



GPS Triangle Regulations for Sport Class-Gliders

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1 Definition of GPS Triangle soaring for Sport Class Gliders

1.1 Purpose and Goals

GPS Triangle competitions are meant to build a bridge between model soaring and full-size soaring competitions. Its goal is to display cross country soaring competitions of full size soaring in the scale of our model aircraft. The main task when participating a GPS Triangle contest is to fly around a virtual triangle (perimeter ~1,690 km) as often as possible in a period of 30 minutes. In order to obtain comparable results, the maximum starting altitude (usually 400 m) and the maximum starting speed (usually 120 km/h) when crossing the starting line are equal for all pilots. In addition to the before mentioned task, GPS Triangle also provides a special and more exciting task. In the so-called Speed Heat, pilots have to fly around the virtual triangle only one time as fast as possible.

The fascinating aspects of a GPS Triangle contest are:

- Lots of activities in the air (e.g., various gliders flying at the same time, takeoff by hand)
- A lot of flight time for each pilot during the competition
- Offering a wide variety of tactical decisions in combination with optimized teamwork between pilot and helpers.
- Flying with high performance sport- or scale gliders.
- Combining a complex flight task with rules as simple as possible
- Easy organization with only very few helpers

1.2 General Rules

For the execution of a GPS Triangle contest, the technology of satellite navigation with data communication from the model to the pilot is used. Together with the use of Data Loggers, the position (latitude, longitude and altitude) of the glider can be determined and verified in real-time. This simplifies both the flying operations and the evaluation of the flight.

Every pilot must use commercially available navigation equipment, compatible to the specifications described in **Appendix 2**. Pilots are not allowed to use more than two onboard systems, whereas, one is the main system and the other is the backup system. The applied system must be certified by the GPS Triangle Committee.

Every pilots' aircraft must be controlled solely by himself. In the case that the aircraft is controlled by someone other than the pilot, the competitor will receive a zero score (0) for this round.

The scoring of the individual flights to compute the individual results is based on the logged flight data and is calculated in the contest directors' office. The details of the data to be logged for scoring is shown and explained in **Appendix 2**.

For an interim period including 2020 the following flight data from existing and permitted navigation systems can be submitted to the competition officials in order to calculate the results.

The applied system must provide information after the flight about:

- Starting time (in UTC)
- Task starting altitude (in m)
- Task starting speed (in km/h)
- Flight time (i.e., a period starting when glider crosses starting line until it completes last triangle in min:sec)
- Number of triangles (n)
- Average speed, at which the triangles (multiple of 1,690km) were done
- Violation of safety area(s)
- Logging of Motorswitch. "Motor off" shall be logged with according time-stamp

Note: To validate the logger the motor must be switched on for a short time prior to the launch.

In addition, the system must provide a check code. This is generated based on the data above (e.g., starting time, task starting altitude) and is to ensure that no errors occur when processing the information from the flight card to the stationary evaluation software.

The use of additional variometers is limited to devices operating on frequencies in the 2,4 GHz band.

1.3 Use of Telecommunication Devices

The use of any electronic device other than for piloting or navigating the model aircraft is forbidden. Mobile phones have to be switched off or turned into flight mode on the flying site.

1.4 Insurance

Each participant must provide sufficient liability insurance with a coverage of at least € 2 million for personal injury and property damage that covers damage resulting from the use of his model airplane.

1.5 Rules of conduct to avoid midair collisions

To avoid collisions in the air every pilot needs to obey following rules of conduct to avoid midair collisions, or even collisions on the ground.

- If two models head towards each other in straight line flight, every model has to be steered to the right (aileron right) to avoid a collision.
- In every group the circling direction for thermaling is fixed. Group A is circling left, group B right, group C left and so on.
- Circling models have the right of way. Models flying in a straight line must fly around circling models to avoid collisions.
- Avoiding optical crossings of the models' flight paths is mandatory
- Models which came to rest after landing have to be removed from the touchdown area by each pilots' helper as quickly as possible.
- In case of a midair collision or a collision on the ground, there is no right to repeat the flight.

1.6 Safety on the flying site

The organizer must clearly mark the boundary between the landing area and the safety area assigned for other activities. (See sketch "flying field layout")

In each case a distance of (5) meters between the pilots box and the base line of the security zone is mandatory. The pilots box has to be placed with a minimum distance of (5) meters within the outlines of the security zone. The minimum altitude of the security zone above the pilots box is 150m and is independent of other security zones.

The competition director has the right to interrupt the competition out of safety reasons (unsafe conditions) at any time.

1.7 Launching and Landing direction

All launching and landings shall take place in an area as designated by the organizer with provisions made for launching and landing into the wind (headwind component).

1.8 Weather Conditions / Interruptions

a) Interruption and Resumption of the competition due to bad visual conditions:

The Contest Director has to ensure that models flying the triangular course below the dedicated entry altitude will always be visible. If this is not the case (i.e. due to low cloud base or fog) the Contest Director has to neutralize the group in flight and interrupt the competition. It is recommended to launch the group again with a lower dedicated start altitude. If this is again not possible the group has to be launched again as soon as the visible conditions permit.

b) Interruption and Resumption of the competition due to high wind speeds:

The maximum wind speed for contests is twelve (12) m/sec. The contest has to be interrupted or the start has to be delayed by the contest director if the wind speed exceeds twelve (12) m/sec measured three (3) times for at least twenty (20) seconds in a time interval of five (5) minutes two (2) meters above the ground at the start and landing area.

c) Interruption and Resumption of the competition due to rain:

In the case of rain the ongoing round has to be interrupted as well. The Contest Director has to neutralize a group in flight and interrupt the competition until the rain will stop. All pilots have to land their planes as soon as possible as soon as the Contest Director neutralized a group in flight. The group which was neutralized will reassume the competition at a later time as soon as the rainfall has stopped.

d) Interruption and Resumption of the speed task due to rain:

In the case of rain, the contest director must interrupt the contest during Speed task. In case the rain stops after an interruption of less than fifteen (15) minutes, the contest starts again with the pilot that was flying; he receives a re-flight.

The whole number of competitors of the Speed task must be divided in a meaningful number of equal groups depending on the total number of competitors before the task starts. The minimum number of competitors in such an equal group must be at least 10 pilots. If the weather is stable only one (1) group is evaluated; if the competition must be interrupted for more than fifteen (15) minutes, then the interrupted group must start from the beginning and the results are evaluated for each group.

2 Sport Class Glider and Technical Equipment

2.1 Definition of a Sport Class Glider

A Sport Class glider is defined as a radio-controlled glider which is equipped with an electric engine for hand launch and it must comply with the specifications mentioned in paragraph 2.2. Other methods for launching, than launching the model aircraft by hand are not permitted.

2.2 Specification of a Sport Class Glider

2.2.1 General

Value	Size (Maximum)	Tolerance
Wingspan	5000 mm	20 mm
Wingload (wing area)	75 gr/dm ²	For measurements the tolerance of the used scale is valid
Weight	7000 gr	For measurements the tolerance of the used scale is valid

The wing loading in general is determined by the weight of the aircraft divided by its projected wing surface. To projected wing surface is calculated with all trailing edge surfaces (regularly flaps and ailerons) in "0-degree"-position.

The pilot must always be able to prove that his model complies with the rules.

The information on the official homepage of the manufacturer or in case of self-construction the construction plans apply.

2.3 Number of Sport Class Gliders per Pilot

During a GPS Triangle competition each pilot may use a maximum of two Sport Class gliders or two different configurations. These Sport Class gliders are called A-Model and B-Model. Each detachable part of the aircraft which defines its outline must be marked with a distinctive identification label (for instance Model A, Model B). The labels have to be documented on the starting card and for each flight the pilot must checkmark the Sport Class glider used. *(This rule stays active as long as scoring will be done using scorecards)*

2.4 Replacements & Ballast

All parts can be interchanged between A-Model and B-Model, as long as the outline of the model is not changed. The “outline” of the Sport class glider is determined with all trailing edge surfaces (regularly flaps and ailerons) in “0-degree”-position. Changing or replacing components of the radio equipment, navigation system, power unit or electronic items is allowed. Using ballast is permitted. Water ballast is also permitted and can be jettisoned during flight. When ballasting the maximum wing loading limit (see paragraph 2.2.3) must not be exceeded.

2.5 Loss of Parts

If the model aircraft loses a part (other than water ballast) during takeoff or flight the aggregate flight will be scored with zero points. The loss of a part after a midair collision or during the landing will not be considered in scoring.

2.6 Navigation & Data-logger

For navigation during flight a compatible navigation system has to be used. This system transfers GPS-data from the Sport class glider to a receiving device (Ground station) and/or records relevant flightdata in an onboard-logger. Additionally following requirements must be fulfilled:

- The performance of a flight (number of triangles, starting altitude, average speed over all triangles) can be determined immediately after landing using the receiver equipment or a readout of the onboard logfile.
- Only systems fulfilling the specification (cf. Section 7 “Appendix 2”) are allowed for the flight navigation and flight evaluation.

The technical details for basic requirements concerning the navigation systems as well as a list of accredited systems is shown in Appendix 2.

2.7 Gyros, Auto Pilots & Telemetry

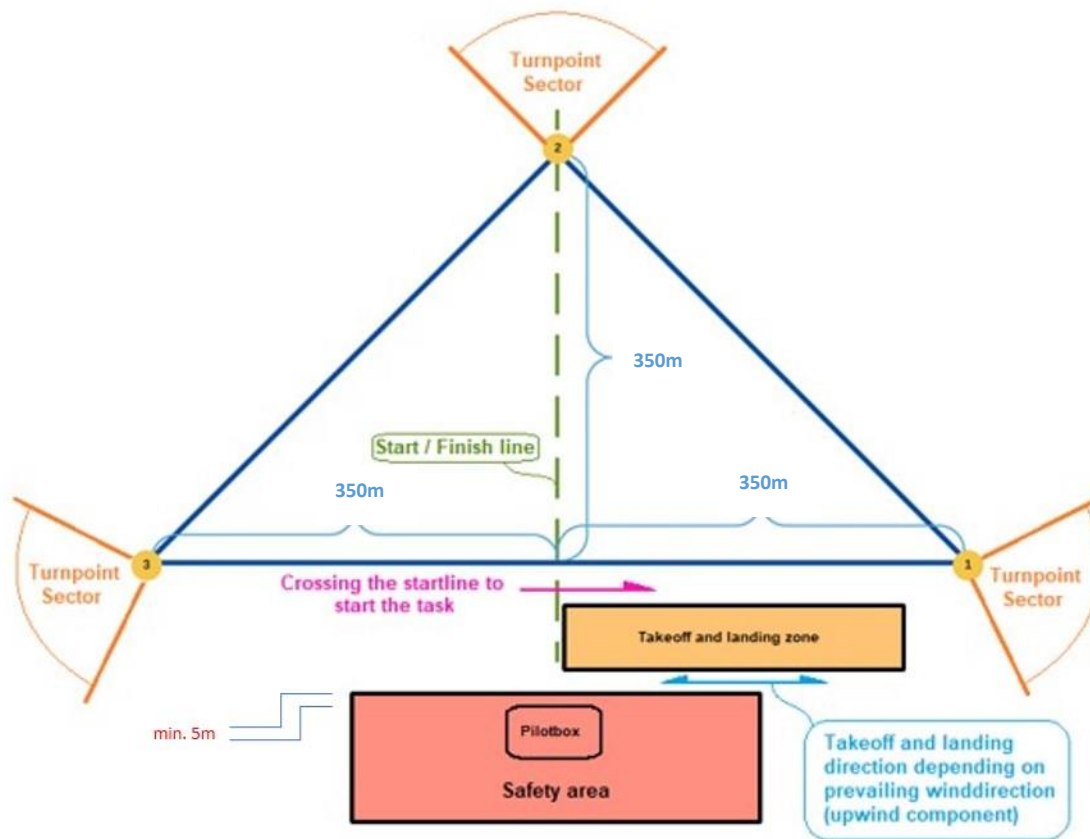
Gyros, flight augmentation systems or Autopilot systems, or the usage of data generated by such systems for flight attitude control are not permitted.

It is not permitted to connect the telemetry-receiving unit with the radio control transmitter (e.g. Speed Indicator Signal with Flap Function) in order to send a corrective signal to the model.

Doing so will result in disqualification from the GPS Triangle contest.

3 Flying Field

The flying field and the virtual triangle design:



The position and the size of the Takeoff and Landing Zone as well as the Safety Zone may vary because of geographical circumstances of the flying field (see § 5.6.2). The Take-off and Landing Zone conforms to the minimum width of the airstrip of 25 meters and a length of at least 80 meters. The Pilotsbox's position inside of the Safety Zone can be chosen freely by the contest director, but has to be at least minimal 5m apart of its outside boundaries. The sketch above is not true to scale. The view of the area in which the triangle is placed should be unrestricted. The altitude band of the Safety Zone above the Pilotbox has to be at least 150m AGL.

Depending on the terrain the organizers of the competition may declare Security Zones which are defined by an outline and a height tape. If one of these Security Zones is overflowed, this flight is getting judged with zero points.

4 Organization of a GPS Triangle Contest

4.1 General Rules

4.1.1 Contest Organization

The contest organization provides the following personnel:

- Contest director: He is responsible for the entire GPS Triangle contest and shall not participate as active pilot in the contest.
- Supervisor of Flying (SOF): He responsible for coordination of departures, landings, times and weight of the models. Every pilot having finished the official task will announce his landing. The SOF will confirm the correct landing procedure (see 5.6.2) on the control card except for the Speed-Heat (there are no landing points).
- Evaluation officer: He is responsible for entering the flight results and creating intermediate and final ranking lists
- Jury: three persons well knowing the GPS Triangle contest rules and being able to decide in cases of doubt or problems. Jury members which are also pilots must be replaced by other persons for questions / problems concerning themselves.
- Tasks of the jury: Possible irregularities, or decisions made by the contest director or the supervisor of flying respectively can be claimed by every competitor. In case of an appeal the jury has to come together to decide whether or not the appeal will be overturned.
- The reason for a complaint in verbal- or in written form is to get a correction without the need of a formal protest. It is recommended to submit a complaint before submitting a protest.
- Protests have to be submitted to the contest director in written form and in English language. Furthermore the protest is linked to a fee amounting to 100 Euro. The jury which has been nominated prior to the start of the competition has to come together and has to agree on a decision in this case. A simple majority within the jury members is sufficient to refuse or grant a protest. The protest fee is only going to be refunded if the protest is granted. No appeal or protest can be lodged against the decision of the jury.

Deadlines for submitting protests

- Prior to the start of the event: A protest against the validity of participation, the qualification of the participants (pilots), the competition rules, the flying field and the competition area, the processing of glider models, the jury or other officials has to be submitted at least one hour before the event starts.
- During the event: A protest against a decision of the contest director, other officials, or against a mistake or irregularity committed by another participant during the event must be submitted as soon as the competition allows. The complaint must not be filed any later than 90 minutes after the start time frame of the respective group in which the incident occurred. Note: A protest against official results must be submitted immediately after the official results have been published on the airfield, but no later than at the award ceremony.

4.1.2 Pilot & Navigator

The participants are randomly assigned to a group by the GPS Triangle Evaluation Software. During a flight, a pilot may be assisted by a single navigator. It is of importance that only pilot and navigator are inside the Pilots Area. The noise level has to be reduced to a minimum. As a consequence voice prompts (except beeps and similar sound signals) should be transmitted via headphones.

4.1.3 Radio Frequency Control

Only frequencies authorized by the national authorities may be used; it is the responsibility of the participant to ensure this. The contest director or the Supervisor of Flying are authorized to perform a frequency control at any time.

4.1.4 Navigation System Frequency Control

The contest director assigns each pilot/navigator team a maximum of two frequencies for the transmission module of the GPS system in the glider model. The correct setting of the frequency is up to each pilot. It is recommended to make use of the four-eye principle (pilot/navigator are monitoring each other). At any time there are exactly two frequencies which may be used by the pilot/navigator team. The commissioning of a navigation system with a frequency other than the assigned frequency will result in disqualification from the competition. This rule does not apply to navigation systems with frequency hopping.

4.2 Definitions

4.2.1 Definition of the Contest

A GPS Triangle contest consists of at least three GPS Triangle heats. One out of six heats (for the case, that more than 5 heats are flown) has to be a Speed Heat. The Speed Heat is announced by the SOF during the briefing and taking weather conditions into account.

The glider model or configuration used for the Speed Heat must have been used in at least two of these four heats. Therefore it has to be used at least once in a heat which is not the Speed Heat. If this is not the case, the Speed Heat will be judged with zero points.

4.2.2 Definition of a Heat

For each heat, the GPS Triangle Evaluation Software equally distributes (random) the participating pilots into groups. The number of pilots determines both the individual group size and the number of groups.

A normal Heat always consists of at least 2 groups, whereby, each contains a minimum of 3 and a maximum of 13 pilots. However, a Speed Heat consists of solely one group containing all participating pilots, as long as the weather conditions permit this. Should the weather conditions require an interruption of more than 15 minutes, the Speed Heat has to be repeated or a separate classification using group scoring will be applied (See paragraph 1.8.d)

A heat consist of one or more attempts for the pilot as per 4.2.3 and 4.2.4 and subsequently the official flight (see section 4.2.5)

When distributing the pilots into groups, it must be guaranteed that two pilots of one team are not assigned to the same group and subsequently do not have to fly at the same time. Therefore, the pilots need to inform the officials about their team membership when signing up for the contest. In a single heat, each competitor of pilot/navigator team will be used as a pilot once and once as a navigator.

4.2.3 Definition of an Attempt

An attempt begins with the take-off of the sport class glider from the pilots' or his helpers' hand. Any other method of launching is not permitted. The attempt is completed when the sport class glider reaches the predefined starting altitude of the heat. Note that in the speed heat it is not allowed to switch on the motor again after reaching the predefined starting altitude and after the motor has been switched off.

4.2.4 Repetition of an Attempt

An attempt may be repeated if the sport class glider has not reached the predefined starting altitude of the heat. The number of repetitions is not limited as long as the official Flight Window of the group is open.

However, after the first attempt, it is not allowed to replace any parts of the scale glider. This applies to all mechanical parts (see Paragraph 2.4).

The engine can be switched on again to regain altitude for a new evaluated flight, as long as the start time window is still open. However, the previous evaluated flight is cancelled.

This is not applicable for the Speed heat. After reaching the task altitude for the first time, it is not allowed to use the motor again. If the pilot decides to restart because of penalty points, he can do so, but without using the engine a second time.

If the engine is turned on during the evaluated flight, it will be judged with zero points. Zero points will also be rewarded, if the flight has not been started before the start time window has been closed.

It is the pilots' right to change his model without breaking rule 4.2.1 if:

- a) His Sport class model has collided with another Sport class model during the flight and his glider model cannot be repaired in time or
- b) His Sport class model was damaged during landing by another landing Sport class model.

4.2.5 Definition of an official Contest Flight (evaluated flight)

After a completed attempt the pilot must start the official evaluated flight by crossing the starting line at or below the predefined starting altitude with a maximum of 120 km/h. If the pilot flies too high or too fast when crossing the starting line he may accept a penalty or needs to re-cross the starting line. Each pilot can do only one official evaluated flight per heat.

5 Flight and Scoring

5.1 Preparation (Normal Heat)

In a Normal Heat, the groups are randomly determined via the GPS Triangle Evaluation Software. It has to be made sure that the two pilots of a helper team are never assigned to the same group. Should a heat consist of more than three groups, the pilots of the same team may not be assigned to consecutive groups within the heat. The Contest Director sets a start time window for each group and announces this time window before the start of the heat. The start time window determines within which time from the start time all pilots of the group have to have flown over the starting line. The duration of the start time window depends on the number of pilots in a group and is between 5 minutes and 59 seconds and 10 minutes and 59 seconds long. The start time window is given in whole minutes, counting the last minute to the start time window.

Table: Start time window in minutes, plus 59 seconds each depending on the group size

Pilots per Group	StartTime Window in Minutes
3	5
4	5
5	5
6	6
7	7
8	8
9	9
10	10
11	10
12	10
13	10

The start time window is communicated by the contest director as soon as possible. Nonetheless, the start time window opens not earlier than 5 minutes after the last Sport Class glider of the preceding group has landed.

5.2 Preparation (Speed Heat)

In the Speed Heat the next Sport class model to be launched is taking off as soon as the previous Sport class model has passed Turning Point 1 after overflying the starting line. Under these circumstances there is the least risk of a collision between a Sport Class Glider which is being started and a Sport Class Glider flying at high speed.

5.3 Cancelation & Restart of a Group

The contest director may stop the competition if one or more reasons for such an interruption occur. These circumstances are shown in Paragraph 1.8.

5.4 Flight Task and Flight Time

A GPS Triangle contest consists of two different flight task types performed in two different heat types.

Independent from the heat type, the following rules must be followed:

- The finish line must be crossed with a speed of at least 20 km/h; otherwise the crossing and also the last round will not be counted.
- The pilot has to fill out the evaluation card right after the flight and present it to the SOF. The SOF will verify the landing points by signing the evaluation card. The pilot has to sign as well to accept the scoring.

5.4.1 Speed Heat

The flight task of the Speed Heat is to pass all the Turning Points of the defined triangle, in the defined order, exactly once and in the lowest time possible.

5.4.2 Normal Heat

The flight task in a Normal Heat consists in flying around the defined triangle as many times as possible within the specified flight time (usually 30 minutes). The flight time starts with the last crossing of the starting line within the predefined start time window.

5.5 Scoring rawpoints

The score is computed by the triangle points, the landing points, and the penalty points.

$$\text{Rawpoints} = \text{Triangle Points} + \text{Landing Points} - \text{Penalty Points}$$

The score for the Speed Heat is the result of the speed-related points for flying around the triangle deducting all the cumulated penalty points .

$$\text{Rawpoints} = \text{Rawpoints for } \frac{\text{individual average speed}}{\text{best average speed}} - \text{Penalty Points}$$

5.5.1 Triangle Points

Every pilot gets 200 rawpoints per completed triangle. If there is more than one pilot in a group having the same number of completed triangles, the points for the last triangle are calculated as follows:

- Only the pilot with the highest average speed over all his triangles gets 200 rawpoints for the last triangle
- Pilots with the same amount of completed triangles are only getting partial points. These points are a certain proportionately to the highest possible score of 200 rawpoints the pilot with the highest average speed gets. The points are calculated as follows:

$$\text{Rawpoints for the last absolved triangle}_{\text{pilot}} = 200 * \left(\frac{v\emptyset_{\text{pilot}}}{v\emptyset_{\text{fastest Pilot}}} \right)$$

$$\begin{aligned} v\emptyset_{\text{pilot}} &= \text{average speed of the according pilot} \\ v\emptyset_{\text{fastest Pilot}} &= \text{average speed of the fastest pilot} \end{aligned}$$

Hereby the average speed is calculated as follows:

$$\begin{aligned} \text{average speed } v\emptyset & \\ &= \frac{(\text{number } (n) \text{ of triangles} * \text{course distance of 1 triangle in km})}{\text{flight time in h}} \end{aligned}$$

5.5.2 Landing Points

The landing zone has to be marked properly. Its width has to be at least 25 meters and its length at least 80 meters.

The direction of landing is declared by the SOF and has to be visibly displayed. If the wind conditions change the SOF may change the landing direction within the current group. Altering the landing direction is only viable, if no glider model is currently in the landing process.

Note that in the Speed Heat no landing points are awarded.

In every other heat there will be landing points for the pilot.

400 landing points are awarded, if:

- The Sport class model came to a full rest inside the landing zone. That means at least one part of the Sport class models' fuselage is inside the boundaries of the landing zone.
- The landing must always take place by crossing the base line of the landing zone first (Not mandatory to do it in flying manner). Crossing the side line of the landing zone is not permitted and results in 0 landing points.
- The Sport class model is immediately capable of starting again.

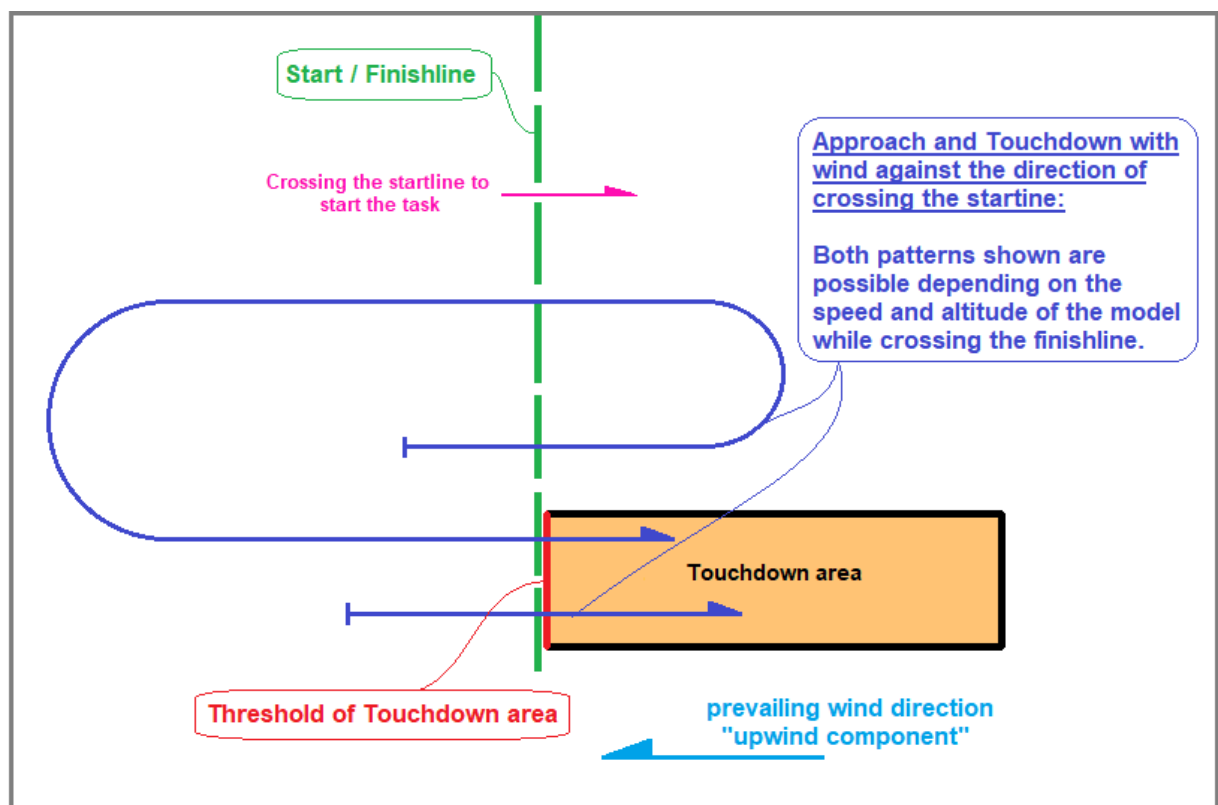
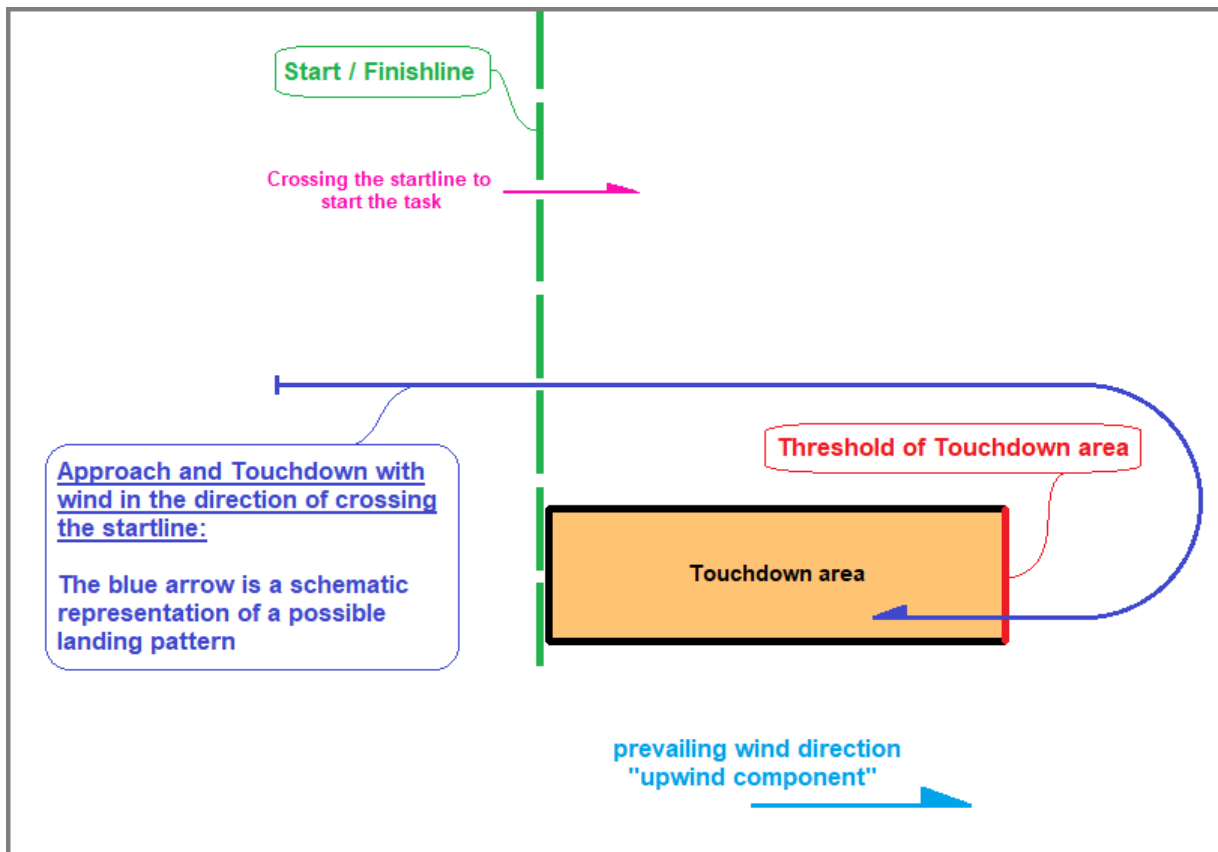
0 landing points are awarded, if:

- The landing sequence is completed against the previously declared direction of landing
- The base line of the landing is not crossed
- The Sport class model lands and comes to rest outside of the landing zone with no part of its fuselage touching the landing zones boundaries.
- A part of the Sport class model enters the Safety Area

To avoid several simultaneous landing approaches, the Contest Director or the SOF can instruct a pilot to switch on the engine for safety reasons. This then doesn't affect the pilots' score.

If the engine is switched on without the instruction of the Contest Director after overflying the start line and the start line is not overflown again within the start time window, the flight is judged with 0 points.

The following schematic depicts flight paths for potential landing sequences according to the prevalent wind direction. The position of the start/finish line as well as the position of the landing zone may vary because of the geographical conditions of the airfield. However, the layout of the airfield should be as implemented as close as possible to Sketch 3 point 3 "airfield".



5.5.3 Penalty Points

Crossing the starting line above the predefined starting altitude and/or at a speed above the maximum starting speed of 120 km/h, the pilot gets penalty points as follows:

$$PenaltyPoints = 50 + 2 * (Starting\ Alt. - Max.\ Starting\ Alt.) + 2 * (Entry\ Starting - Max.\ Starting\ Speed)$$

The pilot may accept a penalty and start the official contest flight or may do a new attempt in re-crossing the starting line as long the start time window is open. The penalty points are deducted from the total rawpoints score of the pilot.

Note: overflying a security zone (area, height) will result in 0 points for this flight

5.5.4 Evaluation of Points for the Speed Heat

For a Speed Heat only the average speed over one flown lap is crucial. The pilot with the highest average speed over this lap is awarded with 200 rawpoints. The other pilots are getting a proportionate result according to the following formula:

$$Rawpoints_{Pilot} = \left(\frac{v_{Pilot}}{v_{Best}} * 200 \right) - PenaltyPoints$$

v_{Pilot} = Average speed of the according pilot

v_{Best} = Highest average speed

5.6 Results

5.6.1 Evaluation of the Results

For every group there is a separate classification of 1000 points. The pilot with the highest score in rawpoints – possible Penalty Points taken into consideration – is awarded with 1000 points. The other pilots in this group are getting proportionate scores in relation to the highest score within the group.

$$Points_{Pilot} = \frac{Raw - points_{Pilot}}{Raw - points_{Best}} * 1000$$

$Rawpoints_{Pilot}$ = Points of the pilot

$Rawpoints_{Best}$ = Best score of a pilot in this group

It is neither possible in Normal Heats nor in Speed Heats for a pilot to get a result lower than 0 points. The calculation methods, definitions and algorithms for the evaluation of the results are shown in Appendix 2.

5.6.2 Intermediate Score and Final Ranking

The evaluation officer creates an intermediate score list after each heat. The results have to be made public by the Contest Director not more than 30 minutes after the heat was completed (Chance to appeal and protest).

The cumulated points are the final results according to 5.7. If there are six (6) heats or more, the worst heat of a pilot is not added to the final result. Before publishing the final ranking, the contest director must control the final calculation of the results according to a standardized check list.

If multiple pilots reached the same final score, the ranking of these pilots depends on the following criteria sorted in order of priority:

1. The highest score omitted for calculation.
2. The overall number of completed triangles
3. The highest average speed in one of the Normal Heats.
4. The highest score in one of the Speed Heats.

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

**Version: 1.7b
15.05.2019**

1. 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.

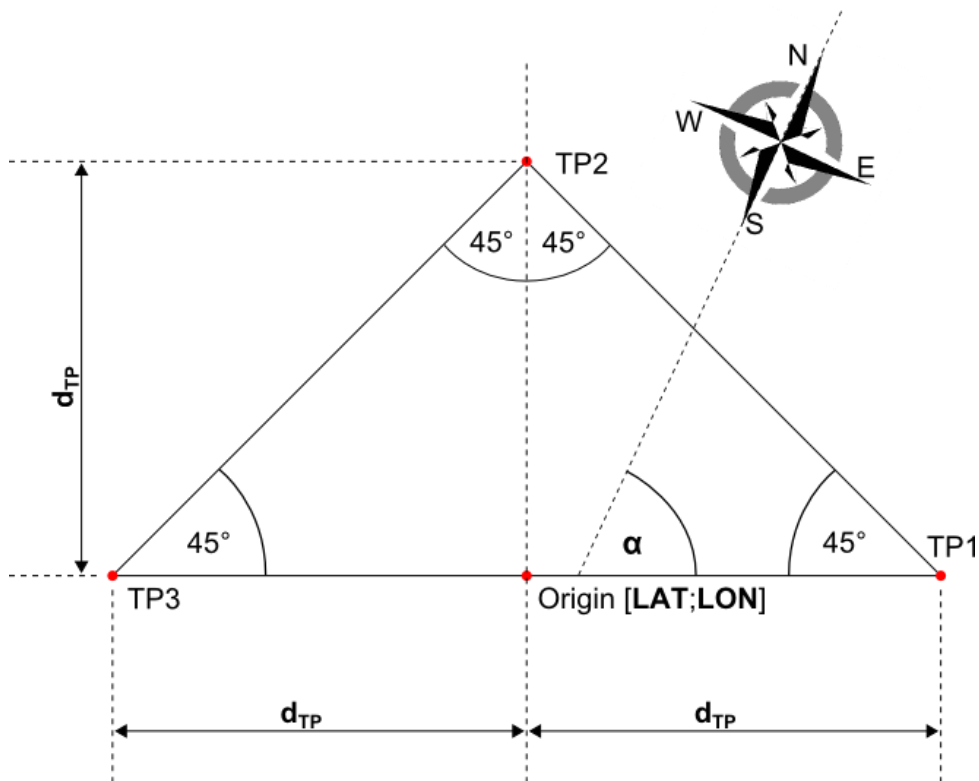
The navigation system shall not directly influence the flight attitude of the airplane in a way to perform autopilot or automatic flight path control capabilities.

2. 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

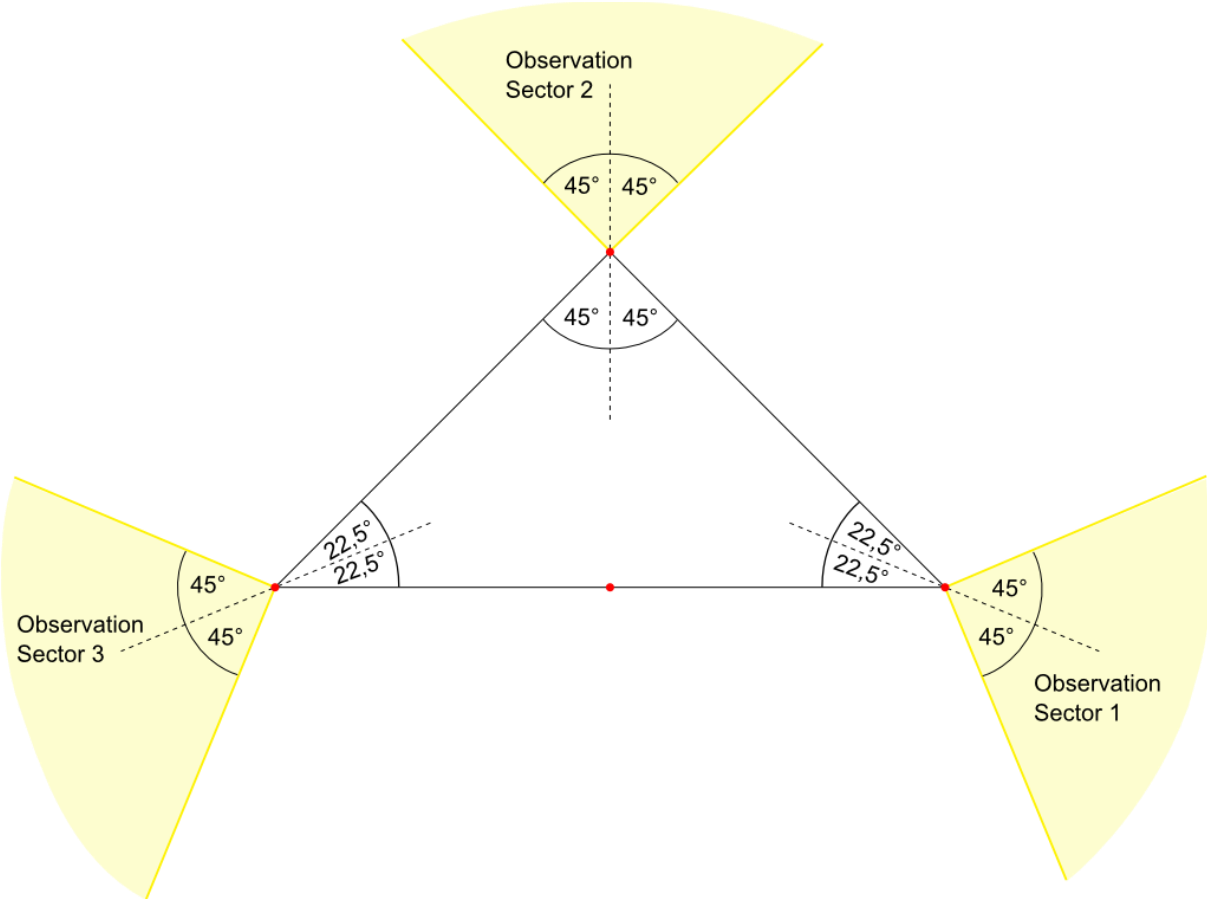
The triangle is defined by:

- 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



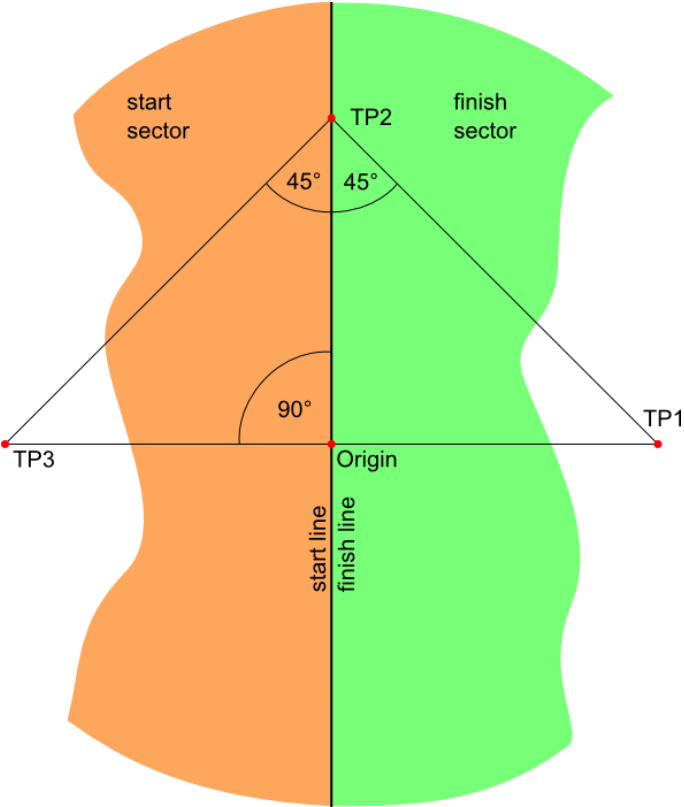
The observation sector for each turnpoint is defined by:

- 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



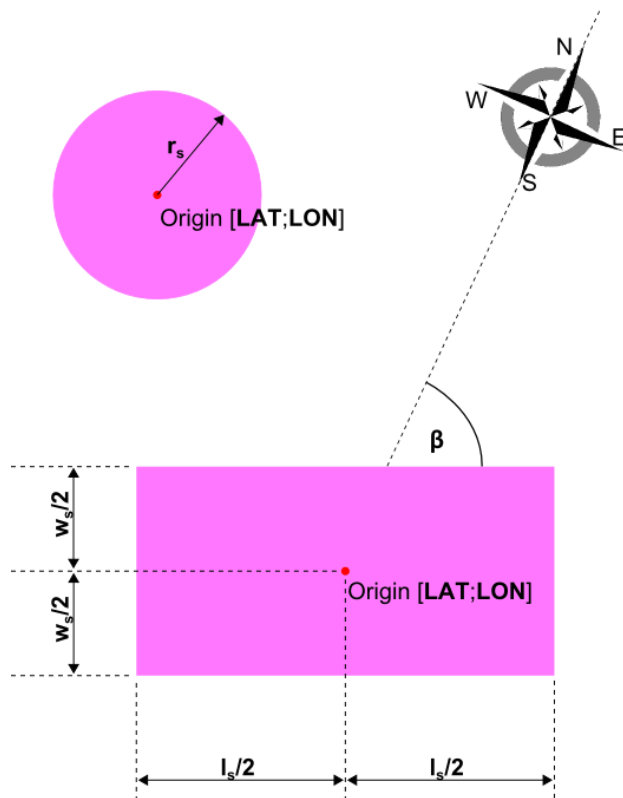
The start and finish observation sector is defined by:

- 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



3. 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

4. Measurements

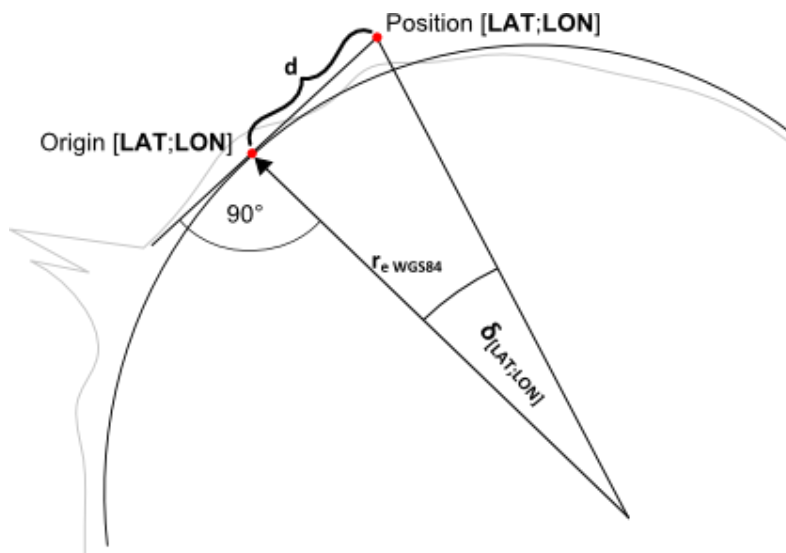
- All measurements shall have a minimum update rate of 4Hz
- Any applied filters for measured values shall not cause a response time greater than 0.5 seconds to change of flight attitude
- The GPS receiver shall be used in a mode without position forecast algorithms
- The GPS position shall only be declared 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:

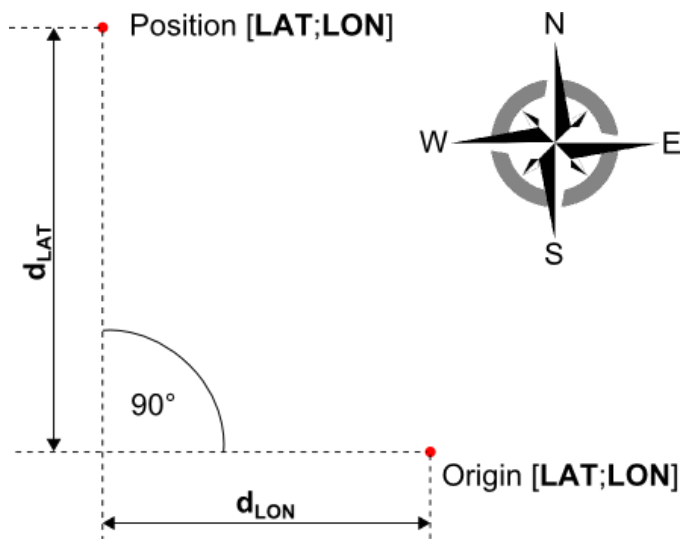
- All GPS coordinates shall be based on the WGS84 ellipsoid model
- The used resolution on all calculations shall be decimal degrees with 6 decimal places [0.000001°]

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
 - $d_{LAT} = r_{e\text{ WGS84}} \cdot \tan(\delta_{LAT})$
 - $d_{LON} = r_{e\text{ WGS84}} \cdot \tan(\delta_{LON}) \cdot \cos(\text{LAT}_{Origin})$



- 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]

5. 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.

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

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

6. 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 4 ~~Measurements~~ Measurements) 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

7. 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"

8. 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 9 [Log File Description](#) ~~Log 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 Geodic 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>

9. 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 10 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 11 [List of Manufacturers](#))
 - 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 11 [List of Manufacturers](#))
 - 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: HFDTE: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 3 [AssessmentAssessment](#):

- 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 3 [AssessmentAssessment](#)).
 - 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 10 [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>
HFDTE DATE: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>
C140816000000221018000003RC 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>

10. 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

11. List of Manufacturers

The following table gives an overview of manufacturers for navigation systems or data loggers that may be used on a GPS triangle competition

Manu- facturer ID	Manufacturer Contact	Systems used	Integrity Validation tool
XCM	Christoph Mächler	SkyNavigator in combination with Hardware of: <ul style="list-style-type: none"> • Weatronic • Jeti • Flymate • RC T3000 	Not available
XCT	Claus Tonnesen	Flymate	Not available
XRE	RC Electronics Andrej Vrečer Slovenia	<ul style="list-style-type: none"> • RC T3000 • Snipe 	Not available

If manufacturer of navigation system (i.e. tablet application) and hardware for measuring values and transmitting to tablet are not the same, the manufacturer ID is always from that device (i.e. tablet application), that creates the IGC file. The three letter code in the A record of the logfile is also used to identify the right tool for checking the file integrity. The hardware manufacturer has to be listed in the FTY information in header record (i.e. HFFTYFRTYPE: RC Electronics, T3000<CR><LF>)

12. 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