



## Shedding Light on Windshear

DTN Light Detection and Ranging (LiDAR) Windshear Alerting System (LiWAS) is a state-of-the-art monitoring solution that tracks headwind/tailwind changes for airports.

LiWAS features a flexible scanning strategy and is easy to implement. It can be a stand-alone, enhance existing DTN LLWAS, or fully integrate with DTN Weather Systems.

This white paper describes its main components and methods, including its detection algorithm and configuration tool.

Wind changes over short distances are categorized as windshear. A wide range of phenomena can produce windshear, including thunderstorms, land and sea breezes, low-level jet streams, mountain waves, and frontal systems in both wet and dry environments.

Wind has a significant impact on flight safety. Windshear has been a primary or contributing factor in numerous aircraft accidents. When the headwind component changes sharply, the aircraft may experience a sudden loss of airspeed and lift, which can lead to a stall.

According to International Civil Aviation Organization, ground-based windshear detection systems should provide pilots with information on significant\* changes in wind along the take-off and final approach paths, up to 500 m (1,600 ft) above runway level. Particular emphasis is placed on the layer between the runway surface and 150 m (500 ft), including the runway itself.



### Enhancing windshear alerting systems in airports with LiDAR technology

Windshear is a sudden change in wind speed and/or direction over a short distance.

It can occur both horizontally and vertically and is dangerous for aircraft during takeoff and landing.

\* Significant changes are defined as those exceeding a headwind/tailwind change of 7.5 m/s (15 kt).

## Extending existing LLWAS

The ground-based windshear detection systems are classified as:

- In situ detection systems based on anemometers Low-Level Windshear Alerting System (LLWAS).
- Remote sensing systems based on Doppler Weather Radars or 3D Doppler Wind LiDAR.

These technologies can be used separately or as part of a system.

LLWAS is the most installed windshear alerting system worldwide, offering best-in-class windshear detection performance across all weather conditions. However, the performance of anemometer-based LLWAS depends directly on network geometry, and extending coverage area is not always feasible due to airport location or land-use restrictions in surrounding areas.

In such cases, integrating LLWAS with a remote sensing system installed within airport boundaries can improve coverage. LiDAR systems are well-suited for airports where windshear events occur primarily in clear-air conditions, such as sea breezes or terrain-induced windshear in dry weather.

A coherent Doppler LiDAR operates by transmitting an infrared laser beam and detecting radiation backscattered by atmospheric aerosol particles. The frequency shift in the returned signal (the Doppler effect) enables measurement of the line-of-sight component of the air motion.

## The glide path

LiDAR LiWAS is the result of years of research and detailed testing in adverse weather conditions. It is compatible with existing LLWAS or as a stand-alone solution.

In addition, DTN provides a windshear alert system integration algorithm that combines these systems into a single, unified output.

A key differentiator of the DTN LiWAS is its ability to detect windshear events not only near the runway threshold but also along the glide path.

Unlike other remote sensing systems that measure at a fixed elevation, LiWAS divides the glide path into different sections. It directs a laser beam to each section, measuring wind speed at the exact location through which the aircraft will pass. As a result, detection is more representative of actual flight conditions.

Depending on the runway's configuration, one or more LiDAR devices can be installed to optimize measurement accuracy and coverage.

// Users are informed of potential windshear events so they can anticipate and be prepared if conditions get worse.

## The LiWAS algorithm

The Glide Path Optimal Scanning Strategy Generator (GPOSS) is a configuration tool developed by DTN.

Based on the runway characteristics defined in the Aeronautical Information Publication, GPOSS determines where LiDAR aims and for how long, enabling reconstruction of the glide path headwind profile once per minute.

Once the system is fully deployed, LiWAS receives wind data in real-time. The main phases of the algorithm are:

1. **Headwind profile reconstruction.** Measurements are acquired from the LiDAR and reorganized along the line-of-sight between the touchdown zone and the glide path. This feature can be disabled.
2. **Three-step filtering.** In addition to LiDAR's built-in noise-cancelling features, unreliable measurements are removed using:
  - a. A signal-to-noise ratio threshold.
  - b. Comparison with adjacent data to identify outliers.
  - c. Temporal tracking of valid data points to detect inconsistencies.
3. **Effective range estimation.** When the data becomes too noisy, the farthest valid measurement defines the effective LiDAR range. This depends on atmospheric conditions and particle concentration.
4. **Smoothing at the windshear length-scale.** A convolution with a Gaussian distribution (i.e., a moving average) is applied to the filtered data, using a standard deviation such that fluctuations, which are significantly smaller than the windshear length-scale, are largely removed from the initial spiky set.
5. **Ramp detection.** Segments of wind speed gain/loss are detected in the smoothed profile. When overlapping ramps are detected, they are prioritized based on the ratio of total gain/loss to the horizontal distance over which it occurs. Ramp magnitude is derived from the input data.

6. **Windshear criteria (ICAO).** An alert is issued when the change in headwind exceeds 7.5 m/s (15kt).
7. **Alerting system users.** When a detected ramp meets all criteria and is classified as a windshear alert, the LiWAS screen in the DTN MetConsole® application displays its magnitude and location in a map, as well as in the alphanumeric alarm display.
8. **Log and replay.** Meteorological observers and forecasters can review historical alerts via a dedicated display that gives access to logged algorithm results.

## Integrate DTN weather systems

LiWAS is part of DTN MetConsole Aviation Weather Suite, a comprehensive solution that provides aviation professionals with real-time weather information.

Through MetConsole, LiWAS displays up-to-date, detailed information, generates visual and audible alerts, automatically integrates alarms with LLWAS networks, and archives results in a historical database.

Air traffic controllers benefit from LiWAS and MetConsole features that support rapid decision-making, enhance safety during critical operations, and extend the coverage of other detection systems.

## Tested in adverse conditions

The Bilbao Airport in Spain is known for challenging landing conditions. When winds blow from the south, the surrounding orography disrupts air flow, and pilots may encounter windshear along the approach path, particularly on runway 12. Crosswinds can further complicate conditions.

During extensive testing at Bilbao, DTN installed a LiDAR system near runway 12 to compare its measurements with those from an existing DTN LLWAS System. The LiDAR collected terabytes of raw data, which were processed by the LiWAS algorithm and compared against LLWAS data.

The effective range proved to be a key performance indicator, depending on atmospheric conditions. The main conclusions were:

- LiWAS generated alarms independently of LLWAS while also validating a majority of LLWAS-generated alarms.
- Windshear was typically detected up to 3 NM (5,556 m) from the runway threshold, and up to 4.5 NM (8,334 m) under optimal aerosol concentration, extending detection several nautical miles beyond LLWAS coverage.
- The evolution of the wind field and windshear could be seen (appearance, movement, and dissipation) along the glide path at intervals of less than one minute.





## High spatial resolution

With a range resolution of ~100 m, LiWAS can resolve windshear at length scales between 400 m and 4 km.

## Scanning flexibility

Compared to conventional weather radars, LiDAR has a smaller scanner that enables a more flexible scanning strategy. This allows precise measurement of air flow in terrain-induced disturbances, particularly along the glide path, from the aircraft's perspective.

## Mid-range coverage

Up to 10 km, depending on aerosol conditions in the airport's area, to cover the final nautical miles during approach and departure.

## Ease of deployment

The LiDAR system is compact and can be housed in a rectangular fiberglass equipment shelter of ~ 2 – 3 m in length. Due to its small footprint, it can be installed near the runway while remaining compliant with obstacle limitation surfaces.

The system uses an eye-safe laser and requires minimal maintenance.

## Measurement capability

Measurements can be performed at any elevation or azimuth angle, enabling detection of both horizontal windshear and vertical wind structures such as inversions and low-level jet streams.

## Affordable investment

LiDAR is easier to deploy than a C-band TDWR with an 8-m radius antenna dish. Its mid-range coverage can reduce the need for an extensive anemometer network, avoiding the cost of installing additional wind stations typically required for LLWAS systems outside airport boundaries.

## Full integration

LiWAS was designed as an enhancement to LLWAS networks and can be integrated with other DTN weather systems to maximize performance and reliability.