White Paper:

A path to shed light on the windshear

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The DTN LiWAS (LiDAR Windshear Alerting System) is a state-of-the-art solution to track headwind/ tailwind changes in those airports concerned about windshear events.

There is always one person on-board that feels panic every time the aircraft experiences turbulence. Sometime later it’s just remembered as an awkward scare, but we will have realized 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 sharply (or increases), the effect on the aircraft is a sudden loss of air speed and lift, and can lead to a stall.

A windshear event is a difference in wind speed in the atmosphere, occurring with a length-scale between 400 m and 4 km. They last at least a few seconds of the flight time, which is particularly threatening when the aircraft encounters them at low altitude.

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 wet and dry environments.

According to ICAO, the information that ground-based shear detection system should provide a pilot is: significant changes in wind along the take-off and final approach paths extended to 500 m (1,600 ft) above runway level, with particular emphasis on the layer between runway level and a height of 150 m (500 ft), including the runway itself. Significant changes are defined as those exceeding a headwind/tailwind change of 7.5 m/s (15 kt).

A LiDAR to extend the existing LLWAS systems

The ground-based wind shear 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 two technologies (in situ and remote sensing) may be used separately or as part of a sole system.

The LLWAS is the most installed windshear alerting system in the world, and has the best windshear detection performance, in all weather conditions. Still, performance of anemometer-based LLWAS is directly related to network geometry and 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 the 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 (LiDAR) system is particularly effective in those airports where the events mainly 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 (known as Doppler effect) in the reflected light allows the measurement of the line-of-sight velocity component of the air motion field.

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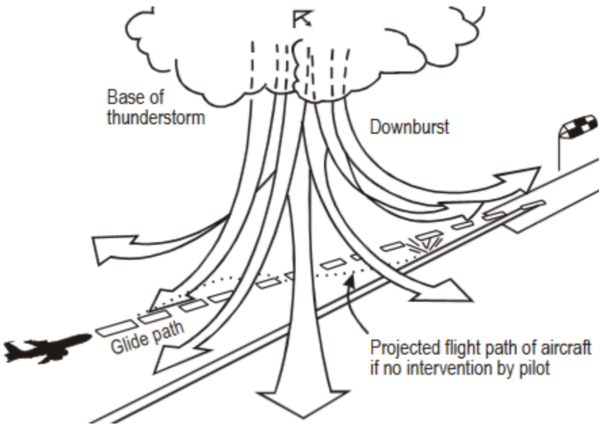


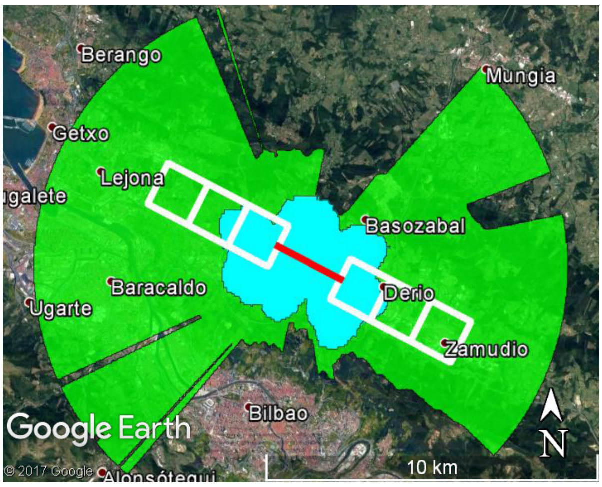
Unexpected landing path due to downburst.
Credit: ICAO.

Shedding light on the glide path

DTN provides several aeronautical meteorology systems including LiDAR Windshear Alerting Systems (LiWAS). This is the result of years of research and a detailed testing campaign of cutting-edge technology in adverse climatological conditions, leading to a system that presents excellent results working either with an existing LLWAS or as stand-alone.

Moreover, DTN features a Windshear Alert System Integration Algorithm to merge the aforementioned two systems, so that users can work with an 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, the LiWAS divides the GP in different sections and sends a laser beam to each of them, to measure the wind speed component in the exact gate which the aircraft will go through. As a result, the detection is closer to what the pilot would report.



Comparison between a typical LLWAS range (blue) vs. LiWAS range (green), using an ASTER GDEM simulation. For reference, the runway (red line) and the ARENA (white grid) are drawn.

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

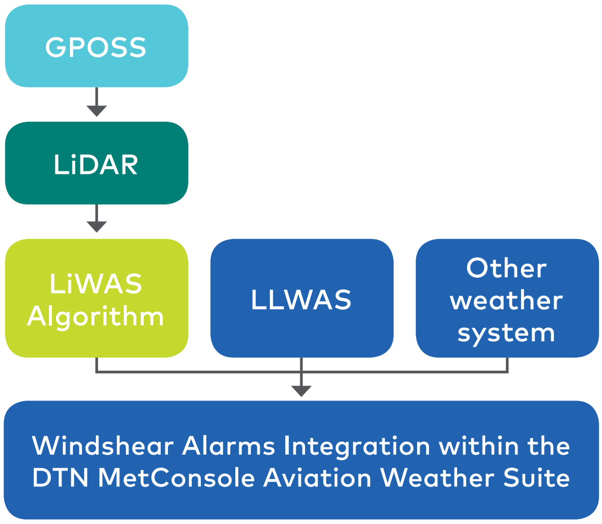


Diagram of interactions between the most relevant components of a LiWAS System.

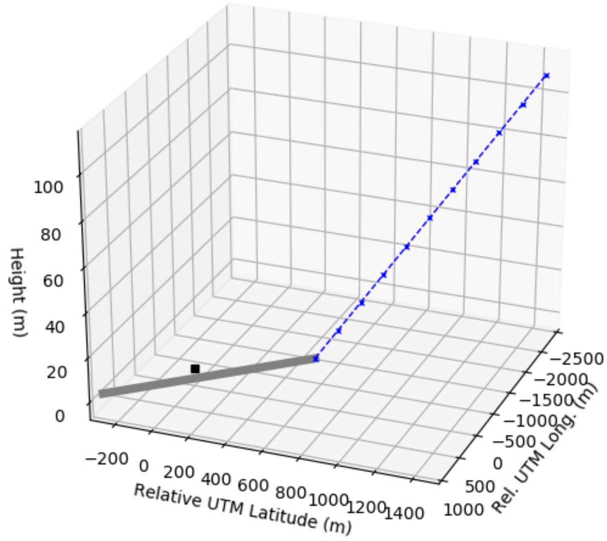
The LiWAS algorithm in-depth

It all begins with the 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, the GPOSS will indicate the LiDAR where to aim and for how long, to allow a later reconstruction of the headwind profile of the glide path, at least once every minute.

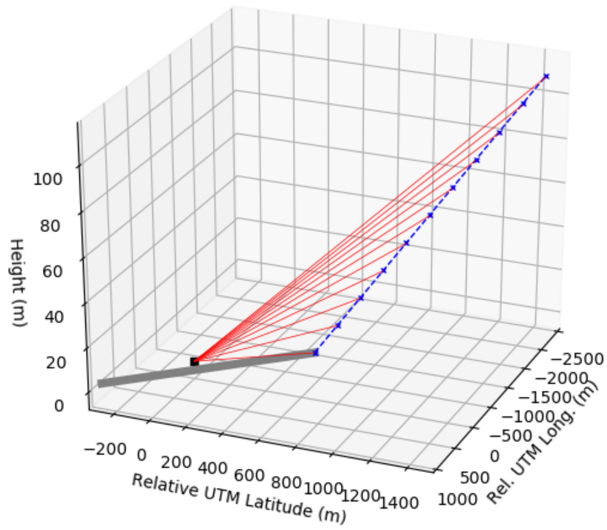
Once the system is fully deployed and the LiDAR is switched on, the LiWAS receives the wind data in real-time. The main phases of the Algorithm are as follows:

1. Reconstruction of the headwind profile. The measurements are LiDAR-centered, and the data is rearranged so the algorithm works in the line-of-sight between Touchdown Zone (TDZ) and the aircraft, i.e., the glide path. This feature can be switched off in case of having selected the stare option in the GPOSS.
2. Three-step filtering. Apart from the LiDAR built-in noise cancelling features, the unreliable measurements are removed by means of:
   a. a signal-to-noise ratio (SNR) threshold,
   b. a comparison with the adjacent data to identify outliers,
   c. a tracking of acceptable points using data from previous instants to notice inconsistencies.

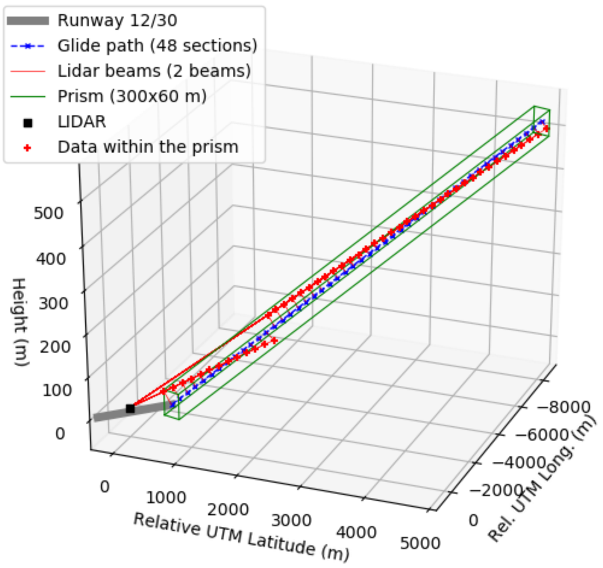
3. Effective range estimation. When the data becomes too noisy, the farthest valid measurement will determine the actual range of the LiDAR. Typically it depends on the atmospheric conditions and concentration of particles.
4. Smoothing to length-scale of windshear. A convolution with a Gaussian distribution (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 7.5 m/s (15 kt).
7. Alerting to system users. If a detected ramp satisfies all criteria and becomes a windshear alert, the LiWAS Screen on DTN's MetConsole® application will display the magnitude and location in a map, and also in the Alphanumeric Alarm Display (AAD).
8. Log and replay of results. Meteorological observers and forecasters will be able to consult the historical of alerts via an additional Screen that accesses a log of the algorithm results.



The physical characteristics of the runway (gray stripe) and the chosen location for the installation of the LiDAR device (black point) lead to the tridimensional modelling of the glide path (blue line)

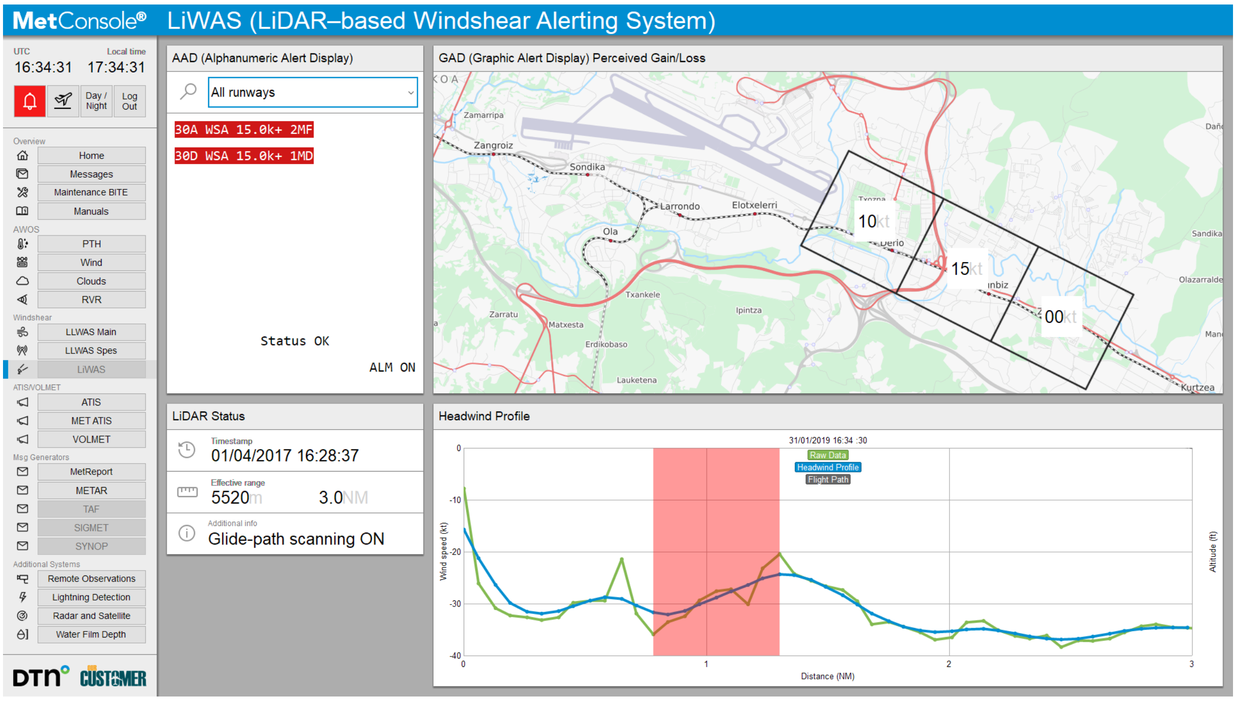


The glide path is divided into evenly-spaced sections. By leveraging the LiDAR's scanning flexibility, the beams (in red) that can measure wind speed at these sections are computed.



A prism of tolerance (green prism) is introduced. When different sections of the glide path are measured as different gates of the same beam, scanning duration can be minimized and the overall performance, improved. The figure above reproduces the graphical output of the Glide-Path Optimal Scanning Strategy (GPOSS).

The LiWAS System is part of DTN MetConsole Aviation Weather Suite, a comprehensive and state-of-art solution that provides aviation customers the real-time weather information needed for their daily operations.



LiWAS Screen displaying a windshear alert in MetConsole.

Perfectly integrated with DTN Weather Systems

Through MetConsole, the 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 a historical database.

Air Traffic Controllers can benefit of the LiWAS and MetConsole features to support quick and accurate decision making, increasing safety in the most critical operations and extending the range of other detection systems.

Tested in adverse conditions

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

During the extensive tests performed at Bilbao, a LiDAR was installed by DTN near runway 12, in such a way that the measurements could be compared with the 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 are:

- The LiWAS created alarms independent of the LLWAS but also validated a majority of the alarms generated by the LLWAS System,
- Windshear was normally detected up to 3 NM (5556 m) from the runway threshold, and up to 4.5 NM (8334 m) in optimal aerosol concentration, meaning detection was achieved several nautical miles farther than LLWAS system coverage, and
- 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 about 100 m, LiWAS is able to resolve windshear, which has an internationally recognized length scale between 400 m and 4 km.

Scanning flexibility

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

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.

Mid-range coverage

Up to 10 km in case of enough presence of aerosols in the airport area, to cover the last nautical miles in approach and departure.

Affordable investment

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

Measurement capability

Measurements can be done in any elevation and azimuth angles. It allows the detection of not only horizontal windshear, but also events that have a vertical evolution such as inversions and low-level jet streams.

Ease of deployment

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

About us

DTN has been in the Weather Systems business for more than 35 years, providing high value products to comply with the most rigorous standards of its customers.

In particular, DTN's Aviation Weather Solutions have been installed and integrated in more than 300 airports worldwide already.

Get to know LiWAS and the rest of DTN Weather Solutions at www.dtn.com or contact us at +31 345 544 080.

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