing/Tilt-Engine Aircraft and STOL Aircraft.

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1. Introduction

1.1 Reasons for implementation of these requirements are:

- to simplify methods of gathering and certifying flight data during competitions and
- to use more objective methods for measuring flight performance data during competitions.

With suitable equipment a maximum of availability, continuity, integrity, accuracy, and security in gathering and certifying flight data will be achieved.

By implementing flight recorder equipment the quantity of manpower necessary will decrease during FAI, GAC events.

1.2 FAI takes no responsibility for, and has no liability for, the use of equipment for other purposes such as navigation, airspace avoidance, terrain avoidance, or any matters concerning flight safety.

1.3 (*deleted 2007)*

1.4 (*deleted 2007)*

1.5 Equipment not yet approved has to go through testing by GAC experts before used in GAC events.

2. Glossary of Terms and Abbreviations

This expands the Glossary *in the main volume of Section 2 of the Sporting Code (SC2). This glossary contains more specialized terms concerned with equipment.*

Numerical

2D Position - A navigational position in terms of plan (horizontal) position (i.e. lat. and long.). In GNSS systems, at least three position lines (ie correct data from three satellites, that is valid fixes) are needed for a 2D positional fix.

3D Position - A navigational position in terms of plan position and altitude. In GNSS systems, at least four position lines (i.e. correct data from four satellites, that is valid fixes) are needed for a 3D fix.

4D Position - A navigational position in terms of plan position, altitude, and time. Since highly accurate time is an integral part of the principle of operation of the GNSS system, it is automatically available with every GNSS fix.

Alphabetical

ACIAS - availability, continuity, integrity, accuracy, and security eg of stored GNSS FR data

Aerial - As Antenna

Analysis - Authentication of flight data followed by the verification process.

Authentication - The process of determining whether data originated in a correct manner from a particular FR, or is a faithful copy of original data. Electronic flight data is authenticated by manufacturer's authentication software on a controlled PC such as by using the appropriate VALI.EXE file. The authentication software checks the Digital Signature which is on the file transferred from the FR, indicates that data originates from a particular FR, and has not been altered since initial transfer from the FR.

CEP - Circular Error Probable, normally to a 50% level of probability unless stated otherwise.

Constellation - The list of satellites used to determine the GNSS fix. This may be used to verify the validity of the recorded flight data, since individual satellites above the local radio horizon at any time can be predicted.

Controlled PC - A PC used for flight analysis which is free from influence by anyone who may have an interest in a result leading to verification of the flight. Used typically at an NAC and FAI. Access to a Controlled PC must be restricted to authorized persons.

Data Analyst - A person knowledgeable in analysis of electronic flight data and authorized by an NAC to carry out analysis on their behalf using a controlled PC.
Datum – The GNSS Geodatic Datum (qv). For GAC purposes, the WGS84 datum must be used.

Download - Not used in this document because of possible ambiguity. The word `Transfer' is used instead. The majority of manufacturers, and the avionics industry, use the term `Download'
to mean the transfer of data from an aircraft FR to a ground-based PC, but others use the term to mean the transfer of data from a PC to the FR.

Ellipsoid - A three-dimensional ellipse, the same as an oblate (flattened) spheroid. The term ellipsoid is preferred compared to spheroid or Geoid (qv) because it is mathematically unambiguous. An ellipsoid is the best simple mathematical model of the overall shape of the Earth and the currently accepted best simple overall earth model, WGS 84, is ellipsoid based, as are other geodetic datum's (qv).

EMI - Electromagnetic Interference. Interference with the working of equipment (hardware, software or firmware) due to Electromagnetic radiation external to the equipment. May be due to Radio Frequency (RF) radiation from radios in the aircraft itself, or from powerful RF sources outside the aircraft such as from radar and other equipment transmitting in the RF bands.

EPE - Estimated Position Error - An estimate by a GNSS receiver of the probability of position error in each fix, taking into account the geometry factors of DOP (qv below) with the addition of factors such as received signal strength. The probability used in the calculation should be stated so that the significance of the size of the resulting shape (frequently a circular error) is known. Commonly probabilities are calculated to a 95% (two-sigma) level, implying that there is a 95% chance that the true position is inside the shape concerned. The probability figure applies to a single fix in isolation and is increased by taking into account adjacent fixes and with knowledge of how aircraft are flown

DOP - Dilution of Precision - The reduction of precision in a GNSS fix due to the geometry of the constellation of satellites used for the fix. Computed by a GNSS receiver for each fix, see also EPE.

Fix - A sample which successfully records the parameters required for assessment is a fix. A sample is where the FR is set to record UTC, latitude, longitude, GNSS altitude, and any other variable required with each sample and specified by GAC. See 2D, 3D, 4D and the definitions below. A flight log consists of a series of fixes in time order.

Fix, Spurious - A GNSS fix with a significant error in time or three-dimensional position. Determined by analyzing the fix concerned and adjacent fixes; the spurious fix will generally show an anomalous position (a side-step in 2-D position or in altitude, or both) and involve an unlikely ground speed between it and adjacent correct fixes. It may or may not have a high EPE or DOP (see above). For flight analysis purposes spurious fixes must be rejected.

Fix, Valid. For GAC flight analysis purposes, a valid fix is a fix which successfully records the minimum parameters required for the analysis concerned, and is not assessed as Spurious (see above). For the purpose of assessing the geographical position shall be taken as the center of the coordinates of the fix, ignoring any error circles.

FR - Flight Recorder. In GAC terms, a device recording data for the purpose of flight validation to GAC/FAI criteria, such as a GNSS FR. A GNSS FR is a device capable of producing a Flight Log, and includes a GNSS receiver, and a memory storage device. It may also include other transducers.

GAC Approval, - Certain equipment is subject to a special approval process before it can be used in the verification process for flight performances before validation of the performance to GAC/FAI criteria. GNSS and associated Flight Recorders (FRs) are examples

GD - Geodetic Datum, see below

Geodetic Datum (GD) - When a mathematical model of the earth's shape is fixed at a particular orientation and position with respect to the Earth, it constitutes a so called `Geodetic Datum', over which a grid of latitude and longitude (or other geographic reference system) can be constructed. Many Geodetic Datum's are based on the shape of an ellipsoid; WGS 84 is an example. Having fixed a geodetic datum, normal map projection methods are then used to represent the three-dimensional earth model on a two-dimensional map.

Geoid - The shape of an assumed earth using a theoretical water surface (i.e. a surface completely at a theoretical sea level all over the earth, an equipotential surface) as it would be if only the gravity effect of terrain was present, and without external gravity (i.e. no spin, no tides). A geoid is therefore a smooth surface close to real mean sea level over the whole earth (WGS84 ellipsoid +60m-110m, the variation depending on gravity effects of mountains, trenches & crustal thickness and density). The exact geoid shape is complex and varies with locality. It is not used in GNSS calculations, but was used in the past in the selection of the ellipsoid (qv) which was the “best fit” for the region concerned. See also Ellipsoid and Spheroid.

GLONASS - Global Orbiting Navigation Satellite System (Russian GNSS)

GNSS - Global Navigation Satellite System. A generic term for specific systems such as the Russian GLONASS and the US GPS. It implies the use of equipment in the aircraft which receives signals from the relevant constellation of Navigational Satellites in earth orbit. Such equipment calculates time delays between signals from different satellites and, by knowing the exact position of the satellites and the exact time to great accuracy, together with an assumed mathematical model of the earth's shape (see Ellipsoid and Geodetic Datum) is able to calculate position information on the earth's surface in four dimensions (4-D, see above) through software programs. The US GPS system time does not allow for the so-called `leap seconds' which are occasionally used to change UTC/GMT to allow for the slowing down of the Earth's rotation. In 1997 GPS time was 12 seconds ahead of UTC/GMT, but most receivers automatically compensate and output UTC rather than GPS time, although some do not. Track records stored in some GPS units do not take leap seconds into account and output in GPS system time and not UTC, whereas NMEA data outputs generally include leap seconds and output as UTC.
GNSS equipment for the flight verification process includes the GNSS receiver and associated FR including the aerial (antenna), and all associated hardware such as the processing, data storage, cockpit display and keyboard modules. It also includes the associated software and firmware (Such as ROMs) both in the aircraft GNSS equipment and also where used for transferring data into and from the aircraft equipment from PCs. Software processing using PCs includes the analysis and presentation of flight

data, and may also include the preparation of data about, turn points, time zones, geodetic datum's, pilot information, and so forth; for transfer into the aircraft GNSS equipment, in accordance with the procedures in this code.

GNSS Altitude - The altitude above the ellipsoid datum set, calculated solely from GNSS position lines.

GPS - Global Positioning System, the US GNSS administered by the Departments of Defense and Transportation (DoD, DoT).

ISA - International Standard Atmosphere

Leap Second - see under UTC

OO ID - This is a OO's code which may (or may not) be entered into the FR prior to flight. Four alphanumeric characters should be provided for this purpose. It may be used to identify the individual flight on the recording, and provide an indication that subsequent data was not manufactured beforehand.

Pilot Event - The pilot records an event in time and space, generally by pressing an `event button' which takes an additional GNSS fix and marks the time as a pilot-recorded event. Has no significance in the flight verification process but may be useful to the pilot as a reminder of what happened at that time. May also be used to trigger a sequence of fixes at short time intervals (fast-fix facility).

Pressure Altitude - In a GNSS FR, this is a five numeric group indicating the pressure altitude in meters with respect to the International Standard Atmosphere (ISA) used in aviation. (Not mandatory for GAC competitions)

PROM - Programmable Read-only Memory

Proof Drive or Flight - A method of checking that a Flight Recorder produces a correct flight log. Under the control of an OO or official, the GNSS/FR is taken on a drive in a vehicle or on a flight in an aircraft, over a course with known co-ordinates. A proof drive in hilly terrain can be used to check appropriate altitude data from the FR, and a proof flight can check not only altitude data but other recorded data. A proof drive including an identifiable turn at a surveyed point can be used to check GNSS fix accuracy and is used during FR testing.

RF - Radio Frequency. eg RF radiation, RF Frequency Spectrum (eg HF, VHF, UHF etc), RF Interference (RFI), etc.

SBAS - Satellite-based augmentation system is a system that supports wide-area or regional augmentation through the use of additional satellite-broadcast messages. Such systems are commonly composed of multiple ground stations, located at accurately-surveyed points. The ground stations take measurements of one or more of the GNSS satellites, the satellite signals, or other environmental factors which may impact the signal received by the users. Using these measurements, information messages are created and sent to one or more satellites for broadcast to the end users.

Security - When used in the context of GNSS FRs, a security record in the flight file is used to verify that the flight data has not be altered during or since the flight. This security record contains a complex digital signature, the key to which is only known to the FR manufacturer. At the NAC, the flight file is interrogated by a VALIDATE file program (VALI.EXE) which originates from the FR manufacturer. This VALI program checks the security signature and other features in the flight file, and authenticates it as genuine and unaltered since being transferred from the FR. Detection of alteration or manufacture of data can also be helped by analyzing features which can be checked from other sources such as wind drift in thermals, pressure altitude and exact positions at takeoff and landing, satellite constellation (actual satellites used for fixes), etc.

Sigma - in statistics (probability theory), the Standard Deviation. Sigma (s) itself equating to a percentage probability of 68.3, 2-Sigma probability to 95.5%, and 3-Sigma probability to 99.7%.

Spheroid - A three-dimensional oblate (flattened) sphere in the form of a three dimensional ellipse (an ellipsoid). The term ellipsoid is preferred to spheroid because it is mathematically unambiguous, whereas `flattening' of a sphere could imply shapes other than an ellipse.

Spurious Fix - see under Fix

Track - The true track (continuous sequence of actual 2D positions) over the ground which the aircraft has achieved.

Upload - Not used in this document because of possible ambiguity, `Transfer' used instead. See Download

UTC - Universal Time Coordinated. Used to be called Greenwich Mean Time (GMT) and other than for astronomical purposes can be regarded as identical to GMT. The US GPS system time does not allow for the so-called `leap seconds' which are used to change UTC/GMT by a whole second at a time, to allow for the slowing down of the Earth's rotation. GPS time was UTC in 1980 when the system first became operational, and has steadily diverged. In 1997, GPS time was 12 seconds ahead of UTC/GMT. However, the GPS system keeps track of leap seconds corrections, and these are sent as part of the satellite's message to users. Most receivers use the GPS satellite message automatically to compensate and output UTC rather than GPS time, although some receivers do not. GAC requires data file times to be in UTC. The Russian GLONASS system changes its system time with every leap-second, but while system clocks are being reset, the system is off-line and not usable.

WGS 84. World Geodetic System 1984, the currently accepted best overall ellipsoidal mathematical model for the earth's shape and upon which all GAC GNSS fixes and calculations are based. The ellipsoid radii and orientation for WGS 84 are as follows:

Major Axis (the Equator), radius = 6378.1370 km

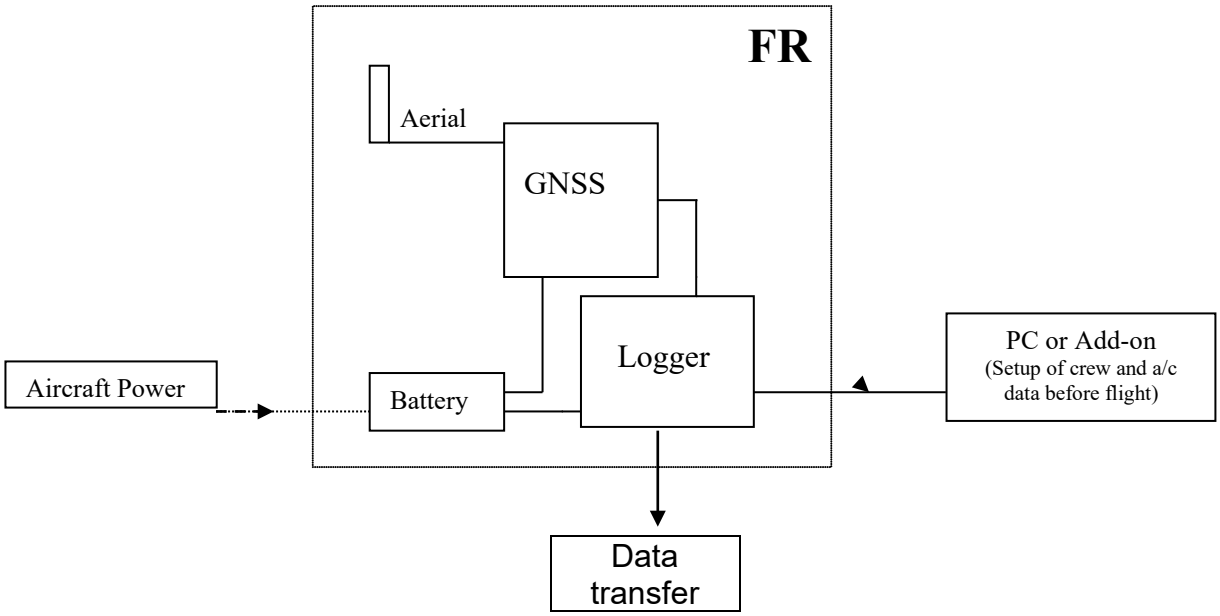
Minor Axis, (Polar) radius=6356.7523 km

Orientation The minor axis is between the Geographic Poles

3. Requirements

3.1 Flight Recorder

The Flight Recorder is composed of four components : GNSS antenna, GNSS receiver, logger, power supply. These elements may be joined together into one unit.



3.2 Technical requirements for the Flight Recorder used in GAC competitions

	Minimum requirement	Recommended
GNSS receiver	8 channel (parallel)	12 channel (parallel)
GNSS antenna	passive	active
Logger recording interval	1/sec	1/sec
Storage capacity of logger (at 1/sec)	3 h	5 h
Power supply	aircraft power	batteries

3.3 Technical requirements for Flight Recorder used in GAC **record trials.**

Detailed requirements for record trials are presently in the process of being drafted.
The final version of the record trials requirements will form a new Annex. Until the new Annex becomes effective the following guidance may be used:

Depending on the accuracy required during record attempts (see Section 2, paragraph 4.4) more specialized Flight Recorder may have to be used. GAC is authorizing the use of GNSS-FR in record attempts as long as

- the equipment meets or exceeds the requirements set up for FR's certified for GAC competitions,
- the NAC responsible for the record attempt forwards a detailed report of the GNSS-FR and the procedures used in the record attempt to GAC (including a performance report of the GNSS-FR from the FR producer or an independent source).

Examples of B record and I record data formats for fix intervals less than 1 second can be found in Attachment 2.

3.4 Dimension of recorded/presented data:

Time recorded will be UTC time, HH MM SS (not satellite time nor the internal clock of the logger).
Co-ordinates will be recorded to 1/1000 of a minute (i.e.: 49° 23,934' N) in WGS84 geodetic system.
GNSS altitude will be recorded in feet[ft].
Speed data will be in 1/10 of a knot (i.e.: 75,3 kts)

3.5 Requirements on displayed information's and handling of the FR.

The Flight Recorder (FR) may indicate to the pilot/crew through visual or oral signals only information to support the operation of the FR (NOT FOR THE OPERATION OF THE AIRCRAFT), i.e.:

- On/off indication,
- indication of correct or incorrect operation of data gathering and recording,
- indication of "low battery" condition,
- indication of "low storage capacity" of the FR,
- indication when event marker is activated,
- other information necessary for the operation of the FR.

The FR must not present any navigation information to the pilot/crew
(i.e.: course, position, ground speed, altitude etc.).

3.6 Standardized data format.

The FR data file that any GAC organizer is using in evaluating an event must be in conformity with the standard IGC format defined in Technical specification for IGC approved GNSS Flight Recorder.

In addition the following information must be available:

- Groundspeed in 1/10 kts
- Track in degree

In addition the following information may be added (see example of format below)

- EPE (Estimated Position Error)

Example of extended format (I Record):

See Technical specification for IGC approved GNSS Flight Recorder–Appendix 1-Paragraphs 3.4, 4.1 and 7

I033639GSP4042TRT4346FXA

I	: I Record -Fix extensions (define the extension of the mandatory fix B record)	
03	: Number of extensions	
36	: Start byte number for GSP	Ground Speed between character 36 to 39
39	: Finish byte number for GSP	
GSP	: Ground Speed	
40	: Start byte number for TRT	True Track between character 40 to 42
42	: Finish byte number for TRT	
TRT	: Track true	
43	: Start byte number for FXA	Estimate of fix accuracy between character 43 to 46
46	: Finish byte number for FXA	
FXA	: Estimate of fix accuracy in metres	

Example of data format (B Record):

B1601114816962N00700724EA0031000370075323300 12

Standard	B	: B Record - Fix
	160111	: Time in HH MM SS = 16:01:11 [UTC]
	4816962N	: Latitude = 48°16.962'N
	00700724E	: Longitude = 007°00.724'E
	A	: Valid data, (V = invalid data)
	00310	: Pressure Altitude = 310 m. If an optional barographic sensor is used, if no barographic sensor is used the value indicated should be 99999
	00370	: GNSS altitude in feet = 370 ft
Append	0753	: Ground Speed in 1/10 of knots = 75,3 kt
	233	: True track in degree = 233°
	0012	: Estimate of fix accuracy = 12 m (optional, if not available the value indicated should be 9999)

Note: If the FR-data must be converted to this format the conversion-software must be approved by GAC together with the FR

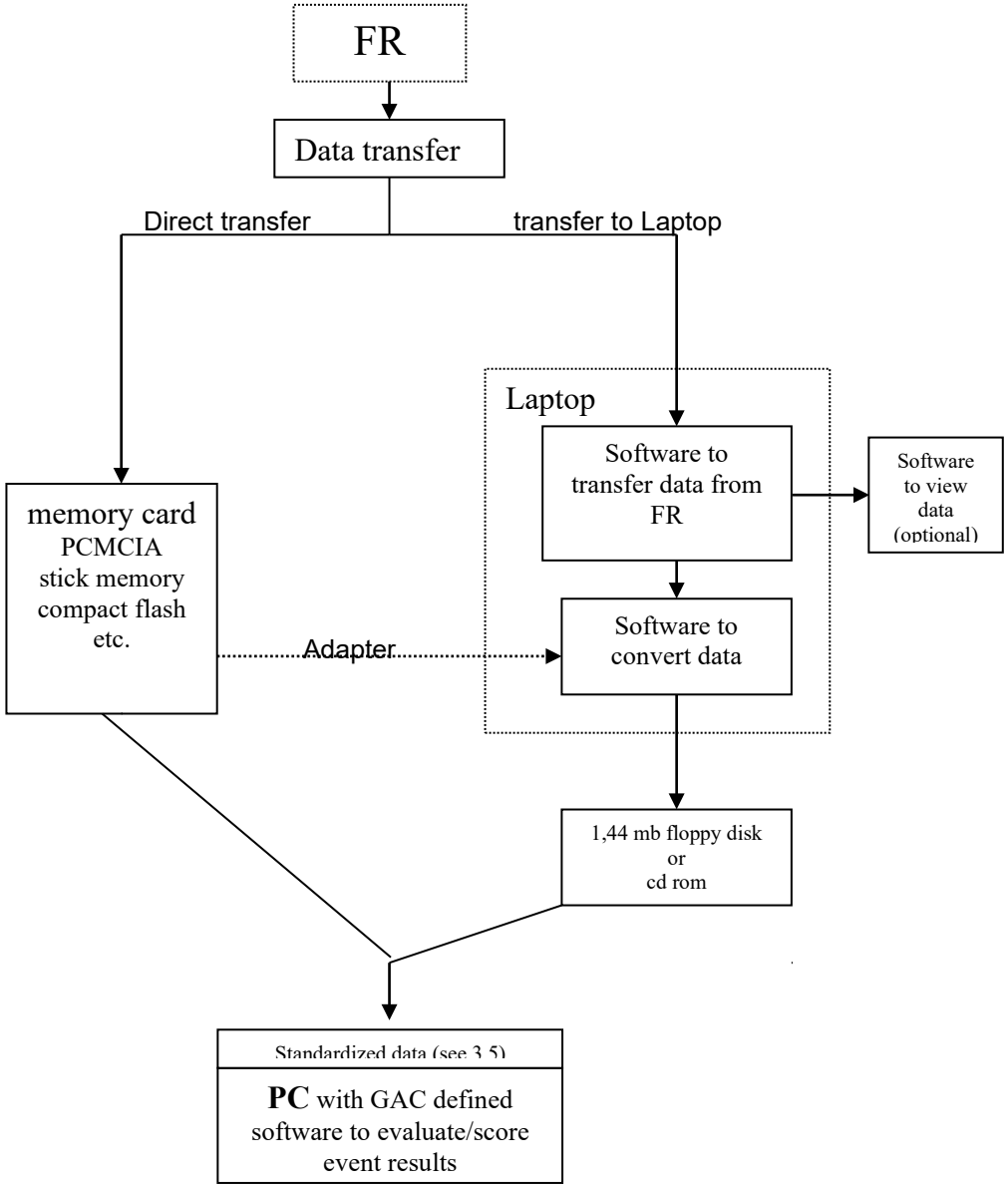
As an additional format the open GPX format is approved from the GAC. The example and description for the GPX format is published on following internet link:
https://en.wikipedia.org/wiki/GPS_Exchange_Format
All other requirements are not affected.

3.7 Data transfer requirement

The data gathered with the FR must be made available in a format as prescribed under 3.5 on memory card (PCMCIA, stick memory, compact flash or similar), 1,44MB Floppy Disk or CD-ROM for further analysis and presentation in relation to GAC Rules and Regulations.

3.8 Possible data transfer from FR to evaluation/scoring PC

The following diagram suggests a solution for data transfer from the FR to a PC the Organizer of GAC event is using for analysis, presentation, evaluation and scoring of an event.



4. Testing of equipment

4.1 Flight recorders with integrated GNSS need approval from GAC authorities before using them in GAC events.

4.2 Test requirements

4.2.1 Test of conformity
Check that FR meets requirements set up under 3.2 and 3.4 to 3.8.

4.2.2 Reliability test
Recording of GNSS data with a FR and a PC from a fixed station for a specified number of hours. After data transfer the two files must not deviate by more than 1%.

4.2.3 Timing test
Recorded times will be checked at specific points for deviations of less than 0.5 sec.

4.2.4 *(deleted 2007)*

4.2.5 GAC experts performing the above mentioned required test have to document the results in a written report.

4.3 A list of GAC approved FR's will be published in Attachment 1 to this document.

Attachment 1

GAC-Approvals for GNSS Flight Recorders

The following Flight Recorder (FR) are approved in accordance with Sporting Code, Section 2, Annex 4 for the use during GAC precision and rally events.

GNSS	FR Producer	email	Web
AFLOS	BeHeTec GmbH & Co. KG	AFLOS@BeHeTec.com	http://www.AFLOS.com
Air Observer	Tilt-Tech cc	sales@tilt-tech.co.za	http://www.tilt-tech.co.za/airObserver.html
Air Observer Mini Logger			
Air Observer Micro Logger			
FFA Skytraq Version 6	Canmore Electronics Co. Ltd. GT-730FL-S	n/a	https://doc-track-analyzer.openflyers.com/Help-FFA-SkyTraq-V6
FS-Logger	Icarosystems	info@icarosystems.com	https://sites.google.com/site/icarosystems2/
FR-Pocket (DG100)	Icarosystems	info@icarosystems.com	
	GlobalSat company	http://www.globalsat.com.tw/contact.php	www.globalsat.com.tw
FR-Pocket (DG200)	GlobalSat company	http://www.globalsat.com.tw/contact.php	www.globalsat.com.tw
GeoTracker	C&N GIS/GPS-Technology	gps@c-n.at	http://www.c-n.at/pr_gps.php
TinyBrother GPS			

Attachment 2

GNSS Flight Recorders for use during GAC record attempts

Example of extended format (I record) for flight recorders used in GAC record attempts:

I043637TMX3840LAX4143LOX4447FXA

I	:I Record
04	:Number Of Extensions
36	:Start Byte Number For Time Extension (TMX)
37	:Finish Byte Number For Time Extension
TMX	:Time Extension
38	:Start Byte Number For Latitude Extension (LAX)
40	:Finish Byte Number For Latitude Extension
LAX	:Latitude Extension
41	:Start Byte Number For Longitude Extension (LOX)
43	:Finish Byte Number For Longitude Extension
LOX	:Longitude Extension
44	:Start Byte Number For Fix Accuracy (FXA)
47	:Finish Byte Number For Fix Accuracy
FXA	:Estimate Of Fix Accuracy In Meters

Example of data format (B record) for flight recorders used in GAC record attempts:

B1601114816962N00700724EA0031000370051234560012

B	:B Record - Fix
160111	:Time In HHMMSS
4816962n	:Latitude = 48 Degrees 16.962 Minutes North
00700724e	:Longitude = 007 Degrees 00.724 Minutes East
A	:Valid Data (V = Invalid Data)
00310	:Pressure Altitude = 310 M
00370	:GNSS Altitude In Feet = 370 Ft.
05	:Time Extension Of 0.05 Seconds Time = 16 Hrs 01 Min 11.05 Sec
123	:Latitude Decimal Minutes Extension Latitude = 48.16.962123N
456	:Longitude Decimal Minutes Extension Longitude = 007.00.724456E
0012	:FXA - Estimate Of Fix Accuracy