*Fédération
Aéronautique
Internationale*

CIVL GAP 2012

Centralized Cross-Country Competition Scoring System for Hang-Gliding and Paragliding

**2012 Edition
Effective May 1st, 2012**

Editor's note: Hang-gliding and paragliding are sports in which both men and women participate. Throughout this document the words "he", "him" or "his" are intended to apply equally to either sex unless it is specifically stated otherwise.

March 10, 2013, Joerg Ewald

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Contents

1 Introduction

This document contains all definitions required to score centralized cross-country competitions for both hang-gliding and paragliding. Its purpose is to serve as an educational tool for all parties involved in such competitions, but also as a reference for scoring systems, as well as a basis for future improvements and modifications. The driving factor behind its creation is the author's point of view that fair and transparent scoring can only be achieved if a complete and where applicable mathematical definition of all aspects of the scoring system is available to every person involved in competitions, be it pilots, score keepers, team leaders or any others.

1.1 Scope

The document's scope is restricted to scoring of FAI Category 1 cross-country competitions for hang-gliding and paragliding: World and continental championships in both sports. CIVL's rule setting targets these competitions exclusively, whereas organizers of FAI Category 2 competitions as well as non-sanctioned competitions are free to score their competitions however they like. Most of them do follow CIVL's lead, though, so this document should also cover the majority of Category 2 events as well.

1.2 Sources

The remainder of this document is based on:

- "The GAP Guide" (2011 edition)
- FAI Sporting Code Section 7A for Hang-Gliding (2012 edition)
- FAI Sporting Code Section 7B for Paragliding (2012 edition)
- The scoring implementation within CIVL's scoring software, FS (aka "FScomp")
- Appendix C of the Paragliding World Cup Association's 2012 Competition Rules

1.3 Differences between Hang-Gliding and Paragliding

Initially, both hang-gliding and paragliding competitions used the same system for scoring, generally known as "GAP". But over time, through their two separate sporting codes, the two disciplines introduced more and more changes that would only apply to one, but not the other. This mainly in non-standard situations such as stopped tasks, pilots landing just short of goal, or pilots crossing the start line too early. Where not explicitly stated otherwise, the contents of this document always apply to both disciplines. Definitions applying only to one, but not the other, are clearly marked as such.

Text marked in turquoise applies exclusively to hang-gliding.

Text marked in lilac applies exclusively to paragliding.

2   The GAP Philosophy

CIVL's scoring system is generally known as "GAP", named after the first-name initials of its three inventors Gerolf Heinrichs (G), Angelo Crapanzano (A) and Paul Mollison (P). Their intention was to "create a fair scoring system easily adaptable to any competition anywhere in the world, both for hang gliding and paragliding, with a philosophy that is easy for the pilot to understand, regardless of the mathematical complexity of the underlying formulas".

2.1   History

Work on GAP started in 1998, and it was officially introduced in 2000, to allow scoring of competitions based on GPS track logs, instead of photographic evidence as it had been used until then.

In 2002, an updated version, named "GAP 2002" was published. This introduced the concept of leading points, which are calculated by comparing the complete track logs of all pilots in a task. Leading points replaced the departure points used in GAP 2000

In 2005, a variation of GAP 2002 was introduced in Australia, named "OzGAP" or "OzGAP 2005". The difference to GAP lies mainly in the way arrival points are calculated, but this was never adapted by CIVL.

In 2008, "GAP 2008" was officially released. The main scoring mechanisms remained unchanged from the 2002 edition, but the implementation of GAP 2008 included several rules introduced in the sporting codes for either hang-gliding or paragliding. These cover stopped tasks, starting too early, and landing between the end of the speed section and goal.

In 2011, "GAP 2011" marked another software release where the main scoring remained unchanged from the 2002 definition and implementation. The main changes were all for paragliding: altitude bonus in stopped tasks, as well as a reduced number of available points in stopped tasks and in tasks with no pilots in goal.

In 2012, the "Jump the Gun" rule for early starts in hang-gliding competitions changed in S7A. This was implemented in FS, but this was also released, unfortunately, as "GAP 2011".

2.2   Scoring Process

Scoring follows an eight-step process, as depicted in Figure 1:

1. Setting the competition parameters, or "GAP parameters", according to the competition site, the expected pilot level and the expected tasks. This happens once for each competition, at the outset, and must not be changed throughout the competition. See section 4.
2. Setting a task – this happens typically once per day on flyable days. See section 5.
3. Letting the pilots fly the task. See section 5.6.

4. Evaluating the task, by collecting all pilots' track logs for this task, and determining for each pilot the distance flown and, if the end of speed section was reached, in what time this happened. See section 6.

5. Calculating the task validity based on the task's statistical values such as fastest time to ESS, number of pilots in goal, average distance flown and several others. See section 7.

6. Points allocation: Calculating the maximum number of points awarded for distance, speed, leading and arrival, based on the task validity and the statistical values found in the task evaluation. See section 8.

7. Scoring each pilot's flight, by calculating the awarded points for distance, speed, leading and arrival. The outcome, the pilots' total score, is the sum of these four values. See section 9.

8. Ranking all pilots according to their total score for the task results.

The competition overall score of a pilot is calculated by adding up all of his task scores, and pilots are then ranked according to their overall total score. A female ranking is generated by exclusively listing female pilots, with the score they achieved in the overall ranking.

Nation scores for an individual task as well as for the overall nation ranking are calculated based on the task results of a subset of each nation's pilots.
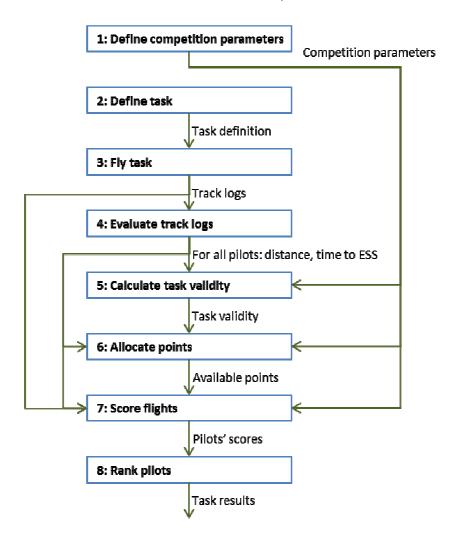

Figure 1: Scoring process

3 Terminology

The following terms are used throughout this document:

Take-off: Place where pilots take off for the task.

Speed section: A timed section of the task where speed points are awarded. The pilots that complete the speed section fastest receive the most speed points.

Start of speed section (SSS): The location where timing of the task starts. In a task definition, this is either an exit or an entry cylinder. For an individual pilot, it's the place where he crossed that cylinder to begin flying the speed section.

Race start: The time when pilots are allowed to cross SSS and begin flying the speed section. In a race to goal task with a single start gate, this is also the start time for all pilots.

End of speed section (ESS): The cylinder/line/point where timing of the task stops.

Goal: The finish line or cylinder defining the task's end. Can be identical to ESS, but is often chosen as a line or a smaller cylinder inside a bigger ESS cylinder for safety reasons.

Start time: Time when a pilot starts flying the speed section.

Start gate: A timing reference for SSS. Depending on the chosen start procedure, multiple Start Gates can be available, offering pilots a choice of different race start times.

Turnpoint (TP): A turnpoint is a geographical point, defined by coordinates and altitude above mean sea level.

Cylinder: A cylinder is defined by a turnpoint at its center, and the cylinder's radius.

Task distance: The shortest possible distance a pilot has to fly to finish the task. This means he has to fly to the boundary of each cylinder, not the turnpoints at the cylinders' centers.

Window open time: The time from when on pilots are allowed to take off.

Task deadline: The time until which pilots' flights are being scored. All distance covered after this time will not be counted for scoring.

4   Competition Parameters

Before the first task, the following parameters must be defined by the meet director, or another person or group as defined by the competition's local regulations:

1. Nominal Distance
2. Minimum Distance
3. Nominal Goal
4. Nominal Time

The values set for these parameters define how each task's validity is calculated. They should therefore be chosen very carefully, considering the realistic potential of the flying site. Setting the values too low will prevent the formula from distinguishing between demanding, high quality tasks and quick, easy low quality tasks which are sometimes the only option due to weather conditions.

4.1   Nominal Distance

Nominal distance should be set to the expected average task distance for the competition. Depending on the other competition parameters and the distances actually flown by pilots, tasks shorter than Nominal Distance will be devalued in most cases. Tasks longer than nominal distance will usually not be devalued, as long as the pilots fly most of the distance.

In order for GAP to be able to distinguish between good and not-so-good tasks, and devalue the latter, it is important to set nominal distance high enough[1].

4.2   Minimum Distance

The minimum distance awarded to every pilot who takes off. It is the distance below which it is pointless to measure a pilot's performance. The minimum distance parameter is set so that pilots who are about to "bomb out" will not be tempted to fly into the next field to get past a group of pilots – they all receive the same amount of points anyway.

4.3   Nominal Goal

The percentage of pilots the meet director would wish to have in goal in a well-chosen task. This is typically 20 to 40%. This parameter has a very marginal effect on distance validity (see section 7.2).

4.4   Nominal Time

Nominal time indicates the expected task duration, the amount of time required to fly the speed section. If the fastest pilot's time is below nominal time, the task will be devalued. There is no devaluation if the fastest pilot's time is above nominal time.

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[1] See also this excellent series of articles on the subject: Part 1:http://ozreport.com/1360767307; Part 2: http://ozreport.com/1360858575; Part 3: http://ozreport.com/1360944246

Nominal time should be set to the expected "normal" task duration for the competition site, and nominal distance / nominal time should be a bit higher than typical average speeds for the area.

5 Task Setting
5.1 *Definition of a task*

A task definition consists of:

1. A launch point, given as GPS coordinates
2. A number of turnpoint cylinders
3. A goal
4. An indication which of the turnpoint cylinders is the start cylinder (start of speed section)
5. If goal does not serve as end of speed section: An indication which of the turnpoint cylinders is the end of speed section cylinder
6. A launch time window
7. Optionally, a task deadline
8. A start procedure, including timing

5.2 *Definition of a turnpoint cylinder*

A turnpoint cylinder is defined as:

1. A center point, given as GPS coordinates
2. A radius r, given in meters
3. An indication whether the cylinder is an "exit" or an "enter" cylinder. This defines whether the corresponding turnpoint is considered reached by a pilot when crossing the cylinder's boundary from its inside to the outside, or from its outside to the inside.

A turnpoint cylinder is then given as the cylinder with radius r around the axis which cuts the x/y plain orthogonally at the cylinder's center point. For task evaluation purposes, only the cylinder's projection in the x/y plain is considered: a circle of radius r around its center point.

Note that for start cylinders (SSS), "enter" only makes sense if the following turnpoint cylinder lies within the SSS cylinder. Likewise, an "exit" only makes sense if the first turnpoint lies outside of the SSS cylinder. Currently, the start direction cannot be set within FS, instead the program automatically scores according to this logic.

5.3 *Definition of goal*

A goal can be

1. A cylinder (enter or exit), see above, or
2. A line, defined by:
   a. A center point, given as GPS coordinates
   b. A length l, given in meters

A goal line is then defined as a band of x/y width l through the center point, which is cut orthogonally by the x/y projection of the connecting line between the center of the last cylinder before goal with a different center point than goal, and the goal line's center point.

For task evaluation purposes, only the band's projection in the x/y plain is considered: a line through the center point (G) which is perpendicular to the connecting line between the center of the last cylinder before goal with a different center point than goal (P), and the goal line's center point, and which extends for *l/2* into both directions from the center point.
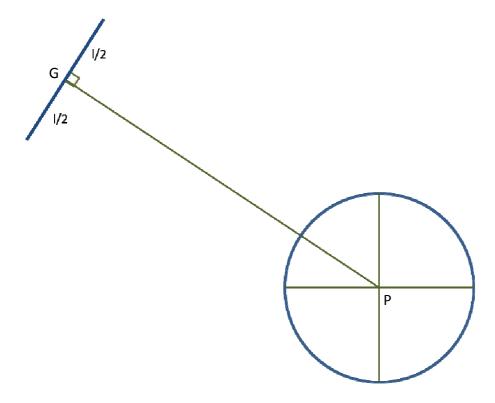

Figure 2: Goal line definition

5.4 Start procedures

Start procedures define how an individual pilot's start time is determined. A start can be either air- or ground-started, and it can be either a race to goal or an elapsed time start.

5.4.1 Air start

For air-started tasks, the competitors are free to launch any time during the launch window, and to fly about, regardless of any turnpoint or start cylinders, up to their race start. Race start is defined as the crossing of the start cylinder in the prescribed direction for the last time before continuing to flying through the remainder of the task.

5.4.2 Ground start

In a ground-started task, the race starts with the pilots' launch. Since a launch can be difficult to detect from a GPS track, the task setters must set a cylinder around the launch area as the first turnpoint. A pilot's start is registered when he exits this cylinder for the first time. In the case of a race to goal task, the launch window open time is the same as the first (or only) start gate time.

5.4.3 Race to goal

A race to goal start is defined by one or more so-called "start gates". The first – or only – start gate is given as a daytime. Subsequent start gates are given as a time interval, along with the number of start gates.

Example 1: "We have a Race to Goal task, the start gate opens at 13:00"

Example 2: "We have a Race to Goal task with 5 start gates from 13:30 at a 20 minutes interval." – the start gate times in this case are 13:30, 13:50, 14:10, 14:30, and 14.50.

Pilots are free to start any time after the first (or single) start gate. A pilot's start time is then defined as the time of the last start gate after which he started flying the speed section of the task.

Example 3: Given the start gates from Example 2 above, pilot A, crossing the start cylinder at 13:49:01, will be given a start time of 13:30. Any pilot starting after 14:50 will be given a start time of 14:50.

Starting before the first (or only) start gate is considered a failed start. Some refer to this as "jumping the gun". The two disciplines handle failed starts differently, see section 10.2.

5.4.4 Elapsed time

An elapsed time start is defined by a single "start gate", given as a daytime. Pilots are free to start any time after this start gate. A pilot's start time is then defined as the time at which he started flying the speed section of the task. Each pilot has therefore an individual start time.

Example 1: "We have an Elapsed Time task, the start gate opens at 12:30" – pilot A starting at 12:31:03 has a start time of 12:31:03, pilot B starting at 15:48:28 has a start time of 15:48:28.

5.5 Distance measurement

Since task evaluation occurs in the x/y plain, distance measurements are always exclusively horizontal measurements.

Coordinates are always given as WGS84 coordinates. The coordinate format can be chosen by the organizers. For evaluation, all coordinates are first converted to degrees latitude and longitude, and then to radians:

$$lat_{rad} = \frac{lat_{deg} * \pi}{180}$$

$$long_{rad} = \frac{long_{deg} * \pi}{180}$$

The distance between two points, identified by their radian coordinates lat1/long1 and lat2/long2, is calculated using the Haversine formula on the FAI sphere with a radius of 6371.0 km.

$$distLat = lat2 - lat1$$

$$distLong = long2 - long1$$

$$a = (\sin \frac{distLat}{2})^2 + \cos lat1 * \cos lat2 * (\sin \frac{distLong}{2})^2$$

$$radianDistance = 2 * \arctan 2(\sqrt{a}, \sqrt{1-a})$$

$$distance = radianDistance * 6371000$$

To reproduce this formula in Excel, the following modification is necessary due to a different implementation of the arctan2 function:

$$radianDistance = \pi - 2 * \arctan 2(\sqrt{a}, \sqrt{1-a})$$

5.5.1 Task distance

Task distance is defined as the path of shortest distance from the start point to goal that touches all turnpoint cylinders. The method to calculate this distance is buried in FS' code and will have to be documented at a later point.

Currently, this method mistreats the case where after ESS one or several turnpoints have to be reached with centers different from ESS' center point: The two legs to and from ESS are optimized for distance as well, which can result in a longer last leg before ESS than what pilots experience in reality. As a result, pilots can reach ESS with a shorter flown distance than what FS indicates is the distance required to reach ESS. This only affects pilots landing between ESS and goal, but does not represent a disadvantage to those pilots. The speed section distance calculation used for scoring (see below) is not affected by this.

5.5.2 Speed section distance

Speed section distance is defined as the path of shortest distance from start of speed section to end of speed section that touches all turnpoint cylinders. The method to calculate this distance is the same as for task distance, and will have to be documented at a later point.

5.6 Flying a task

Given a task definition, the pilots' task then consists in launching at the launch point within the launch time window, reaching all given turnpoint cylinders in the given order and direction (enter or exit), including the start of speed section cylinder at a time permitted by the start procedure. The task is concluded by crossing the goal line in the direction from the last cylinder before goal with a different center point than goal towards goal. In the absence of a goal line, the task conclusion is achieved by reaching the final turnpoint cylinder. If a task deadline is given, flights are only considered up to that time.

6 Task evaluation

From each pilot's track, task evaluation determines the distance this pilot flew along the task, and the time this pilot took to fly the speed section.

6.1 Reaching a cylinder

A cylinder is considered "reached" by a pilot if that pilot's track log shows the pilot crossing out of the cylinder in the case of an exit cylinder, or into the cylinder in case of an enter cylinder, by containing at least one track point closer to the cylinder's center than the cylinder radius (enter) or further away from the cylinder's center than the cylinder radius (exit). During task evaluation, only the x/y coordinates are considered, and a point must lie within (enter) or outside of (exit) the circle representing the turnpoint cylinder in the x/y plain. This is determined by measuring the distance between a track point and the turnpoint. This distance must be greater (exit) or smaller (enter) than the cylinder's radius.

To compensate for different distance calculations and different earth models in use by today's GPS devices, a 0.5% tolerance is used for this calculation. This had to be introduced so that a pilot reading the distance to the next cylinder center from his GPS device can rely on having reached the turnpoint when the distance displayed by the instrument is smaller than the turnpoint radius.

For enter cylinders, this means that a tracklog point that is closer to the turnpoint than r*1.005 is considered proof for reaching the turnpoint. For exit cylinders, this means that a tracklog point that is further away from the turnpoint than r*0.995 is considered proof for reaching the turnpoint.

The time when a cylinder was reached is determined by the time a so-called "crossing" occurred. A crossing is defined as a pair of consecutive track points, of which at least one lies inside the band determined by the turnpoint's center, its radius and the 0.5% tolerance mentioned above.

$$crossing_{turnpoint_i} : \exists j : (\text{distance}(center_i, trackpoint_j) >= radius_i * 1 - 0.5\%$$

$$\wedge \text{distance}(center_i, trackpoint_{j+1}) <= radius_i * 1 + 0.5\%)$$

$$\vee (\text{distance}(center_i, trackpoint_{j+1}) >= radius_i * 1 - 0.5\%$$

$$\wedge \text{distance}(center_i, trackpoint_j) <= radius_i * 1 + 0.5\%)$$

The time of a crossing depends on whether it actually cuts across the actual cylinder, or whether both points lie within the tolerance band, but on the same side of the actual cylinder.

$$(\text{distance}(center_i, trackpoint_j) < radius_i \wedge \text{distance}(center_i, trackpoint_{j+1}) < radius_i)$$

$$\vee (\text{distance}(center_i, trackpoint_j) > radius_i \wedge \text{distance}(center_i, trackpoint_{j+1}) > radius_i)$$

$$\wedge turnpoint_i = ESS : crossing.time = trackpoint_{j+1}.time$$

$$(\text{distance}(center_i, trackpoint_j) < radius_i \land \text{distance}(center_i, trackpoint_{j+1}) < radius_i)$$

$$\lor (\text{distance}(center_i, trackpoint_j) > radius_i \land \text{distance}(center_i, trackpoint_{j+1}) > radius_i)$$

$$\land turnpoint_i \neq ESS : crossing.time = trackpoint_j.time$$

$$(\text{distance}(center_i, trackpoint_j) < radius_i \land \text{distance}(center_i, trackpoint_{j+1}) > radius_i)$$

$$\lor (\text{distance}(center_i, trackpoint_j) > radius_i \land \text{distance}(center_i, trackpoint_{j+1}) < radius_i) :$$

$$crossing.time = \text{interpolateTime}(trackpoint_{j+1}, trackpoint_{j+1})$$

The method used to interpolate the crossing time is buried in FS' code and will have to be documented at a later point.

Finally, given all n crossings for a turnpoint cylinder, sorted in ascending order by their crossing time, the time when the cylinder was reached is determined.

$$turnpoint_i = SSS : reachingTime_i = crossing_n.time$$

$$turnpoint_i \neq SSS : reachingTime_i = crossing_0.time$$

6.2 Flown distance

To determine a pilot's flown distance, a first step determines which turnpoints he reached considering all timing restrictions: launch within launch time window, valid start, but only until the task deadline time. After the last turnpoint the pilot reached, for every remaining track point, the shortest distance to goal is calculated using the method described in section 5.5.1. The flown distance is then calculated as task distance minus the shortest distance the pilot still had to fly. Therefore, for scoring, the pilot's best distance along the course line is considered, regardless of where the pilot landed in the end.

If a pilot flies less than minimum distance, he will be scored for this minimum distance.

If a pilot reaches goal, he will be scored for the task distance.

$$\forall p : p \in PilotsLandingBeforeGoal : bestDistance_p = \max(minimumDistance,$$

$$taskDistance - \min(\forall track_p.point_i \text{ shortestDistanceToGoal}(track_p.point_i)))$$

$$\forall p : p \in PilotsReachingGoal : bestDistance_p = taskDistance$$

6.3 Time for speed section

The time a pilot took to fly the speed section is determined by his start time (which is influenced by the task's start procedure and the time he crossed the start of speed section cylinder) and the time when he crossed the end of speed section after reaching all previous turn points. The smallest unit for time measurement is one second.

Pilots who do not reach the end of speed section cylinder do not get a time.

$$\forall p : p \in PilotsReachingESS : time_p = timeAtESS_p - startTime_p$$

7   Task Validity

The task validity is a value between 0 and 1 and measures how suitable a competition task is to evaluate pilots' skills. It is calculated for each task after the task has been flown, by multiplying the three validity coefficients: Launch validity, distance validity, and time validity.

$$TaskValidity = LaunchValidity * DistanceValidity * TimeValidity$$

7.1   Launch Validity

Launch validity depends on the percentage of pilots actually present at take-off who launched. If everybody on take-off launches, launch validity is 1, while if only 20% of the pilots present at take-off launch, launch validity goes down to about 0.1.

The reasoning behind launch validity: Launch conditions may be dangerous, or otherwise unfavorable. If a significant number of pilots at launch think that the day is not worth the risk of launching, then the gung-ho pilots who did go will not get so many points. This is a safety mechanism.

'Pilots present' are pilots arriving on take-off, with their gear, with the intention of flying. For scoring purposes, 'Pilots present' are all pilots not in the 'Absent' status (ABS): Pilots who took off, plus pilots present who did not fly (DNF). DNFs need to be attributed carefully. A pilot who does not launch due to illness, for instance, is not a DNF, but an ABS.

$$LVR = \frac{NumberOfPilotsFlying}{NumberOfPilotsPresent}$$

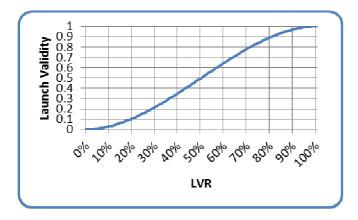$$LaunchValidity = 0.028 * LVR + 2.917 * LVR^2 - 1.944 * LVR^3$$

Figure 3: Launch validity curve

7.2   Distance Validity

Distance validity depends on nominal distance, nominal goal, the longest distance flown and the sum of all distances flown beyond minimum distance. If the task distance is quite short in relation to nominal distance, the day is probably not a good measure of pilot skill because there would not be many decisions to make.

If a task is longer than nominal distance, the day will not be devalued because of distance validity, even if the nominal goal parameter value is not achieved, as long as a fair percentage of pilots fly a good distance. This sounds like a vague statement, but the task setter should try to set tasks that are reasonable for the day and achievable. If everyone lands in goal, you must ask if this was a valid test of skill - it probably was if the fastest time and the distance flown were reasonably long. If everyone lands short of goal, was it an unsuitable task but still a good test of pilot skill? You also can have the case where a task that is shorter than nominal distance, has a distance validity of almost 1. This will happen when a large percentage of the pilots fly a large percentage of the course but, in this case, you still have a practical devaluation because there will be little spreading between pilots' scores.

In the formula below, 'p' denotes an individual pilot.

$$SumOfFlownDistancesOverMinDist = \sum_p \max(0, FlownDist_p - MinDist)$$

$$NomDistArea = \frac{((NomGoal + 1) * (NomDist - MinDist)) + \max(0, (NomGoal * (BestDist - NomDist)))}{2}$$

$$DVR = \frac{SumOfFlownDistancesOverMinDist}{NumPilotsFlying * NomDistArea}$$

$$DistanceValidity = \min(1, DVR)$$

7.3 Time Validity

Time validity depends on the fastest time to complete the speed section, in relation to nominal time. If the fastest time to complete the speed section is longer than nominal time, then time validity is always equal to 1.

If the fastest time is quite short, the day is probably not a good measure of pilot skill because there would not be many decisions to make and, because of this, luck can distort scores as there will be little possibility to recover any accidental loss of time.

If no pilot finishes the speed section, then time validity is not based on time but on distance: The distance of the pilot who flies the furthest in relation to nominal distance is then used to calculate the time validity the same way as if it was the time.

If one pilot reached ESS: $TVR = \min(1, \frac{BestTime}{NominalTime})$

If no pilot reached ESS: $TVR = \min(1, \frac{BestDistance}{NominalDistance})$

$$TimeValidity = \max(0, \min(1, -0.271 + 2.912 * TVR - 2.098 * TVR^2 + 0.457 * TVR^3))$$
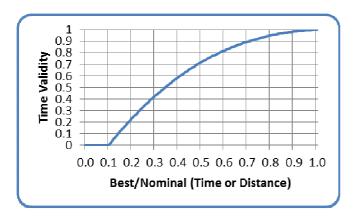
Figure 4: Time validity curve

8 Points Allocation

The available points for each task are 1000*Task Validity. These points are distributed between distance points, time points, leading points and arrival points. The distribution depends on the percentage of pilots who reached goal before the task deadline, compared to pilots who launched, as well as the chosen goal form. It is expressed in terms of weight factors for each of the four point categories: Distance weight, time weight, leading weight and arrival weight. Weight factors are always between 0 and 1. A weight factor of 0.5 for distance, for example, means that 50% of the day's available overall points are available for distance points.

$$GoalRatio = \frac{NumberOfPilotsInGoal}{NumberOfPilotsFlying}$$

$$DistanceWeight = 0.9 - 1.665 * GoalRatio + 1.713 * GoalRatio^2 - 0.587 * GoalRatio^3$$

$$LeadingWeight = \frac{1 - DistanceWeight}{8} * 1.4$$

$$ArrivalWeight = \frac{1 - DistanceWeight}{8}$$

$$TimeWeight = 1 - DistanceWeight - LeadingWeight - ArrivalWeight$$

$$AvailableDistancePoints = 1000 * TaskValidity * DistanceWeight$$
$$AvailableTimePoints = 1000 * TaskValidity * TimeWeight$$
$$AvailableLeadingPoints = 1000 * TaskValidity * LeadingWeight$$
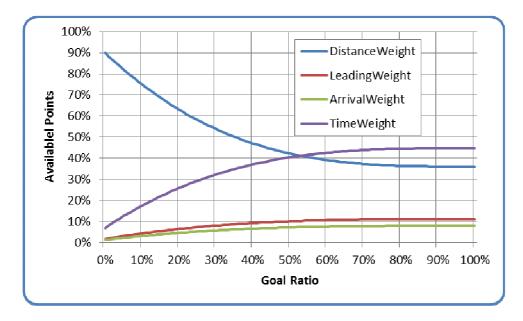$$AvailableArrivalPoints = 1000 * TaskValidity * ArrivalWeight$$

Figure 5: Points allocation curves

8.1 No pilots reach ESS or goal

From the above it follows that if nobody reaches ESS, then a maximum of 900 points are available for distance and 18 points for leading but, of course, no points for time nor arrival. This applies to hang-gliding competitions.

$numberOfPilotsAtESS = 0 :$

$AvailableDistancePoints = 1000 * TaskValidity * DistanceWeight$

$AvailableTimePoints = 0$

$AvailableLeadingPoints = 1000 * TaskValidity * LeadingWeight$

$AvailableArrivalPoints = 0$

$Max(AvailableDistancePoints) = 900$

$Max(vailableLeadingPoints) = 18$

$Max(vailableTotalPoints) = 918$

In paragliding competitions, if nobody reaches goal (regardless whether ESS was reached or not), then the maximum number of points is further reduced by 20%.

$numberOfPilotsAtGoal = 0 :$

$AvailableDistancePoints = 0.8 * 1000 * TaskValidity * DistanceWeight$

$AvailableTimePoints = 0$

$AvailableLeadingPoints = 0.8 * 1000 * TaskValidity * LeadingWeight$

$AvailableArrivalPoints = 0$

$Max(AvailableDistancePoints) = 720$

$Max(AvailableLeadingPoints) = 14$

$Max(AvailableTotalPoints) = 734$

9 Pilot Score

Each pilot's score is the sum of that pilot's distance, time, leading and arrival points.

$$\forall p : p \in PilotsLaunched : TotalScore_p = DistancePoints_p + TimePoints_p + LeadingPoints_p$$
$$+ ArrivalPoints_p$$

9.1 Distance Points

The distance considered for each pilot to calculate distance points is that pilot's best distance along the course line, up until the pilot landed or the task deadline was reached, whichever comes first. In the case of a stopped task, this distance may be increased by an altitude bonus (see 10.3.1). One half of the available distance points are assigned to each pilot linearly, based on the pilot's distance flown in relation to the best distance flown in the task. The other half is assigned taking into consideration the difficulty of the kilometers flown.

$$LinearFraction_p = \frac{Distance_p}{2 * BestDistance}$$

$$iDist10_p = int(Distance_p * 10)$$
$$DifficultyFraction_p = DiffScore_{iDist10_p} + ((DiffScore_{iDist10_p+1} - DiffScore_{iDist10_p})$$
$$* (Distance_p * 10 - iDist10_p))$$

$$DistancePoints_p = (LinearFraction_p + DifficultyFraction_p) * AvailableDistancePoints$$

9.1.1 Difficulty Calculation

To measure the relative difficulty of each 100 meters of the task, we consider the number of pilots who landed in the successive few kilometers, and the distance flown.

In a first step, for each 100 meter section of the task, the number of pilots who landed in that section is counted. Pilots who landed before minimum distance are counted as having landed at minimum distance. Only pilots who landed out are considered for this calculation, pilots who reached goal are not counted.

$$\forall i : i < int(MinDist * 10) : PilotsLanded_i = 0$$
$$PilotsLanded_{int(MinDist*10)} = \sum_{\forall Pilot : int(Pilot.Distance*10) \leq int(MinDist*10)} 1$$
$$\forall i : i > int(MinDist * 10) \& i \leq int(MaxDist * 10) : PilotsLanded_i = \sum_{\forall q : q \in PilotsLandedOut : int(Distance_q*10)=i} 1$$

Then the difficulty for each 100 meter section of the task is calculated by counting the number of pilots who landed further along the task. If 100 pilots land out on a flight of 100 km, the next 3 km are considered. If 10 pilots land out in 100 km, the next 30 km are

considered. The variable LookAheadDist contains the number of 100 meter slots to look ahead for this.

$$LookAheadDist = \max(30, round(\frac{30 * BestDistanceFlown}{NumberOfPilotsLandedOut}, 0))$$

$$\forall i :\leq \text{int}(MaxDist*10) : Difficulty_i = \sum_{j=i}^{j=\min(i+LookAheadDist, \text{int}(BestDistanceFlown*10))} PilotsLanded_j$$

$$SumOfDifficulty = \sum_i Difficulty_i$$

Relative difficulty is then calculated by dividing each 100 meter slot's difficulty by twice the sum of all difficulty values.

$$\forall i : i \leq \text{int}(MaxDist*10) : RelativeDifficulty_i = \frac{Difficulty_i}{2 * SumOfDifficulty}$$

Finally, we can calculate the difficulty score percentage for each 100 meter slot.

$$\forall i : i \leq \text{int}(MinDist*10) : DiffScore_i = \sum_{j=0}^{j=\text{int}(MinDist*10)} RelativeDifficulty_j$$

$$\forall i : i > \text{int}(MinDist*10) \& i < \text{int}(BestDistanceFlown*10) : DiffScore_i = \sum_{j=0}^{j=i} RelativeDifficulty_j$$

$$\forall i : i \geq \text{int}(BestDistanceFlown*10) : DifffScore_i = 0.5$$

9.1.2 Example

For an example, see Figure 6: Note how the slope of the green curve (the total Distance points) becomes steeper before an area where many pilots landed and flatter just after. The red circles show these areas before the big group at the 41 km mark, and after the 46 km mark. There are two reasons for this:

1. For safety and retrieval reasons, we do not want to encourage pilots to fly only a short distance past a group of landed pilots.
2. If a pilot lands somewhere, he or she probably got into trouble just before, and then glided a while before landing.
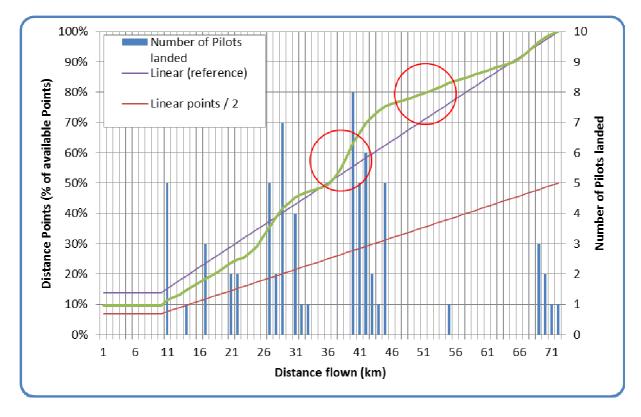
Figure 6: Sample Distance Points

9.2 Time Points

Time points are assigned to the pilot as a function of best time and pilot time – the time the pilot took to complete the speed section. Slow pilots will get zero points for speed if their time to complete the speed section is equal to or longer than the fastest time plus the square root of the fastest time. All times are measured in hours.

$$SpeedFraction_p = \max(0, 1 - \sqrt[3]{\frac{(Time_p - BestTime)^2}{\sqrt{BestTime}}})$$

$$TimePoints_p = SpeedFraction_p * AvailableTimePoints$$

Examples

For three examples of Time Point distributions for tasks with different best times, see Figure 7 and Table 1.
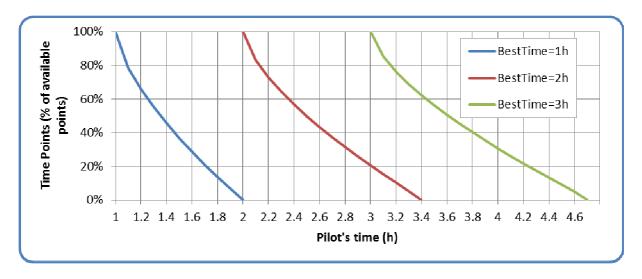
Figure 7: Sample time point distributions

Fastest Time	80% Time Points time	50% Time Points time	0 Time Points time
1:00	1:05	1:21	2:00
2:00	2:08	2:30	3:24 (3.4 hours)
3:00	3:09	3:37	4.42 (4.7 hours)

Table 1: Sample time point distribution (all times in hours:minutes)

9.3 Leading Points

Leading points are awarded to encourage pilots to start early and to rewards the risk involved in flying in the leading group. Pilots will get leading points even if they landed before goal or the end of speed section.

$$LC_{min} = \min(\forall p : p \in PilotsFlown : LC_p)$$

$$LeadingFactor_p = \max(0, 1 - \sqrt[3]{\frac{(LC_p - LC_{min})^2}{\sqrt{LC_{min}}}})$$

$$LeadingPoints_p = LeadingFactor_p * AvailableLeadingPoints$$

To get an impression of the way leading points are awarded depending on a task's minimal leading coefficient, see Figure 8.
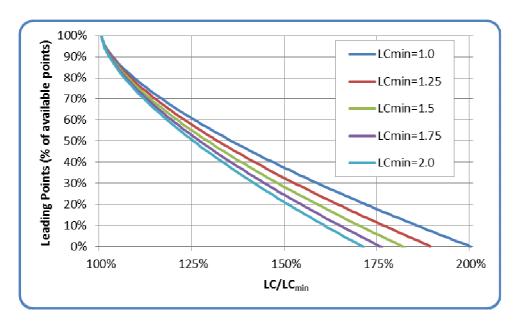
Figure 8: Leading points for various LC$_{min}$

9.3.1 Leading Coefficient

Each started pilot's track log is used to calculate the leading coefficient (LC), by calculating the area underneath a graph defined by each track point's time, and the distance to ESS at that time. The times used for this calculation are given in seconds from the moment when the first pilot crossed SSS, to the time when the last pilot reached ESS. For pilots who land out after the last pilot reached ESS, the calculation keeps going until they land. The distances used for the LC calculation are given in kilometers and are the distance from each point's position to ESS, starting from SSS, but never more than any previously reached distance. This means that the graph never "goes back": even if the pilot flies away from goal for a while, the corresponding points in the graph will use the previously reached best distance towards ESS.

$$LC_p = \frac{\sum\limits_{i:tp_i \in TrackPointsInSS_p} \text{taskTime}(tp_i) * (\text{bestDistToESS}(tp_{i-1}) - \text{bestDistToESS}(tp_i))}{1800 * LengthOfSpeedSection}$$

$\forall p : p \in PilotsLandedOut \wedge \text{taskTime}(tp_{max}) < ESSTime_{LastPilotAtESS} :$

$LC_p = LC_p + LastTime_{LastPilotAtESS} * \text{bestDistToESS}(tp_{max})$

$\forall p : p \in PilotsLandedOut \wedge \text{taskTime}(tp_{max}) \geq ESSTime_{LastPilotAtESS} :$

$LC_p = LC_p + \text{taskTime}(tp_{max}) * \text{bestDistToESS}(tp_{max})$

$\text{taskTime}(tp) = \min(TaskDeadline, \text{time}(tp))$

$\text{bestDistToESS}(tp_0) = LengthOfSpeedSection$

$\forall i : i > 0 \wedge tp_i \in TrackPointsInSS_p :$

$\text{bestDistToESS}(tp_i) = \min(\text{bestDistToESS}(tp_{i-1}), LenghtOfSpeedSection - \text{distanceFlown}(tp_i))$
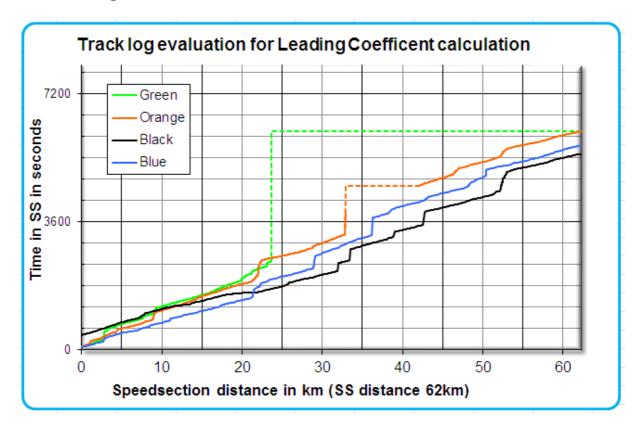
9.3.2 Example

Figure 9: Sample track log graphs for LC calculation

Blue was the first to enter the speed section, but Black was the first pilot to cross the end of speed section. Green started at the same time as Blue, but landed short, after about 23km and just over 40 minutes of flight inside the speed section.

Black was fastest, therefore will get the most time points, but he started late, probably had pilots out front to show the way during the first 22km, but was leading after that.

If a pilot lands along the course (Green), or if his track log is interrupted (Orange), his track log is completed as shown by the dotted lines: Missing parts are calculated as if the dotted line was the actual track log, so LC becomes bigger, lowering the leading points for that pilot, compared to a track where that part is not missing. A pilot landing just short of goal will be less penalized and could even get full leading points if he led for a long while.

The pilot who used best the earliest part of the day (i.e. Black, who has the smallest area below the track log graph) gets all the available leading points, while the others gets their points according to the same formula used for the time points for the same reasons. If the task in the example is fully valid, and 30% of pilots reached goal, then Black will get all of the available 81 leading points and full time points, as he was fastest; Blue gets 45 leading points because he started early but was slower; Orange receives only 18 leading points as he was slow and had a gap in his track log; Green gets 0 points even though he started early, because he was the slowest and landed fairly short.

9.4 Arrival Points

Arrival points depend on the position at which a pilot crosses ESS: The first pilot completing the speed section receives the maximum available arrival points, while the others are awarded arrival points according to the number of pilots who reached ESS before them. The last pilot to reach ESS will always receive at least 20% of the available arrival points.

$$AC_p = 1 - \frac{PositionAtESS_p - 1}{NumberOfPilotsReachingESS}$$

$$ArrivalFraction_p = 0.2 + 0.037 * AC_p + 0.13 * AC_p{}^2 + 0.633 * AC_p{}^3$$

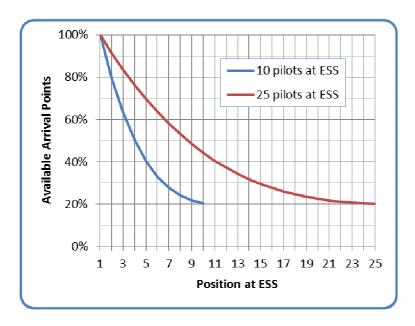$$ArrivalPoints_p = ArrivalFraction_p * AvailableArrivalPoints$$

Figure 10: Sample arrival points distributions

10 Special Cases
10.1 ESS but not goal

In a task where ESS and goal are not identical, a pilot may reach ESS, but not goal. The way this case is handled differs between hang-gliding and paragliding competitions:

In paragliding competitions, reaching goal is seen as "validating" one's speed section performance. A pilot who does not reach goal after reaching ESS will lose his time and arrival points, he will only score distance points for the distance actually covered, and leading points. This is seen as a safety measure, since it encourages pilots to plan their final glide to ESS with enough altitude to safely reach goal. This discourages high-speed final glides low to the ground.

$$\forall p : p \in PilotsLandedBetweenESSandGoal : TotalScore_p = DistancePoints_p + LeadingPoints_p$$
$$+ 0 * (TimePoints_p + ArrivalPoints_p)$$

In hang-gliding competitions, landing between ESS and goal is seen as a slight mishap, which incurs a penalty on the pilot's total score: Of the time and arrival points scored on the speed section, the pilot will only receive 80%[2].

$$\forall p : p \in PilotsLandedBetweenESSandGoal : TotalScore_p = DistancePoints_p + LeadingPoints_p$$
$$+ 0.8 * (TimePoints_p + ArrivalPoints_p)$$

10.2 Early start

An early start exists if a pilot's last SSS cylinder boundary crossing in start direction (enter or exit) occurred before the first (or only) start gate time.

In paragliding, pilots who perform an early start are only scored for the distance between the launch point and the SSS cylinder, as calculated when determining the complete task distance (see 5.5.1).

In hang-gliding, the so-called "Jump the Gun"-rule applies: If the early start occurred within a time that is close to the first (or only) start gate time, the pilot is scored for his complete flight, but a penalty is then applied to his total score.

The penalty calculation is based on two values X and Y, which are set in S7A, but can be changed at the task briefing (presumably by the meet director and/or the task committee). For each X seconds a pilot starts early, he incurs a 1 point penalty, up to a maximum of Y seconds. If a pilot starts more than Y seconds early, he will only be scored for minimum distance.

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[2] Note that this „rule" is not defined in S7A, but is implemented in FS. Some clarification on the rightfulness of this will be required.

$$X_{default} = 3$$

$$Y_{default} = 300$$

$$timeDiff_p = firstStartGateTime - lastStartTime_p$$

$$timeDiff_p <= 0 : jumpTheGunPenalty_p = 0$$

$$timeDiff_p > Y : jumpTheGunPenalty_p = 0, totalScore_p = scoreForMinDistance$$

$$0 < timeDiff_p <= Y : jumpTheGunPenalty_p = \frac{timeDiff_p}{X}$$

$$totalScore_p = totalScore_p - jumpTheGunPenalty_p$$

10.3 Stopped tasks

A task can be stopped at any time by the meet director. The time when a stop was announced for the first time is the "task stop announcement time". This time must be recorded to score the task appropriately. For scoring purposes, a "task stop" time is calculated. This is the time which determines whether a task will be scored at all. Pilots' flight will only be scored up to this task stop time.

In hang-gliding, stopped tasks are "scored back" by some time: The task stop time lies one start gate interval, or 15 minutes in case of a single start gate, before the task stop announcement time.

$$numberOfStartGates = 1 : taskStopTime = taskStopAnnouncementTime - 15min.$$

$$numberOfStartGates > 1 : taskStopTime = taskStopAnnouncementTime - startGateInterval$$

In paragliding, scoring back is not applied, task stop announcement time and task stop time are identical.

$$taskStopTime = taskStopAnnouncementTime$$

10.3.1   Requirements to score a stopped task

For a stopped task to be scored, it must fulfil certain requirements, which differ between the two disciplines:

In hang gliding, a stopped task can only be scored if either a pilot reached goal or the race had been going on for a certain minimum time. The minimum time depends on whether the competition is the Women's World Championship or not. The race start time is defined as the time when the first valid start was taken by a competition pilot.

$$typeOfCompetition = Women's : minimumTime = 60\min.$$

$$typeOfCompetition \neq Women's : minimumTime = 90\min.$$

$$taskStopTime - timeOfFirstStart < minimumTime \lor numberOfPilotsInGoal(taskStopTime) = 0 : taskValidity = 0$$

Note that this is currently not enforced by FS: The decision whether a stopped task is cancelled or scored must be taken by the score keeper.

In paragliding, no such minimum requirements are mentioned in the rules.

10.3.2 Reduced validity

In paragliding competitions, if no pilot reached goal in a stopped task, then task validity is reduced by 30%.

$$taskIsStopped \wedge numberOfPilotsInGoal = 0 :$$
$$AvailableDistancePoints = 0.7 * 1000 * TaskValidity * DistanceWeight$$
$$AvailableTimePoints = 0.7 * 1000 * TaskValidity * TimeWeight$$
$$AvailableLeadingPoints = 0.7 * 1000 * TaskValidity * LeadingWeight$$
$$AvailableArrivalPoints = 0.7 * 1000 * TaskValidity * ArrivalWeight$$

10.3.3 Altitude bonus

In paragliding competitions, to compensate for altitude differences at the time when a task is stopped, a bonus distance is calculated, based on each pilot's altitude above goal, and added to the pilot's actual distance. All altitude values are GPS altitude values, as received from the pilots' GPS devices (no compensation for different earth models applied by those devices). For all distance point calculations, including the difficulty calculations, these new stopped distance values are being used instead of the best distance values. Time and leading points calculations remain the same: they do not consider the altitude bonus or stopped distance values. This also means that pilots flying just before goal at task stop time, and whose stopped distance would take them into goal, will still not receive any Time Points.

$$GlideRatio = 2.0$$
$$StoppedDistanceRaw_p = \max(BestDistance_p,$$
$$DistanceAtStopTime_p + (AltitudeAtStopTime_p - GoalAltitude) * GlideRatio)$$
$$StoppedDistance_p = \min(TaskDistance, StoppedDistanceRaw_p)$$

10.4 Penalties

Penalties for various actions are defined in the rules. These penalties are either expressed as an absolute number (e.g. "100 points") or as a percentage (e.g. "10% of the pilot's score in the task where he performed the punishable action"). The corresponding number of points is then deducted from the punished pilot's score to calculate his final score.

$$finalScore_p = score_p - absolutePenalty_p$$
$$finalScore_p = score_p * (1 - percentagePenalty_p)$$

These penalties are completely independent of any "Jump the Gun"-Penalty a pilot may have incurred.

The penalty mechanism can also be used to award bonus points to a pilot for some actions like helping a pilot in distress. In that case the penalty must be given as a negative number.