# AeroCell C1

Wing-mounted airspeed, tracking & traffic unit

Technical whitepaper & GAP 2027 rule proposal

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A different approach to make paragliding competitions fair and safe again

# 1 · Executive summary

Paragliding competition has no verified airspeed measurement. Because speed cannot be measured, it is limited indirectly, through equipment rules in the CIVL Competition Class (CCC): a 140 mm cap on accelerator riser travel enforced by physical limiters, a ban on any device other than the controls that alters airspeed, and hand-measured line geometry. These rules are hard to police, easy to quietly exploit, and they constrain wing designers in ways that have nothing to do with safety.

The AeroCell C1 is a 68-gram sensor unit that lives **inside the wing**: its body sits flat in a standardised pocket sewn onto the bottom surface of the centre cell, and only a compact 52 mm sensor barrel rides outside, flush against the sail. It measures indicated, calibrated and true airspeed at the wing itself, fuses GNSS, barometric and inertial data, and streams a cryptographically signed telemetry feed three ways: to the pilot's instrument over Bluetooth, to the race server over LTE-M, and to nearby aircraft over FLARM.

On top of this measurement we propose one new task parameter for GAP 2027: **max_airspeed**. The meet director sets a maximum IAS per task, the scoring server enforces it automatically on a 5 s rolling average with a small tolerance, and sustained excursions receive progressive penalties computed from data that every pilot and steward can replay. With speed capped in the air instead of in the hardware, the CCC geometry rules that exist only to prevent cheating can be progressively retired, freeing manufacturers to build faster, cleaner and safer competition wings.

# 2 · The problem with indirect speed limits

## 2.1 · Airspeed is invisible today

A GPS tracklog records ground speed. Wind, thermals and gradient make it useless as evidence of what the wing was doing through the air. Riser-mounted airspeed probes exist (and prove pilots value the data), but they sit in air disturbed by the pilot's body (numerical simulations for riser-mounted sensors show roughly 5% underestimation from pilot proximity), and a rider-supplied, rider-positioned sensor can never serve as an enforcement instrument.

## 2.2 · Equipment rules as a proxy

The CCC requirements (FAI Sporting Code, Section 7G) bound top speed through hardware. Full acceleration may shorten the frontmost risers by at most 140 mm (tolerance 5 mm), and physical limiters must make any further shortening impossible. The controls must be the only means of altering airspeed in flight, which rules out trim tabs and similar devices. Line lengths are documented in the certification manual and checked at competitions with a tolerance of ±2 cm. Enforcement is physical: every glider is presented at registration for an acceptance check in the configuration in which it will be flown (Common Section 7, 5.2.5). Modifications made after that check, such as extended accelerator travel or re-trimmed lines, are effectively undetectable in the air. Honest pilots suspect rivals; protests are unresolvable; designers optimise around fraud-prevention geometry instead of aerodynamics.

## 2.3 · Safety by proxy fails exactly when it matters

A fixed geometric limit produces very different real speeds on a glassy evening task and in strong, rough air at 4,000 m. The parameter a safety committee actually cares about, how fast pilots fly through the air in today's conditions, is the one nobody can see or set.

# 3 · The AeroCell C1

## 3.1 · Mounting: inside the wing, outside the turbulence

The C1 consists of a 56 × 56 × 16 mm base plate that sits in a pocket sewn onto the interior of the bottom surface at the centre cell, immediately behind the shark-nose cell opening, closed with a zip and a numbered tamper seal, and a 52 mm sensor barrel that rides outside the sail on a 10 mm neck through a sealed grommet (total height 43 mm). Airspeed is measured right behind the shark nose. The barrel lies flush against the bottom surface with no gap between barrel and sail, so there is nothing for a line to catch; its pitot port faces forward into air that is metres away from pilot wake and riser interference, with static ports on the barrel aft of the pocket. All antennas (LTE, FLARM, GNSS, BLE) are integrated inside the case, so there is no wiring in the sail: the unit slides in and out of the pocket in seconds for charging and scrutineering, and nothing but the probe disturbs the airflow. The pocket pattern, grommet position and probe geometry are standardised across all CCC wings, so every pilot flies the same probe in the same aerodynamic reference position. Mass at the centre cell is the least sensitive location on the span for handling; 68 g is comparable to fabric-weight differences between size variants of the same model. Above all, the mounting point is chosen because it is physically out of the pilot's reach in flight: sealed into the wing at registration, the unit cannot be tilted, shielded, unplugged or repositioned once airborne, which no riser-mounted or cockpit-mounted sensor can guarantee.

## 3.2 · Hardware architecture

| Subsystem | Component (target spec) | Role |
|---|---|---|
| Airspeed | Dual differential pressure sensors, 50 Hz | IAS/CAS/TAS; redundancy and icing detection |
| GNSS | Multi-band L1/L5 receiver, 10 Hz | Position, ground speed, wind triangle |
| Barometer | ±0.1 hPa absolute sensor,<br>fed by probe static line | ISA altitude, airmass, TAS density correction |
| IMU | 9-axis, 100 Hz | Attitude, pitch events, gust rejection |
| Traffic | FLARM transceiver, ADS-L ready | Gaggle awareness, sailplane/rescue visibility |
| Live link | LTE-M / NB-IoT modem, 1 Hz uplink | Signed telemetry to race server |
| Pilot link | BLE 5.3 | Live IAS + alerts to XCTrack, SkyTrackPro,<br>SeeYou, FlySkyHi |
| Integrity | Secure element (ECDSA P-256) | Per-packet signatures, sealed identity |
| Storage | Signed IGC+ flight log, 200 h | Post-flight scoring evidence and replay |
| Power | LiPo 1.2 Ah, USB-C, 28 h endurance | Full comp week on two charges |

Total mass including barrel and pocket hardware: ≈ **68 g**. All antennas are internal to the case. Environmental target IP55, –20…+60 °C. No user-serviceable parts; the seal is broken only by scrutineers.

## 3.3 · Airspeed computation

The probe measures total pressure at the forward port and static pressure at circumferential ports. The differential pressure gives IAS via Bernoulli's relation; a single factory calibration, identical for every unit, converts IAS to CAS; density from the barometric and temperature channels yields TAS. No per-wing calibration is required: because every unit is identical and every wing carries it at the same standardised station, readings are directly comparable across the whole field, and the limit applies to the standardised reading itself. A small residual position error, shared equally by everyone, has no effect on fairness. Pitot-static probes of this type hold their accuracy over roughly ±40° of flow misalignment, comfortably covering pitch and AoA excursions in accelerated flight. A Kalman filter fusing pressure, GNSS and IMU channels rejects gusts and detects sensor disagreement; target system accuracy is ±1 km/h IAS in cruise.

### 3.4 · Static pressure: why the barometer is plumbed to the probe

The interior of a paraglider is not at ambient pressure: ram air through the cell openings holds the canopy inflated at close to stagnation pressure, noticeably above static, and it fluctuates with angle of attack and collapses. A barometer simply vented inside the pocket would therefore read low altitude and noisy data. The C1 housing is sealed against the pocket environment; its absolute pressure sensor samples the barrel's static line, exactly as an aircraft altimeter uses the static port. One probe supplies airspeed, barometric altitude and the density input for TAS.

## 4 · Data path and anti-tamper design

### 4.1 · Three consumers, one signed stream

| Channel | Rate | Content | Consumer |
|---|---|---|---|
| BLE 5.3 | 10 Hz | IAS/CAS/TAS, limit state, alerts | XCTrack, SkyTrackPro, SeeYou, FlySkyHi |
| LTE-M | 1 Hz | Signed position + airspeed frames | Race server: live tracking, scoring, replay |
| App relay | opportunistic | Same signed frames, forwarded by the pilot's instrument over its own connection | Race server: redundant second uplink |
| FLARM | std | Position broadcast + traffic alerts | Nearby gliders, sailplanes, rescue aircraft |
| IGC+ log | 10 Hz | Full signed flight record | Scorer download; protest-proof evidence |

### 4.2 · Why it can't be gamed

Every frame is signed by a secure element fused to the unit's identity at manufacture. The unit is sealed into the wing pocket at registration; seal number, unit ID and wing serial are recorded together. The scoring server accepts only frames signed by the registered unit. Removing the unit, feeding it recorded data, or substituting another unit breaks the signature chain or the physical seal. Loss of LTE coverage on the unit is mitigated twice over: the pilot's instrument, which already receives every frame over BLE, relays the same signed frames to the race server over its own internet connection whenever it has one. This is redundancy without trust: frames are signed end to end, so a relayed frame is exactly as trustworthy as a direct one, and the app can add nothing and alter nothing. If both paths drop, the signed IGC+ log remains the authoritative record, and the live feed is merely its preview. This extends existing practice rather than replacing it: the CIVL flight recorder specification (Section 7H) already makes A, H, B and G records mandatory and requires every IGC file to end in a digital security G record, and tracklogs from Category 1 events are already sent to CIVL and published. The C1 hardens the same G-record mechanism with a key that never leaves the sealed unit, and records at 10 Hz where Section 7H asks for fix intervals no longer than 30 s (1 to 10 s in practice). A pilot whose unit fails in flight falls back to the same rule used for tracker failure today: the signed log from the on-board record scores the task; total absence of a valid stream voids the task result.

# 5 · GAP 2027 proposal: the max_airspeed task parameter

## 5.1 · Definition

GAP scoring is already fully parameterised: the task committee sets nominal distance, nominal time, nominal goal, nominal launch and minimum distance, and CIVL's scoring software FS ('FScomp') computes results from GPS tracklogs (Section 7F). max_airspeed simply adds one parameter: the committee publishes, with the task board, a maximum indicated airspeed for the task, e.g. **max_airspeed = 57 km/h**. IAS is chosen deliberately: it is altitude-independent, matches the wing's aerodynamic loading, and is what the standardised instrument delivers most accurately. The value can change every day: it is distributed in the machine-readable task definition file (read by the scoring software and by pilots' instruments with the rest of the task), and the C1 writes it into the header of every signed IGC+ log, so each flight record permanently carries the limit it was flown under and remains self-contained evidence in any later protest or re-score. Technically this is a small extension of existing IGC practice: the limit is one more header line, and measured airspeed rides as B-record extensions declared in the I record, the same mechanism the IGC format already uses for fields such as ENL.

## 5.2 · Enforcement model

| Element | Proposed value | Rationale |
|---|---|---|
| Scored quantity | Vavg(t) = the 5 s rolling average of IAS from the sealed unit | One defined signal. Collapses, spiral exits and gust spikes are absorbed by the average, and there is no per-event grace timer that a pilot could reset by dipping under the limit |
| Overspeed | dV(t) = Vavg(t) – (max_airspeed + 2 km/h), counted only when positive | The +2 km/h tolerance covers sensor accuracy; at or below it the penalty is exactly zero |
| Straight-flight gate | Penalty and ceiling apply only while the 5 s mean turn rate (from GPS heading) is below 10°/s | Thermalling circles (15 to 20°/s) and spiral dives (40°/s and more) are legitimate climbing and descent maneuvers, not racing: they are exempt automatically, so an escape spiral never costs points |
| Penalty | $0.01 \times dV^3$ points per second, integrated over the whole task, rounded to 0.1 pt | Progressive from near zero: 1 km/h over costs 0.01 pt/s, so honest noise never adds up even over a 100 km task; 5 over costs 1.25 pts/s; 8 over costs 5 pts/s. Cubic in overspeed, as aerodynamic power is |
| Safety ceiling | Vavg(t) > max_airspeed + 10 km/h at any moment: the task scores zero | A hard wall on the averaged value: a one second spike cannot trigger it, five seconds of deliberate speed will |

The penalty fits the existing framework: Section 7 already expresses penalties as an absolute number of points or a percentage of the pilot's task score, ranging from a warning to disqualification (12.7.1). All thresholds are parameters in the GAP definition file; a plenary can retune them from event data without touching the rule text. Penalties are computed by the scoring software (FS-compatible) directly from the signed stream; results appear in the normal task report with per-second detail any pilot can audit.

Why there are no loopholes: there is no grace window, no event counter and no state to reset. Every second of the task is scored by the same published curve from the first, so there is no threshold to surf and no timer to game. The turn-rate gate cannot be exploited either: staying exempt means holding at least 10°/s of sustained turning, and S-turns that sharp lose more ground distance to heading error than the extra airspeed can recover, so weaving never pays; racing is straight, and straight flight is scored. The formula, its constants and the day's max_airspeed travel in the machine-readable task file; the pilot's instrument displays the same 5 s average the scorer uses; and the scoring software recomputes the identical number from the signed IGC+ log, so the live feed, the pilot's screen and the final score can never disagree.

### 5.3 · What it unlocks

**Pilots** get true airspeed on their instruments for the first time, better speed-to-fly decisions, FLARM visibility in the gaggle, and certainty that the leader flew the same limit. **Manufacturers** get a path out of anti-cheat geometry: with the limit enforced in the air, speed-system travel caps, riser constraints and trimmer bans can be relaxed stepwise, and CCC design effort returns to glide, stability and recovery behaviour. **Organizers and CIVL** replace rented trackers with integrated live tracking, replace post-flight forensics with live compliance, and gain a per-day safety lever for setting the task. What AeroCell delivers is a safer and fairer competition.

## 6 · Open questions and risks

| Risk / question | Mitigation path |
|---|---|
| Probe icing at altitude | Dual sensors; a frozen channel is flagged by cross-check against the GNSS wind triangle. A duty-cycled tip heater is an option only if prototype testing shows the battery budget allows it |
| Probe damage on launch / landing | Carbon probe on breakaway mount; spare units at scrutineering; tracker-failure rule applies |
| Sensor drift between units over time | Identical factory calibration for every unit; annual re-check and re-seal at scrutineering |
| Added mass and pocket certification | 68 g at centre cell; pocket pattern part of CCC load test; sail makers consulted on grommet spec |
| Cost per pilot / event | Target ≈ €300 per unit; replaces separately rented live trackers; federations may pool units |
| Data privacy of live IAS | Live feed to director only during task window; public feed carries position, not airspeed |
| EMC / radio certification (LTE + FLARM in one unit) | Standard module certification path; FLARM licensing precedent exists in powered devices |

## 7 · Roadmap

| Phase | Window | Milestone |
|---|---|---|
| Prototype | Q4 2026 | Wind-tunnel validation of pocket + probe; heater power-budget test; 10 units |
| Field trials | Spring 2027 | Guest category at PWC events; cross-wing validation on 3 CCC models |
| Rule proposal | CIVL Plenary 2027 | max_airspeed into Section 7 / GAP definition; enforcement parameters |
| Adoption | Season 2028 | Mandatory in Cat 1; FS scoring integration shipped |
| Deregulation | 2029 → | Stepwise relaxation of CCC geometry rules as enforcement data accumulates |

# 8 · References and prior art

1. FAI Sporting Code, Section 7G: CIVL Competition Class (CCC) Paragliders Requirements. Accelerator travel limited to 140 mm riser shortening (tolerance 5 mm) with mandatory physical limiters; controls must be the only means of altering airspeed; competition line checks against the manual at ±2 cm. fai.org.

2. FAI Sporting Code, Section 7F: XC Scoring (GAP), 2024 edition. Task parameters (nominal distance, time, goal, launch, minimum distance); scoring from GPS tracklogs by FS (FScomp); penalties as absolute points or a percentage of task score; Cat 1 distance tolerance 0.1%. fai.org.

3. FAI Sporting Code, Common Section 7 (2024, v3). Acceptance check of gliders at registration in flight configuration (5.2.5); penalty range from warning to disqualification (12.7.1); IGC files sent to CIVL and made public (12.6.5). fai.org.

4. FAI Sporting Code, Section 7H: CIVL Flight Recorder Specification (2024). A, H, B and G records mandatory; digital security signature appended as the G record; pressure and GNSS altitude both required; fix interval no longer than 30 s, typically 1 to 10 s. fai.org.

5. Vector Vario airspeed documentation, vectorvario.com. Riser mounting sits in pilot-disturbed air with roughly 5% underestimation shown by numerical simulation; differential-pressure measurement stable to about ±40° of flow misalignment; IGC+ recording of airspeed and attitude.

6. FLARM (flarm.com) and EASA ADS-L: collision-awareness broadcast protocols in gliding and light aviation.

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This document is a concept mockup produced for discussion. All specifications are targets, all names are working names, and the penalty model is illustrative.