

**Triangle definition, minimum measurement
and assessment requirements for GPS-
Triangle competition navigation systems**

**Version: 1.7b
15.05.2019**

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2. Version History

Version	Date	Origin	Content / Changes
0.1	24.11.2016	Stefan Müller	Brainstorming list
0.2	26.06.2017	Stefan Müller	Added measurement and assessment requirements, improved description
0.3	25.07.2017	Stefan Müller	Added sketches for Triangle, added safety zones, more precise definitions
0.4	15.09.2017	Stefan Müller	Added sketch for Distances, updated Measurements chapter, added DataLogging, Scoring and File description chapters
0.5	13.10.2017	Stefan Müller	Improved description for distance calculation, added file descriptions
0.6	28.10.2017	Stefan Müller	Average speed resolution changed to 0.1km/h, there was bug in mind during calculation of necessary resolution
0.7	18.03.2018	Stefan Müller	Added Start Speed and Start Altitude assessment definitions, improved distances calculation description, added landing, added sketch for LAT, LON distance calculations, updated symbols and list of abbreviations and symbols, improved file descriptions, extended scoring chapter
0.8	22.03.2018	Stefan Müller	Added preamble, improved logging requirements, added data types and description for log values
0.9	01.04.2018	Stefan Müller	Added rounding rules, improved filename description for Taskfile, precised ASCI/UTF8 coding rules, precised speed and altitude measurement and logging, crossing start line status change information, added maximum flight and assessments area, data storage as hex (partwise still missing), User data storage precised
1.0	11.04.2018	Stefan Müller	More detailed sketches for triangle definition and observation areas, data storage completed, adapted list of datatypes for task and log, CRC calculation and logfile example partwise not yet finished
1.1	28.09.2018	Stefan Müller	Finalized all remaining issues beside min Altitude vs min speed as finish line requirement to finalize document. This version will be edited by Andrej Vrečer to have IGC Format with some small extensions to adopt our requirements for the competition and assessment.
1.2	23.10.2018	Andrej Vrečer	Small comments on format, integrated IGC description, <CR><LF> for TaskFile, only ASCII allowed
1.3	29.10.2018	Stefan Müller	Updated scoring for 200 points in last round according to average speed, started to precise IGC Format
1.4	29.11.2018	Stefan Müller	Fully integrated log file description, file integrity, fixed all open issues, done formatting of document. Version will be double checked and released as 2.0
1.5	07.12.2018	Stefan Müller	Integrated minor corrections from Andrej, Pilot ID equals Nickname of GPS Triangle webpage
1.6	10.12.2018	Stefan Müller	Integrated minor changes of Andrej, PEV instead of ARM

			Event, TPC instead of TPx to follow IGC standards, precisely defined barometric altitude referencing and 3d speed calculations. Added minimum log time of 1 minute prior to start
1.7	09.01.2019	Stefan Müller	Integrated chapter Data exchange with assessment systems, is complete besides answer from webservice in case of failures
1.7b	15.05.2019	Stefan Müller	Precise formula for penalty point in case of altitude and speed violation

3. Preamble

This document shall give a physical description of the GPS triangle competition task. It also defines all the parameters and the necessary measurements for a navigation system used on GPS Triangle competitions.

The Navigation system shall record the flight path of the airplane as precise as possible to allow fair assessment with equal opportunities for every competitor. This document also describes the data exchange between Navigation System and Competition Office.

The navigation system shall give the pilot confidence about the flight attitude of the airplane. Therefore it supports him on navigation around the course and performing his challenge on the competition.

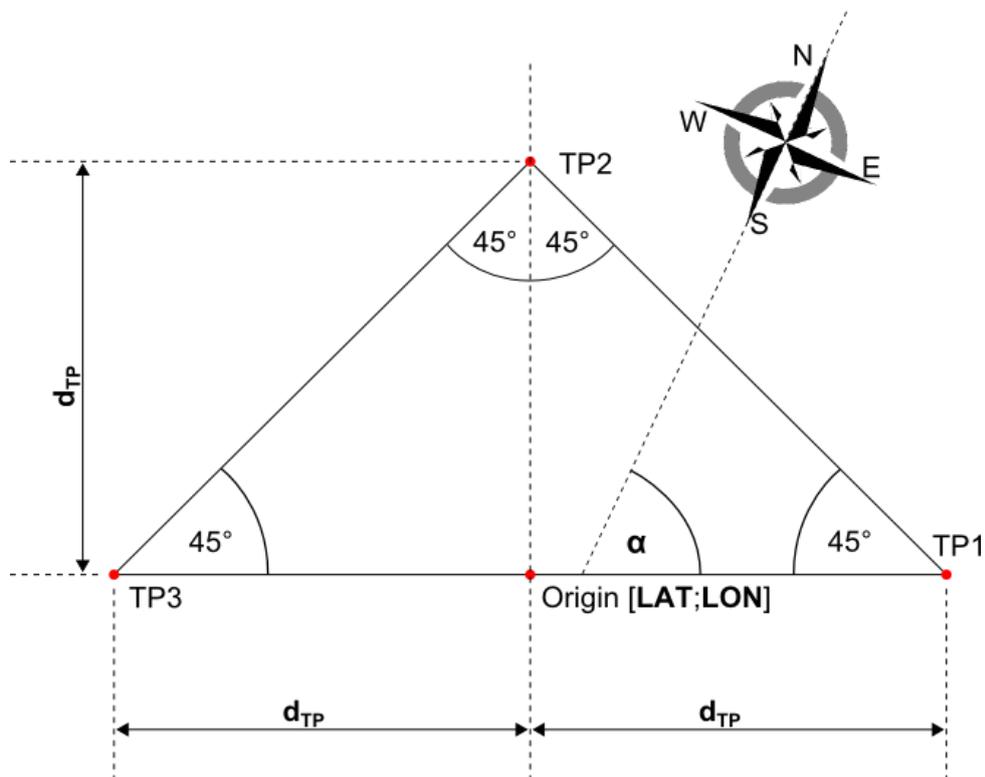
The navigation system shall not directly influence the flight attitude of the airplane in a way to perform autopilot or automatic flight path control capabilities.

4. Definition of Triangle Course

All definitions are only valid inside the maximum flight and assessments area which has a radius of 2km around the origin of the triangle

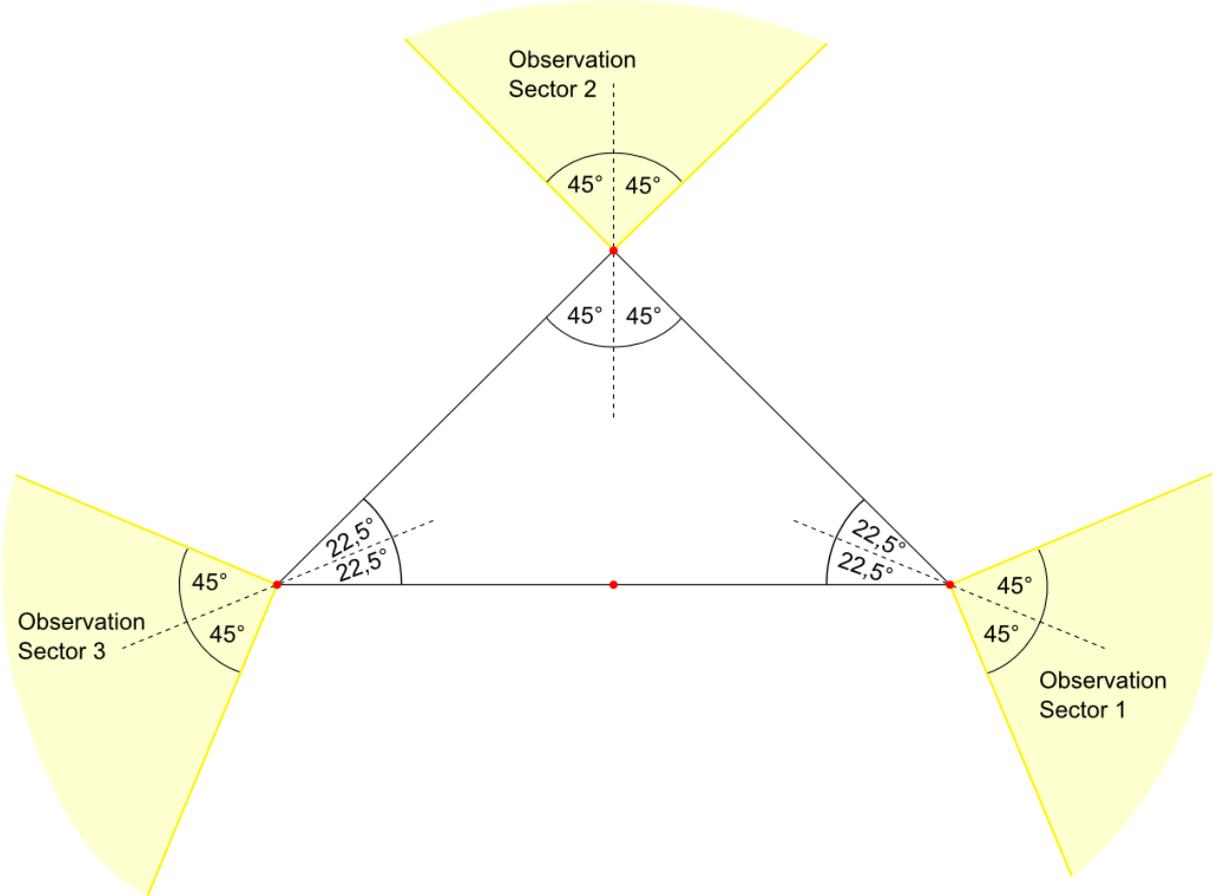
The triangle is defined by:

- Isosceles right triangle
- The 3 vertexes are the turnpoints TP1, TP2 and TP3 of the flight task
- The parameters of the triangle are given by the flight task, these are:
 - Origin in the middle of hypotenuse given by GPS coordinates **LAT** and **LON**
 - Distance from origin to vertexes **d_{TP}**
 - Angle between hypotenuse and north direction **α**



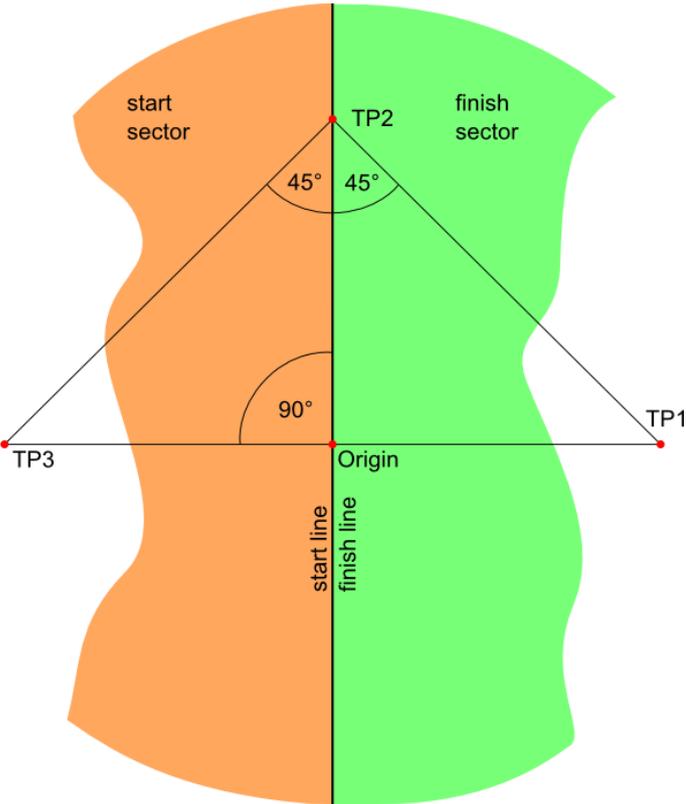
The observation sector for each turnpoint is defined by:

- A quadrant of airspace having its apex at the turnpoint
- Bisecting line of observation sector equals bisecting line of triangle legs
- The observation sector does not exceed the maximum flight and assessments area and therefore has a 1.5km radius



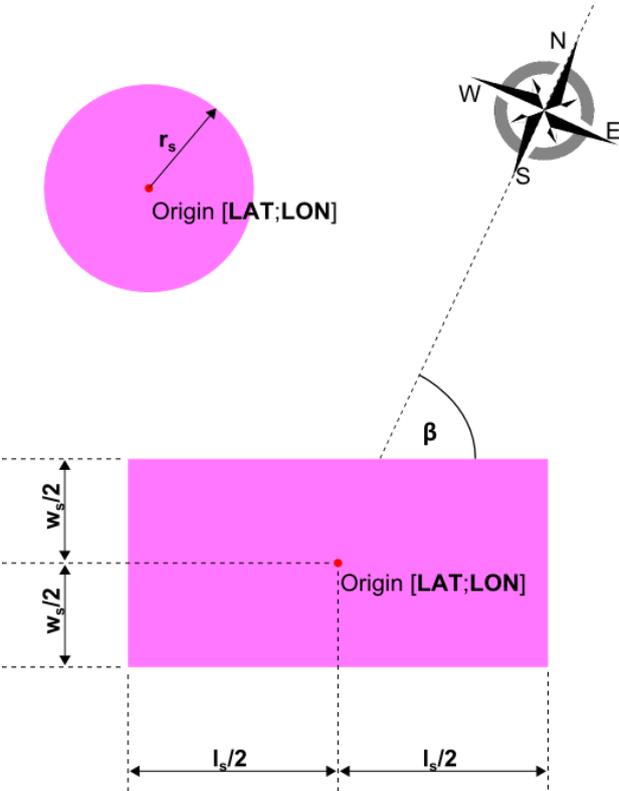
The start and finish observation sector is defined by:

- A start and finish line dividing the airspace with the origin being part of the line and the line being perpendicular to hypotenuse of triangle
- The length is limited by the maximum flight and assessments area and therefore has a length of 4km – 2km each side
- The area from the line towards TP3 is defined as start sector
- The area from the line towards TP1 is defined as finish sector



The observation area for a safety zone is defined by:

- A limited area of airspace, either an circle or an rectangle
- The parameters of a safety zone are given by the flight task, these are:
 - Origin in the middle of the zone given by GPS coordinates **LAT** and **LON**
 - Size by radius r_s or length l_s and with w_s
 - Angle between length and north direction β
 - Bottom altitude limit a_b
 - Top altitude limit a_t
- There may be up to 5 safety zones coexisting



5. Assessment

Begin of flight is detected as:

- The 3D speed is more than 20km/h
- At the same time the altitude is bigger than 20m above airfield elevation

Crossing start line:

- Moving the airplane across the start line in the direction to turnpoint 1 and therefore leaving start sector
- The start time, the start speed and the start altitude are taken from the last measured set of GPS data inside start sector
- The maximum start speed and the maximum start altitude are defined by the flight task
- Crossing start line is only valid:
 - in a defined time slot provided by the competition office called start time slot
 - The pilot has initiated his navigation system in an “ARMED” state to point out that the cross of start line is intended
- Valid cross of start line is the only event that changes the state of the navigation system from “ARMED” to “STARTED” state
- The user shall get a notification of the status change. This confirms the data use for assessment

Reaching a turnpoint:

- A turnpoint is reached as soon as one set of GPS coordinates is measured inside its observation area
- Reaching a turnpoint is only valid if:
 - difference in time between start time and finish time is less or equal to working time defined by the flight task
 - The previous turnpoint was reached
 - In case of turnpoint 1 the start line was crossed before
 - The state of the navigation system is “STARTED”

Crossing finish line:

- Moving the airplane across the finish line from the direction of turnpoint 3 and therefore reaching finish sector
- The finish time and the finish altitude are taken from the first measured set of GPS data inside finish sector
- Crossing finish line is only valid if
 - difference in time between start time and finish time is less or equal to working time defined by the flight task
 - turnpoint 3 was reached before
 - The state of the navigation system is "STARTED"
 - The measured speed is greater than minimum speed for crossing finish line

One triangle is completed by:

- Crossing start line
- Then reaching the turnpoints in order 1,2,3
- Then crossing finish line

Flight time:

- Time between start time and last completion of a triangle

Average speed:

- The average speed is calculated by the flight time and the minimum necessary distance to complete the number of flown triangles.
- Average speed equals number of completed triangles (**n**) multiplied by perimeter (**p**) of triangle divided by flighttime (**t**)

Entering a safety zone:

- A safety zone is entered as soon as one set of GPS coordinates and altitude is measured inside its observation area
- The Navigation System should inform the Pilot but not cancel the flight instantly as jumping GPS Position may rarely lead to wrong detection.

End of flight is detected as:

- The altitude is below 20m and at the same time
- for more than 5 seconds the 3D speed is uninterrupted less than 5km/h

The navigation system changes from “STARTED” to “STOPPED” state by:

- End of flight detection or
- Expiration of working time or
- User intention i.e. by clicking a button

6. Measurements

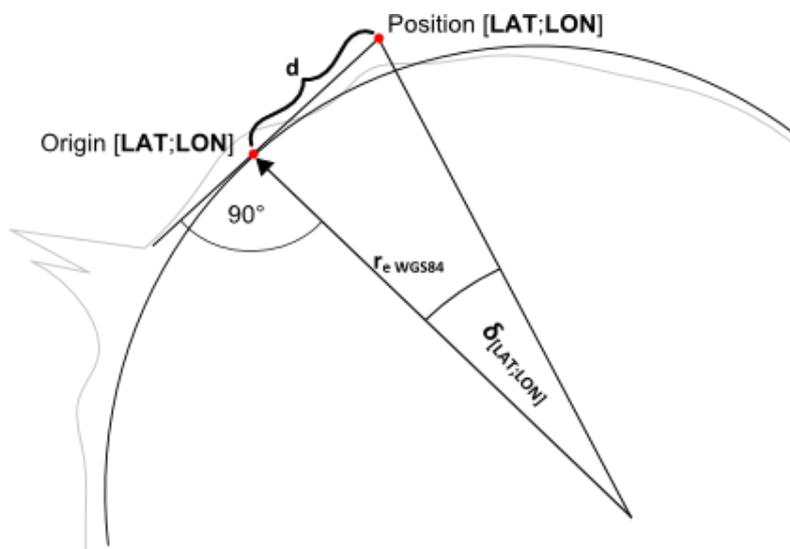
- All measurements shall have a minimum update rate of 4Hz
- Any applied filters for measured values shall not cause a response time greater than 0.5 seconds to change of flight attitude
- The GPS receiver shall be used in a mode without position forecast algorithms
- The GPS position shall only be declared as valid:
 - As soon as 5 or more satellite signals are available and in use and
 - The GPS receiver reports a 3D fix
- Position accuracy shall not be increased by interpolation between GPS coordinates
- Any measurement inaccuracy shall always be to the disadvantage of the pilot
- Any rounding shall be based on mathematical rules

GPS coordinates:

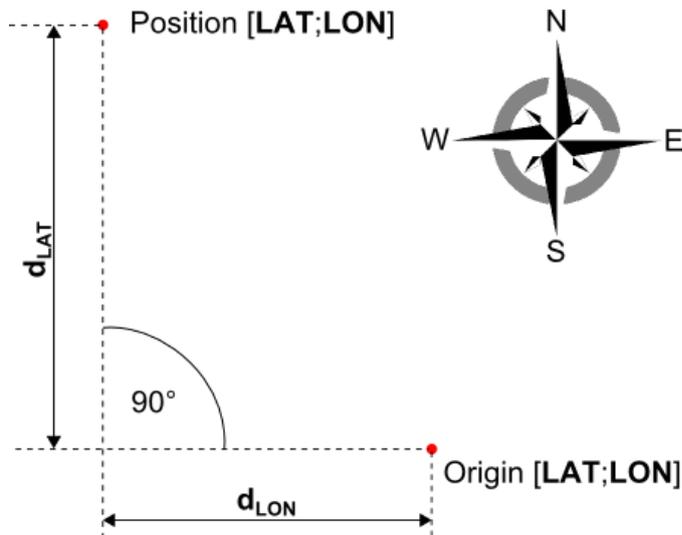
- All GPS coordinates shall be based on the WGS84 ellipsoid model
- The used resolution on all calculations shall be decimal degrees with 6 decimal places [0.000001°]

Distances:

- The calculation of distances in meter shall be performed by projection. Therefore a tangential plane is put to the origin of the triangle
- As distance to center of earth, and therefore the length of the projection, the earth radius given by WGS84 ellipsoid model shall be used



- Due to the coordinate system the distance in east-west direction is not constant for a given δ_{LON} angle on different latitudes.
- Distance for latitude and longitude are calculated separately and correct the difference in Longitudinal distance by $\cos(\text{Latitude})$ factor
 - $d_{LAT} = r_{e\ WGS84} \cdot \tan(\delta_{LAT})$
 - $d_{LON} = r_{e\ WGS84} \cdot \tan(\delta_{LON}) \cdot \cos(\text{LAT}_{Origin})$



- The used resolution on all calculations shall be full meter [1m] rounded on mathematical rules

Altitude:

- The measured GPS Altitude of the airplane shall be based on EGM96 Geoid Model delivering all altitudes above mean sea level MSL
- The Altitude shown and used in calculations shall be measured relative to the elevation of the airfield e given by the flight task
- Any additional measurement method to improve the accuracy and performance of altitude information is allowed. The recorded value shall be stored to the IGC file. At the time being the GPS Altitude is the only altitude source for assessment.
- In case a barometric sensor is used to improve altitude information any pressure change due to speed, motor use or any other reason not related to altitude shall not lead to a constant measurement error in altitude

- The initial value of barometric altitude shall be set with a reference GPS altitude taken at the startup of the system. The reference GPS altitude shall fulfill at least the following criteria:
 - It is an average value of at least 15 seconds
 - During the time of measurement the GPS receiver reported uninterrupted 3D fix
 - During the time of measurement the GPS altitude change is 5m or less
 - During the time of measurement barometric altitude change is as well 5m or less
 - During the time of measurement the 3D speed is maximum 6 km/h
- The used resolution on data output shall be full meter [1m] rounded on mathematical rules

Speed:

- Speed shall always be measured in 3D relative to ground. This means that the velocity in Latitude, Longitude and Altitude shall be used for the speed.
- For best accuracy it is recommended to use the 3D speed value delivered by the GPS receiver based on Doppler effect/frequency shift
- If the GPS receiver does only deliver 2D speed based on Doppler effect/frequency shift, it is recommended to use this value and add the vertical speed (altitude difference over time) by vector addition. The vertical speed shall be taken from barometric Altitude as the lag of GPS altitude would cause seriously wrong 3D speed
- The used resolution on all calculations shall be full kilometers per hour [1km/h]

Time:

- Time base is always UTC
- Time for every GPS Frame shall be measured with 1/100 seconds resolution[hh:mm:ss.01]

Average speed:

- The average speed is calculated by the flight time and the minimum necessary distance to complete the number of flown triangles.
- The perimeter of the triangle is calculated by: $p = 2d_{TP}(1 + \sqrt{2})$
- Average Speed is calculated: $v = \frac{np}{t}$
- The used resolution for average speed shall be 1/10 kilometers per hour [0.1km/h]

7. Scoring

The assessment and scoring will be performed by the competition office based on the recorded GPS data from the log file.

For every completed triangle beside the last triangle a pilot gets 200 points. The pilot with the highest average speed in a group of pilots with equal number of triangles gets full 200 points for the last triangle as well. The others get less points for the last triangle proportional to their average speed.

$$\text{last triangle points}_{pilot} = 200 * \frac{v_{pilot}}{v_{fastest pilot}}$$

To give the pilot confidence about his flight path, the navigation system should provide basic information about scoring. Besides the course around the triangle the following parameters are relevant:

Maximum entry altitude:

- The maximum allowed altitude for crossing start line is defined by the flight task
- In case the measured altitude exceeds this value the pilot will get penalty points according to this formula: ***penalty = 50 + (measured altitude – altitude limit) · 2***
- In case the measured altitude and the measured speed as well exceeds the limit, the 50 penalty points offset will be applied only once and the formula will be used like this: ***penalty = 50 + (measured altitude – altitude limit) · 2 + (measured speed – speed limit) · 2***

Maximum entry speed:

- The maximum allowed speed for crossing start line is defined by the flight task
- In case the measured speed exceeds this value the pilot will get penalty points according to this formula: ***penalty = 50 + (measured speed – speed limit) · 2***
- In case the measured altitude and the measured speed as well exceeds the limit, the 50 penalty points offset will be applied only once and the formula will be used like this: ***penalty = 50 + (measured altitude – altitude limit) · 2 + (measured speed – speed limit) · 2***

Safety zones:

- In case a safety zone is entered this flight will be scored as zero by competition office

Minimum finish speed:

- The minimum 3D speed for crossing finish line is defined by the flight task
- In case the measured value is less, the line cross will not be valid as it is assumed the airplane was not in flight condition

8. Data Logging

Scope of data logging:

Any system shall be capable to generate a file that contains the received GPS data during the flight.

Furthermore it should be capable to read any of these files and replay the flight data.

In case of reading an existing logfile the system shall show all data like it is, similar to live data provided by GPS receiver.

It must not be possible to generate a new logfile out of the old data.

In any case the assessment on a GPS Triangle competition is done by post processing of the recorded GPS data in the competition office.

Furthermore the information stored in the logfile can be used for easy comparison and universal use also apart from competitions.

Requirements for data logging:

- All data shall be logged with a update rate of 1Hz
- Furthermore any data that is used for assessment shall be logged. Therefore the logging rate can be increased to improve precision. To keep the size of the file small, this shall only be done on parts of the logfile like crossing line and reaching turnpoint.
- The logging shall begin minimum 1 minute prior to start of airplane
- The logging shall continue uninterrupted until detection of landing
- The logging is therefore not controllable by the pilot
- All calculated data used for navigation, i.e. referencing of the barometric sensor, shall be based on data that are visible in the logfile
- In case of interruption of logging due to system failures the system should continue to write the file as soon as possible
- In case of invalid GPS data or loss of 3D fix (see chapter 6Measurements) the system should write the frame with the last valid position, mark its status as invalid but continue to write time and any further information that is properly available

9. Data Exchange with Assessment Systems

Scope of Data Exchange to Assessment Systems

Data Exchange is used on the competition for assessment of flight results or for comparison of flights via online platforms. The Flight Track is sent to a central assessment system that handles the data. To send data the systems uses the http protocol.

Local competition office (on site assessment)

For local assessment the competition office provides a WiFi Network connection. This WiFi Network will be used for all data transfers.

As a backup solution and to keep compliance with some old systems it is still possible to hand in data from a written score card or transfer flight data via Flash Media like USB Stick or Micro SD Card.

Online Assessment platform Soaring League

For online assessment the data can be sent to soaring league homepage on route www.soaringleague.com/bla

Results Transmission (not used for new developments and only available for on site assessment):

Minimum Information Set

Key	Type	Description	Example
pilot	string	GPS Triangle nickname of pilot.	"pilot" : "pkolb"
triangles	integer	Number of completed triangles.	„triangles“ : 5
averageSpeed	double	Average speed of entire task in km/h.	"averageSpeed" : 37.9
startTime	string	UTC time when crossing start line at the beginning of the task.	"startTime" : "2017-09-16T05:38:00.000Z"
penaltyPoints	integer	Calculated penalty points of task.	"penaltyPoints" : 100
penaltyAreaEntered	boolean	Specifies whether a penalty area was entered or not.	"penaltyAreaEntered" : false
checkCode	string	Checkcode of calculated values.	"checkCode" : "034456"

Additional Information Set

Key	Type	Description	Example
startSpeed	double	Speed (in km/h) when crossing start line at the beginning of the task.	"startSpeed" : 115.2
startAltitude	double	Altitude (in m) when crossing start line at the beginning of the task.	"startAltitude" : 478.7

- **RESTful API to upload a flight result:**

HTTP-Method: POST
URL: http://\$BASE_URI\$/result
Headers: Content-Type : application/json
 Authorization : Bearer \$TOKEN\$

- **\$TOKEN\$**

eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJyb2xlIjoibmF2aWFwcCJ9.FueKy0nnZ-i701Z04PFSy2-FJdW668Z7CDO3yadLCjE

- **\$BASE_URL\$**

Must be configurable by the user.
Example: http://192.168.1.1

- **Example content (minimum):**

```
{  
  "pilot" : "pkolb",  
  "triangles" : 5,  
  "startTime" : "2017-09-16T05:38:00.000Z",  
  "averageSpeed" : 37.9,  
  "penaltyPoints" : 222,  
  "penaltyAreaEntered" : false,  
  "checkCode" : "123456"  
}
```

Flight Track Transmission:

Using a standard HTTP file upload approach. Upload XML-based log file and wait for evaluation.
This is NOT implemented yet!

- **RESTful API to upload a flight result**

HTTP-Method:	POST
URL:	http://\$BASE_URI\$/logfile
Headers:	Content-Type : multipart/form-data Authorization : Bearer \$TOKEN\$

- **\$TOKEN\$**

eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJybnR5IjoibmF2aWFwcCJ9.FueKy0nnZ-i701Z04PFSy2-FJdW668Z7CDO3yadLCjE

- **\$BASE_URL\$**

Must be configurable by the user. Example: http://192.168.1.1

Task Information Transmission

TBD

Maybe there will be a unique file for every pilot with a delivery check, ideas are in progress

TBD

basics:

- The file is a text file based on ASCII code
- The name of the file shall not be relevant for processing but help the pilot to identify the file
- The name of the flight task is content of the file line "T"
- The file extension shall be **.rct** => "filename.rct"
- In case task information is provided for each group, the filename will contain round and group information at first, followed by underscore and name: "RG_name.rct"

10. Task File Description

File basics:

- The file is a text file based on ASCII code
- The name of the file shall not be relevant for processing but help the pilot to identify the file
- The name of the flight task is content of the file line "T"
- The file extension shall be **.rct** => "filename.rct"
- In case task information is provided for each group, the filename will contain round and group information at first, followed by underscore and name: "RG_name.rct"

File structure:

- The file content is line based, each line starts with an line identifier:
 - V: version number
 - T: triangle information for flight task
 - R: rectangular safety zone information for flight task
 - C: circular safety zone information for flight task
 - S: start time slot information
 - G: group information for competition
- There is only one line for "T" information
- There may be up to 5 lines for "R" and "C" information
- The identifier is followed by comma separated information
- The name in line "T" is the name of the flight task
- Each line ends with <CR><LF>

Document Version Number:

- Document version is used for identification and to avoid incompatibilities
- Document version used in the taskfile defines the minimum required status for the navigation system
- Latest version should always be implemented to the navigation system as soon as possible
- The document version, used as requirement for the development of the navigation system, shall also be written to the logfile (see chapter 11Log File Description)
- Latest version is published with this document
- Latest version is V:02.0

Triangle information:

- LineIdentifier:Name,LAT,LON,AirfieldElevation,Direction,Distance,MaxEntryAltitude,MaxEntrySpeed,MinFinishAltitude,WorkingTime<CR><LF>
- T:TestTriangle,48.170692,7.682934,324,136,500,500,120,20,30<CR><LF>

Safety zone information:

- Up to 5 safety zones may be coexisting
- LineIdentifier:Name,LAT,LON,Direction,Length,Width,LowerLimit,UpperLimit<CR><LF>
- R:RectangularZone1,48.170692,7.682934,25,100,30,0,100<CR><LF>
- LineIdentifier:Name,LAT,LON,Radius,LowerLimit,UpperLimit<CR><LF>
- C:CircularZone1,48.170692,7.682934,200,1000,5000<CR><LF>

Start time slot information:

- The start time slot is given in ISO8601 format: YYYY-MM-DDThh:mmPmm
- The base time defines the first minute of allowed crossing start line
- The minutes after the P separator define the time slot length
- LineIdentifier:TimeSlot <CR><LF>
- S:2017-06-17T10:08P12<CR><LF>

Group information:

- LineIdentifier:RoundNumber,GroupLetter,Pilot1ID,Pilot2ID,....,PilotnID <CR><LF>
- G:3,B,LoopingLuis,Otto,Sir_Piper,Thermal_Timo,Landing Luke,Mike1976,Clara<CR><LF>

Data types, range and precision:

Name	Range	Datatype	Unit	Info
Name	32 characters	string	ASCII	
Latitude	[-90°;90°]	signed integer, 6 decimal places	degree	+ North, - South
Longitude	[-180°;180°]	signed integer, 6 decimal places	degree	+ East, - West
Airfield elevation	[-999m;9999m]	signed integer	meter	based on EGM96 Geodetic Model
Direction	[0°;360°]	unsigned integer	degree	
Distance	[1;999m]	unsigned integer	meter	
MaxEntryAltitude	[1;999m]	unsigned integer	meter	relative to airfield elevation
MaxEntrySpeed	[1;999km/h]	unsigned integer	km/h	
MinFinishSpeed	[1;999km/h]	unsigned integer	Km/h	
WorkingTime	[1;99min]	unsigned integer	minutes	
Length	[1;9999m]	unsigned integer	meter	
Width	[1;9999m]	unsigned integer	meter	
Radius	[1;9999m]	unsigned integer	meter	
LowerLimit	[0;9999m]	unsigned integer	meter	relative to airfield elevation
UpperLimit	[0;9999m]:	unsigned integer	meter	relative to airfield elevation
Start time slot	ISO 8601	YYYY-MM-DDThh:mmPmm	UTC	2017-07-23T08:10P16
Round	[1;99]	unsigned integer	number	competition round number
Group	[A;Z]	char	char	identifier for group
PilotID	32 characters	unsigned integer		unique ID for pilot, this equals the nickname on GPS Triangle platform
Protocol version	[1;255]	unsigned integer		Is same as for logfile

Example of task file:

3B_Example.rct:

V:02.0<CR><LF>

T:My Airfield,47.826110,9.163680,509,107,500,500,120,40,30<CR><LF>

R:New Rectangular Safetyzone,48.009416,9.165285,134,89,181,0,1000<CR><LF>

C:New Circular Safetyzone,47.346457,10.653798,2000,700,1400<CR><LF>

S:2017-06-17T10:08P12<CR><LF>

G:3,B,16,24,37,38,40,45,52,59<CR><LF>

11. Log File Description

File basics:

- The file is a text file based on ASCII characters
- The structure of the file is compliant to IGC logger specifications
- Full IGC specifications can be found on:
http://www.ukiws.demon.co.uk/GFAC/documents/tech_spec_gnss.pdf
- The file is secured by a integrity code that is added at the end of the file
- The integrity of the file can then be proven by the competition office with help of .exe or DLL provided by the manufacturer of the device that created the file. This integrity code is not compliant to the IGC specifications of public and private keys. See chapter 12 File Integrity for further details
- The naming of the file is according to IGC long file name Style:
 - YYYY-MM-DD-MMM-XXX-NN.IGC
 - All information in the file name is separated by hyphens
 - YYYY-MM-DD = Date of the record, be sure to add leading zeros if necessary
 - MMM = manufacturer three-letter identifier (see table in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**)
 - XXX = unique device identifier, may contain more than 3 characters
 - NN = number of flight of the day
 - Example: 2018-09-17-XRE-ES4711-03.IGC

File structure:

The file content is line based, each line starts with an upper case letter as line identifier:

- A = Manufacturer and device identifier
- B = Position and other frequently recorded information
- C = Task declaration
- E = Event reports
- G = Integrity code
- H = Header section
- I = List of additional data included in B lines
- L = Additional Information

After the line identifier there is either the information content or a short letter code for further subdivision. The subdivision letters are followed by short description and end with colon. Until here no whitespace is used. After the colon there is information content.

Each line ends with <CR><LF>

There is a static section that contains A, C, H, I and L record information. This is followed by a section that contains B and E record information and grows continuously with the time passing.

The last line of the file is the G record information with the integrity code.

Static section of the logfile:

A record:

The first line of the file is always the Manufacturer and device identifier:

- A MMM XXX<CR><LF>
 - MMM = manufacturer three-letter identifier (see table in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.Fehler! Verweisquelle konnte nicht gefunden werden.**)
 - XXX = unique device identifier, may contain more than 3 characters
 - Example: AXREES4711<CR><LF>

H record:

The header information is the first block of data after A record:

- H F DTE DATE:DD MM YY, NN<CR><LF>
 - DD MM YY = Date
 - NN = separated by comma is the number of flight of the day
 - Example: HFDTEDATE:221018,08<CR><LF>
- H F PLT PILOT:NAME<CR><LF>
 - NAME = Pilot in charge, string with PilotID (=nickname on GPS Triangle webpage) or just the name
 - Example: HFPLTPILOT:Sir_Piper<CR><LF>
- H F GTY GLIDERTYPE:TYPE<CR><LF>
 - TYPE = Name and basic info of the model, max 30 characters
 - Example: HFGTYGLIDERTYPE:ASW12B 1:2.5<CR><LF>
- H F GID GLIDERID:IDENT<CR><LF>
 - IDENT = alphanumeric unique registration of individual airplane
 - Example: HFGIDGLIDERID:D-1727<CR><LF>
- H F DTM GPS DATUM: WGS84<CR><LF>
 - WGS84 for position and EGM96 for altitude is mandatory for GPS competition, so this line is just to comply IGC standard
 - Example: HFDTMGPSDATUM:WGS84<CR><LF>
- H F RFW FIRMWARE VERSION: FWSTRING H F RFW FIRMWARE VERSION:
 - FWSTRING = FW Version of the device that created this file
 - Example: HFRFWFIRMWAREVERSION:2.73a<CR><LF>

- H F RHW HARDWARE VERSION: HWSTRING<CR><LF>
 - HWSTRING = Hardware that created this file, also for own design HW
 - Example: HFRHWHARDWAREVERSION: Galaxy Tab A V2<CR><LF>

- H F FTY FR TYPE: FR MANUFACTURER,FR MODEL NAME<CR><LF>
 - MANUFACTURERS NAME = Manufacturer of the flight recorder
 - FR MODEL NAME = Name of the flight recorder<CR><LF>
 - Example: HFFTYFRTYPE: RC Electronics, T3000<CR><LF>

- H F GPS RECEIVER: MANUFACTURER, MODEL NAME, MAXALT<CR><LF>
 - MANUFACTURER = Manufacturer of the GPS module
 - MODEL NAME = Name of the GPS module used
 - MAXALT = maximum altitude above MSL it will work
 - Example: HFGPSRECEIVER:RC Electronics,uBLOX-MAX-8, max50000m<CR><LF>

- H F PRS PRESS ALT SENSOR: MANUFACTURER, MODEL NAME, MAXALT<CR><LF>
 - MANUFACTURER = Manufacturer of the pressure altitude sensor
 - MODEL NAME = Name of the pressure altitude sensor
 - MAXALT = maximum altitude above MSL it will work
 - Example: HFPRSPRESSALTSENSOR:weatronic, GPS Pro, max3276m<CR><LF>

- HFCIDCOMPETITIONID:ID<CR><LF>
 - ID = the competition identification of the airplane, usually 2 letter on the stabilizer
 - Example: HFCIDCOMPETITIONID:PA<CR><LF>

- HFCCLCOMPETITIONCLASS:CLASS<CR><LF>
 - CLASS = The competition class, right now there is SPORT, SCALE and SLS
 - Example: HFCCLCOMPETITIONCLASS:SCALE<CR><LF>

I record:

After the header information there is the I record information that declares all positions and values that are stored additional after the fixed B record. The byte count starts from the beginning of the B Record, taking the first B in the line as byte one

- I NN SS FF TLC SS FF TLC<CR><LF>
 - NN = number of additions
 - SS = Start byte number of the addition in the B record
 - FF = Finish byte number of the addition in the B record
 - TLC = Three Letter Code for identification of the addition

Example:

- I043638FXA3940SIU4143ENL4445SUS<CR><LF>
 - I04 = There are four extensions on the B record
 - 3638FXA = on Byte 36 to 38 FXA (Fix Accuracy) value is stored
 - 3940SIU = on Byte 39 and 40 SIU (Satellites In Use) value is stored
 - 4143ENL = on Byte 41 to 43 ENL (Environmental Noise Level) value is stored
 - 4445SUS = on Byte 44 and 45 SUS (Sub Second) value is stored

As absolute minimum requirement the I record and therefore all B records must contain the SUS (Sub Second) value. This is necessary for precise assessment of crossing start and finish line.

Furthermore it should contain SIU, FXA, ENL or MOP (Means Of Propulsion) value, this is not mandatory now but will be part of the I record minimum information in the future.

L record:

The next part in static section is L information record that is used for additional comments in IGC file. The first line of L record shall be the PilotID used on the GPS triangle competition platform. The next information Line is the version number of this document used as requirement for the development of the navigation system. Furthermore the logfile repeats the complete GPS Triangle task file. The identifier for the task info is TSK, so those lines will start with LTSK.

Example:

```
LPilotID:Sir_Piper
LProtocolVersion02.0<CR><LF>
LTSK:V:02.0<CR><LF>
LTSK:T:CELJE,46.243198,15.228019,250,275.4,500,500,120,10,30<CR><LF>
LTSK:R:New Rectangular Safetyzone,46.243198,15.228019,134,89,181,0,1000<CR><LF>
LTSK:C:New Circular Safetyzone,46.243198,15.228019,2000,700,1400<CR><LF>
LTSK:S:2017-06-17T10:08P12<CR><LF>
LTSK:G:3,B,LoopingLuis,Otto,Sir_Piper,Thermal_Timo,Landing Luke,Mike1976,Clara<CR><LF>
```

C record:

To be able to show the task with standard IGC reply programs, the task should be included in the IGC compliant task format in the C records. Those consist of the first C record line that contains general information followed by lines for Take Off, Start, Turnpoint, Finish and Landing positions. The exact position coordinates to be put to the C record lines must be calculated from the Taskfile, as the IGC format for C record works with Degrees, Minutes, Decimal Minutes.

- C DDMMYYHHMMSS DDMMYY XXXX 03 RC GPS Triangle Racing<CR><LF>
 - DDMMYYHHMMSS = UTC Date and time of the declaration of the task. This is a requirement of the full size gliding to declare the task before start.
 - DDMMYY = Date of the flight
 - XXXX = old and discarded, therefore just put zeros here
 - 03 = This is the number of turnpoints, on the GPS Triangle it must always be 03 and therefore defines the total amount of C record lines
 - RC GPS Triangle Racing = String to describe the task

Example:

- C140816000000221018000003RC GPS Triangle Racing<CR><LF>
 - The Task was declared on 14th August 2016 at Midnight
 - The Flight took place on 22nd October 2018
 - There are 3 turnpoints, like always on RC GPS Triangle Racing tasks
- C DDMMmmmN DDDMMmmmE TAKEOFF TEXT STRING<CR><LF>
C DDMMmmmN DDDMMmmmE START<CR><LF>
C DDMMmmmN DDDMMmmmE TURN POINT 1<CR><LF>
C DDMMmmmN DDDMMmmmE TURN POINT 2<CR><LF>
C DDMMmmmN DDDMMmmmE TURN POINT 3<CR><LF>
C DDMMmmmN DDDMMmmmE FINISH<CR><LF>
C DDMMmmmN DDDMMmmmE LANDING TEXT STRING<CR><LF>
 - DD = Degrees latitude
 - MM = Minutes
 - mmm = decimal Minutes
 - DDD = Degrees longitude
 - N = North / S = South
 - E = East / W = West
 - TAKEOFF TEXT STRING = name of takeoff place, can be same as name of task
 - START, TURN POINT, FINISH= string should be kept like this for proper description
 - LANDING TEXT STRING = same as takeoff

Example:

- C4614591N01513681ECELJE<CR><LF>
C4614591N01513681EStart<CR><LF>
C4614617N01513292ETURN POINT 1<CR><LF>
C4614323N01513644ETURN POINT 2<CR><LF>
C4614566N01514069ETURN POINT 3<CR><LF>
C4614591N01513681EFinish<CR><LF>
C4614591N01513681ECELJE<CR><LF>
 - The name of the airfield was CELJE
 - Start / Finish was at 46°14.591'N 015°13.681'E
 - TURN POINT 1 was at 46°14.617'N 015°13.292'E
 - TURN POINT 2 was at 46°14.323'N 015°13.644'E
 - TURN POINT 3 was at 46°14.566'N 015°14.069'E

Data section of the logfile:

B record:

The B record is used to store frequently updated information, especially time and position data. In case of GPS Triangle competition logfiles, a B record shall be stored every second. Additionally a B record shall be stored with every event. Pay attention that the B record may contain extensions according to information given in I record. Minimum extension is the sub second information. To ensure data consistency over time, make sure all information has the same time origin, i.e. time and position information comes from the same GPS data package.

The standard B record has this format:

- B HHMMSS DDMMmmmN DDDMMmmmE A PPPPP GGGGG<CR><LF>
 - HHMMSS = UTC Time with 1 second resolution
 - DD = Degrees latitude
 - MM = Minutes
 - mmm = decimal Minutes
 - DDD = Degrees longitude
 - N = North / S = South
 - E = East / W = West
 - A = 3D Fix, data valid / V = GPS position data invalid, only 2D or no Fix
 - PPPPP = Altitude to the ICAO ISA above the 1013.25 hPa sea level datum, valid characters 0-9 and negative sign "-". Negative values to have negative sign instead of leading zero
 - GGGGG = GPS Altitude above EGM96 = MSL. Negative values to have negative sign instead of leading zero

Example:

- B1251084617261N01518205EA0017800271<CR><LF>
 - The Time was 12:51:08 UTC
 - Position was 46°17.261'N 015°18.205'E
 - 3D fix, GPS position data valid
 - Pressure Altitude was 178m
 - GPS Altitude was 271m

The B record extended as described by this I record:

- I043638FXA3940SIU4143ENL4445SUS<CR><LF>

- B1252134617205N01517477EA00192002820041201350<CR><LF>
 - The Time was 12:52:13.50 UTC
 - Position was 46°17.205'N 015°17.477'E
 - 3D fix, GPS position data valid
 - Pressure Altitude was 192m
 - GPS Altitude was 282m
 - Fix accuracy was 004m
 - 12 Satellites in use
 - ENL is 013
 - Subsecond is 50 – already seen in first line UTC 12:52:13.50

E record:

The Event record E is also part of data section of logfile. It is used to record specific events on the IGC file that occur occasional at irregular intervals. For the GPS Triangle logfile those events mark the pilot's intention as well as the important positions of the airplane around the triangle course. Keep in mind that assessment of the flight track is done by the assessment system in the competition office, that evaluates all relevant events based on the GPS data.

Nevertheless this information is required in the logfile for easy traceability and universal use also apart from competitions.

Every Event record is followed by an associated B record that gives further information about position, time and flight attitude. The B record contains as well all data listed in the I record!

Structure of event record:

- E HHMMSS TLC<CR><LF>
B1252134617205N01517477EA00192002820041201350<CR><LF>
 - HHMMSS = UTC Time with 1 second resolution
 - TLC = Three Letter Code for identification of the event
 - B12521.... = associated B record with more detail information

For the GPS Triangle logfile the following event Three Letter Codes are used. The Events come along with system status changes, for details see chapter 5 Assessment:

- PEV
 - This event is triggered by the pilot i.e. by clicking a button on the system or changing a switch position on the radio control that is read by the navigation system
 - It points out, that the next cross of startline is intended to start the competition task
 - The navigation system is set to “ARMED” state at this event
- STA
 - This event is triggered by the system to mark the valid cross of start line (see chapter 5 Assessment).
 - Keep in mind that the assessment system on the competition will take all information from the last valid GPS data inside start sector
 - The navigation system changes from “ARMED” to “STARTED” state at this event
- TPC
 - This event marks the valid reach of a turnpoint
- FIN
 - This event marks the valid cross of finish line
 - Keep in mind that the assessment system on the competition will take all information from the first valid GPS data inside finish sector
- STP
 - This event marks the end of the competition task which can be triggered by:
 - End of flight detection or
 - Expiration of working time or
 - the pilots intention i.e. by clicking a button
 - The navigation system changes from “STARTED” to “STOPPED” state at this event

Example:

- E125213ARM<CR><LF>
B1252134617205N01517477EA00192002820041201350<CR><LF>
 - The pilot “armed” the navigation system
 - The Time was 12:52:13.50 UTC
 - Position was 46°17.205’N 015°17.477’E
 - ...

- E125417STA<CR><LF>
B1254174614591N01513681EA00192002820041201320<CR><LF>
 - The pilot crossed the start line
 - The Time was 12:54:17.20 UTC, the last time inside start sector
 - Position was 46°14.591’N 015°13.681’E, the last position inside start sector
 - ...

G record:

The G record stores an integrity code with a length between 16 and 64 bytes. This code is the result of a HASH, CRC or equivalent method applied on every single line of the complete logfile.

The detailed method as well as the precise length of the integrity code is the responsibility of the manufacturer. For details about file integrity check see chapter 12 File Integrity.

The G record will look like this:

- G SSSS... SS<CR><LF>
 - S... = any valid ASCII character, length between 16 and 64 characters

- Example: GdS5jTr7dfRwo2m-Z<CR><LF>

Example of logfile:

The following example will show a logfile in proper order. The data are just used for illustration and do not belong to real GPS track.

```
AXREES4711<CR><LF>
HFDTEDATE:221018,08<CR><LF>
HFPLTPILOT:Marcus Piper<CR><LF>
HFGTYGLIDERTYPE:ASW12B 1:2.5<CR><LF>
HFGIDGLIDERID:D-1727<CR><LF>
HFDTMGPSDATUM:WGS84<CR><LF>
HFRFWFIRMWAREVERSION:2.73a<CR><LF>
HFRHWHARDWAREVERSION: Galaxy Tab A V2<CR><LF>
HFFTYFRTYPE: RC Electronics, T3000<CR><LF>
HFGPSRECEIVER:RC Electronics,uBLOX-MAX-8, max50000m<CR><LF>
HFPRSPRESSALTSENSOR:weatronic, GPS Pro, max3276m<CR><LF>
HFCIDCOMPETITIONID:PA<CR><LF>
HFCCLCOMPETITIONCLASS:SCALE<CR><LF>
I043638FXA3940SIU4143ENL4445SUS<CR><LF>
LPilotID:Sir_Piper
LProtocolVersion02.0<CR><LF>
LTSK:V:02.0<CR><LF>
LTSK:T:CELJE,46.243198,15.228019,250,275.4,500,500,120,10,30<CR><LF>
LTSK:R:New Rectangular Safetyzone,46.243198,15.228019,134,89,181,0,1000<CR><LF>
LTSK:C:New Circular Safetyzone,46.243198,15.228019,2000,700,1400<CR><LF>
LTSK:S:2017-06-17T10:08P12<CR><LF>
LTSK:G:3,B,LoopingLuis,Otto,Sir_Piper,Thermal_Timo,Landing Luke,Mike1976,Clara<CR><LF>
C14081600000221018000003RC GPS Triangle Racing<CR><LF>
C4614591N01513681ECELJE<CR><LF>
C4614591N01513681EStart<CR><LF>
C4614617N01513292ETURN POINT 1<CR><LF>
C4614323N01513644ETURN POINT 2<CR><LF>
C4614566N01514069ETURN POINT 3<CR><LF>
C4614591N01513681EFinish<CR><LF>
C4614591N01513681ECELJE<CR><LF>
B1252104614591N01513681EA00102002020041201300<CR><LF>
B1252114614591N01513681EA00152002420041201300<CR><LF>
B1252124614591N01513681EA00198002920041201300<CR><LF>
B1252134617205N01517477EA00192002820041201300<CR><LF>
E125213PEV<CR><LF>
B1252134617205N01517477EA00192002820041201350<CR><LF>
B1254174614589N01513683EA00192002820041201300<CR><LF>
B1254174614590N01513682EA00192002820041201310<CR><LF>
E125417STA<CR><LF>
B1254174614591N01513681EA00192002820041201320<CR><LF>
```

B1254174614592N01513680EA00192002820041201330<CR><LF>
E125519TPC<CR><LF>
B1255194614617N01513292EA00142002220041201300<CR><LF>
B1255204614627N01513282EA00142002220041201300<CR><LF>
E125520STP<CR><LF>
B1255204614591N01513681EA00102002020041201320<CR><LF>
GdS5jTr7dfRwo2m-Z<CR><LF>

12. File Integrity

Scope of file integrity check:

The integrity check is used to detect mistakes on file transfer and to proof that the file read in the competition office is the same as created by the navigation system. This means that no data can be added, changed or get lost without recognition. This is also precaution against manipulation.

Method for file integrity check:

To ensure that not any single byte can be changed in the file without recognition an integrity code is stored in the G record, which is the last line of a proper logfile.

This integrity code is generated by a cryptographic technology like CRC, HASH or similar, considering all lines of the logfile.

The exact method for generating the integrity code is the responsibility of the manufacturer and shall be kept as a manufacturer's secret.

To allow the competition office to check the file integrity, the manufacturer provides a tool (.exe or DLL) that can be called with and IGC file as a parameter and returns a valid / invalid.

An example tool that runs a MD5 HASH is available via info@gps-triangle.net. You just need to add your own 16-64Byte key, compile the source code and use the same source code and key in the navigation system to generate the integrity code stored in the G record.

Requirements for file integrity check:

- All lines of the file have to be considered for generating the integrity code
- Already one single byte change must result in an invalid file detection
- Multiple byte changes as well as additions and cut outs must also result in an invalid file
- The integrity code stored in the G record shall have a length between 16 and 64 characters
- Only ASCII characters are allowed in the integrity code
- The detailed method as well as the precise length of the integrity code is the responsibility of the manufacturer
- The method for generating the integrity code must be kept as a manufacturer's secret
- In case the example program is used for integrity check the key must be kept secret

13. List of abbreviations and symbols

LAT	Latitude of Origin
LON	Longitude of Origin
α	Direction of hypotenuse to north
β	Direction of safety zone length side to north
δ	Delta angle
a_b	Bottom altitude of safety zone
a_t	Top altitude of safety zone
d	distance
d_{LAT}	Distance in Latitude direction
d_{LON}	Distance in Longitude direction
d_{TP}	Distance from origin to turnpoints
e	Elevation
l_s	Length of safety zone
l_l	Length of landing zone
n	Number of triangles
p	Perimeter of triangle
r_e	Radius of earth
r_s	Radius of safety zone
t	Flighttime
w_s	Width of safety zone
w_l	Width of landing zone