# A Path to Shed Light on the Windshear

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## How to enhance windshear alerting systems in airports by integrating a LiDAR-based system

**A windshear event is a sudden change in wind speed and/or direction over a short distance. It can occur both horizontally and vertically and is particularly dangerous for aircraft during takeoff and landing phases.**

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

Featuring a flexible scanning strategy and easy implementation, LiWAS can stand alone or enhance existing DTN LLWAS, and also fully integrate with DTN Weather Systems.

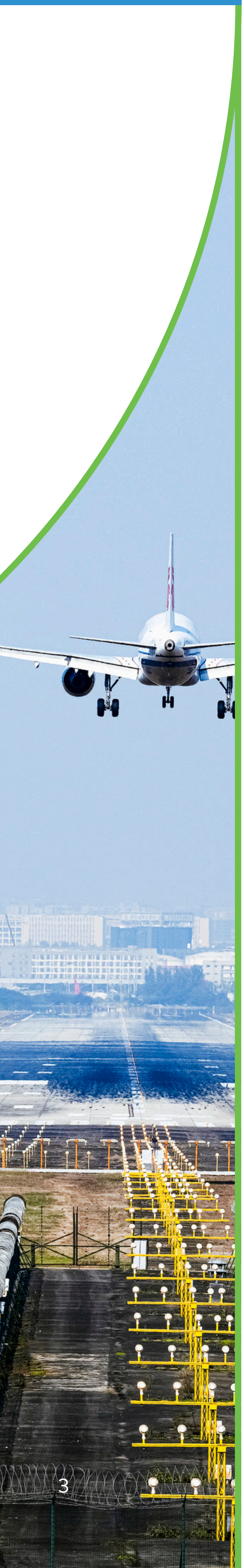
This White Paper introduces the motivation to create such a system and the kind of environment that it is engineered for. We will describe its main components and methods, paying special attention to the detection algorithm and the configuration tool as an overview of LiWAS's functionality.

We know how much winds can impact flight safety. Indeed, windshear has been a sole or contributing cause of numerous aircraft accidents. When the headwind component of wind drops (or increases) sharply, the effect on an aircraft is a sudden loss of air speed and lift, and can lead to a stall.

Wind changes over short distances are categorized as turbulence. There is a wide variety of phenomena that produce windshear including thunderstorms, land/sea breezes, low-level jet streams, mountain waves and frontal systems — in both wet and dry environments.

According to ICAO, the information that ground-based shear detection systems provide a pilot should include significant* changes in wind along the take-off and final approach paths extended to 500m (1,600ft) above runway level—with particular emphasis on the layer between runway level and a height of 150m (500ft), including the runway itself.

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



## LiDAR extends existing LLWAS systems

The ground-based windshear detection systems can be classified as follows:

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

These technologies (in situ and remote sensing, respectively) can be used separately or as part of a sole system.

LLWAS is the most installed windshear alerting system in the world with best-in-class windshear detection performance in all weather conditions. Still, performance of anemometer-based LLWAS is directly related to network geometry; the extension of the coverage area cannot always be accomplished due to airport location or legal restrictions that apply to the surrounding lands.

In these cases, the integration of LLWAS with a remote sensing system installed within the bounds of the airport is an option to consider. The use of a Light Detection and Ranging system (LiDAR) is particularly effective in airports where wind events primarily occur in clear air, such as dry, sea breezes and low-level terrain-induced windshear in non-rainy weather conditions.

A Coherent Doppler LiDAR operates by transmitting an infrared laser beam and detecting the radiation backscattered by atmospheric aerosol particles. The change in frequency in the reflected light (known as Doppler effect) allows the measurement of the line-of-sight velocity component of the air motion field.

## Shedding light on the glide path

LiDAR Windshear Alerting Systems (LiWAS) is the result of years of research and detailed testing in adverse climatological conditions. This improved system demonstrates excellent results with an existing LLWAS or as stand-alone solution.

Moreover, DTN features a Windshear Alert System Integration Algorithm that merges the aforementioned systems, so users can work with a unique combined output.

A key differentiator of the DTN LiWAS is its ability to alert of the windshear events not only close to the runway threshold but along the glide path (GP).

While other remote sensing systems measure at a fixed elevation, LiWAS divides the GP in different sections and sends a laser to each measuring the wind speed in the exact gate which the aircraft will pass through. As a result, the detection is more accurate to what the pilot would report.

Depending on the physical runways configuration, it may be recommended to install one or various LiDAR devices to achieve the best measurement accuracy and coverage area.

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

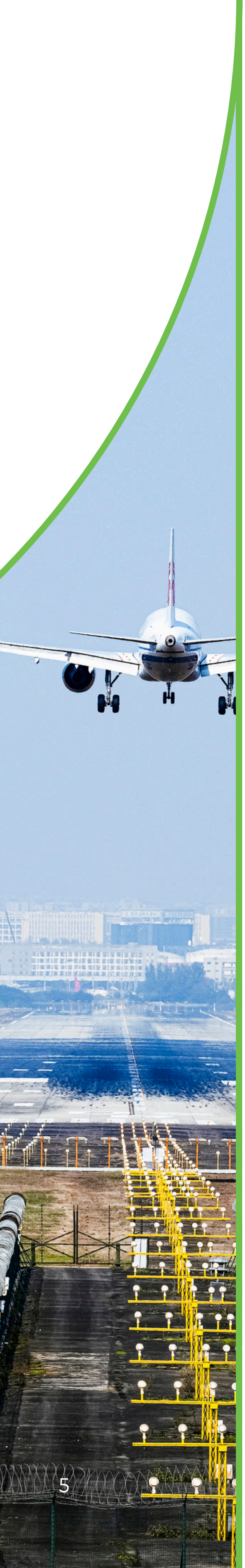
## The LiWAS algorithm in-depth

It all begins with Glide-Path Optimal Scanning Strategy Generator (GPOSS), a configuration tool developed by DTN.

Given the characteristics of the runway as found in the AIP of the airport, GPOSS will indicate where LiDAR aims and for how long, to allow for a reconstruction of the headwind profile of the glide-path, at least once every minute.

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

1. **Reconstruction of the headwind profile.** Measurements are LiDAR-centered and data is rearranged so the algorithm works in the line-of-sight between Touchdown Zone (TDZ) and the glide-path. This feature can be switched off.
2. **Three-step filtering.** Apart from LiDAR's built-in noise canceling features, unreliable measurements are removed by means of:
   a. Signal-to-noise ratio threshold (SNR),
   b. Comparison with the adjacent data to identify outliers,
   c. Tracking acceptable points using data from previous instants to notice inconsistencies.
3. **Effective range estimation.** When the data becomes too noisy, the farthest valid measurement will determine the actual range of LiDAR. This often depends on atmospheric conditions and particle concentration.
4. **Smoothing to length-scale of windshear.** A convolution with a Gaussian distribution (a kind of moving average) is applied to the filtered data, by choosing a standard deviation such that fluctuations which are significantly smaller than the windshear length-scale are to a large extent removed from the initial spiky set.
5. **Ramp detection.** Segments of gain/loss of wind speed are detected in the smoothed profile. A prioritization is done when overlapping ramps are found, based on the ratio between total gain/loss and the horizontal distance where it occurs. The ramp magnitude is taken from the input set.
6. **Windshear criteria according to ICAO recommendations.** An alert will be issued while the gain/loss in headwind change is higher of 7.5m/s (15kt).
7. **Alerting to system users.** If a detected ramp satisfies all criteria and becomes a windshear alert, the LiWAS Screen on the DTN MetConsole® application will display the magnitude and location in a map, and in the Alphanumeric Alarm Display (AAD).
8. **Log and replay of results.** Meteorological observers and forecasters will be able to consult the historical alerts via an additional display that accesses a log of the algorithm results.



## Integrates with DTN Weather Systems

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

Through MetConsole, LiWAS reaches its full capabilities to display up-to-date detailed information, generate visual and audible alerts, automatically integrate alarms with LLWAS networks, and save results to an archive/historical database.

Air Traffic Controllers can benefit from LiWAS and MetConsole features that support quick decisions, increasing safety in the most critical operations while extending the range of other detection systems.

## Tested in adverse conditions

The Bilbao Airport in Spain is infamous because of its known difficult landings. When winds blow from the south, the orography disturbs air flow and pilots encounter windshear turbulence on their paths, in particular, at runway 12. Furthermore, the procedures are often aggravated by the presence of crosswind.

During extensive tests performed at Bilbao, LiDAR was installed by DTN near runway 12 in such a way that the measurements could be compared with an already existing DTN LLWAS System. The LiDAR uninterruptedly collected terabytes of raw data that were passed to the LiWAS algorithm and checked against the LLWAS data.

The effective range proved to be a first performance indicator, which depends on atmospheric conditions. From there, the main conclusions were:

- LiWAS created alarms independent of LLWAS but also validated a majority of the alarms generated by the LLWAS System.
- Windshear was normally detected up to 3NM (5556m) from the runway threshold, and up to 4.5NM (8334m) in optimal aerosol concentration, meaning detection was achieved several nautical miles farther than LLWAS system coverage.
- Evolution of the wind field and windshear could be seen (appearance, movement and dissipation) along the glide-path, in intervals of less than one minute.

## High spatial resolution

With a range resolution of ~100m, LiWAS is able to resolve windshear, which has an recognized length scale between 400m and 4km.

## Scanning flexibility

Compared to conventional weather radars, LiDAR has a smaller scanner allowing more flexibility in designing a scan strategy. This allows precise depiction of the flow in terrain-induced disturbances, particularly along the glide paths to achieve an aircraft's specific point-of-view.

## Mid-range coverage

Up to 10km based on presence of aerosols in the airport's area to cover the final nautical miles in approach and departure.

## Ease of deployment

The LiDAR system instrument is compact and can be housed in a rectangular fiber-glass equipment shelter with a length of 2-3m. The compact dimensions ensure that installation can be done close to the runway while being fully compliant with the obstacle limitation surfaces. Moreover, LiDAR is not an active source of electromagnetic radiation; it is eye-safe with little-to-no maintenance required.

## Measurement capability

Measurements can be accomplished in any elevation or azimuth angle allowing for detection of not only horizontal windshear, but also events that have a vertical evolution such as inversions and low-level jet streams.

## Affordable investment

It is easier to deploy LiDAR than a C-band TDWR of 8m radius antenna dish. What's more, its mid-range coverage replaces the need for a large anemometer network, avoiding the costs of installing additional wind stations for LLWAS systems usually placed outside the boundaries of the airport.

## Full integration

LiWAS was initially conceived as an enhancement to LLWAS networks, and as such, it can be combined with other DTN Weather Systems to maximize its performance and reliability.

Talk with an expert

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