

# Wind shear - poses challenges and dangers at the most critical stages of flight

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## ***Introduction***

Over 40 years ago, in the 1960s, low level wind shear was just being identified as the cause of serious and fatal accidents. At the time very little was known about clear air turbulence or its causes. Serious research was only started, in 1976, after a Boeing 727 crashed on landing at JFK Airport, USA. Theodore Fujita <sup>1</sup> attributed low level wind shear, on the final approach to the runway, to be the cause of the crash. This accident instigated a systematic study, by the NTSB in the USA, of clear air turbulence and low level wind shear.

In 1982, Theodore Fujita <sup>2</sup> participated in the Joint Airport Weather Studies (JAWS) project <sup>3</sup>, which analysed more than 70 microbursts, and his paper, 'The Downburst', explains in great detail, the phenomena of microbursts. The definition of the microburst had a significant impact on the education of pilots. The Wind-shear Training Aid, 1987, <sup>4</sup> issued by the Federal Aviation Administration (FAA) of the USA, states: "avoidance is the best defence against the hazards of wind shear. A severe wind shear condition is beyond the handling ability of commercial aircraft and even highly skilful pilots." So, what is to be done about wind shear? If information on wind shear helps the pilot to deal with the effects, when it is milder, or to avoid it, when it is extreme, then better wind shear information is the solution. Would a wind shear alerting system help ATC to maintain a relatively good flow of traffic, despite the disruption caused by such phenomena?

What effect does an accident, involving fatalities and property damage, have on airport business, operations and reputation? How do delays affect an airport?

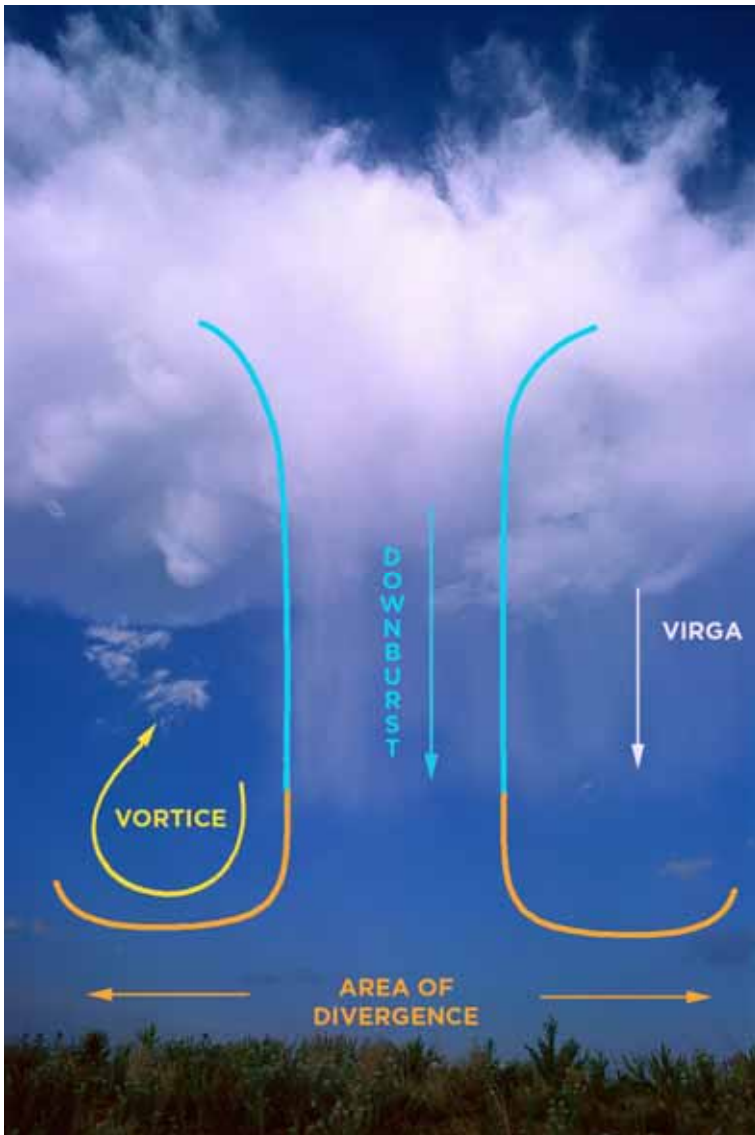
## ***What is wind shear?***

Wind shear is a sudden change in wind speed and/or direction that results from a variety of meteorological conditions. These include temperature inversions, land and sea breezes, frontal systems, strong surface winds and, significantly, thunderstorms. Severe wind shear is defined as a rapid change in wind causing aircraft airspeed changes of greater than 15 knots, or vertical speed changes of greater than 500 feet per minute.

The wind shear associated with thunderstorms is referred to as a microburst (the vertical element is also known as a downburst). A microburst is an intense, localized downdraft of air that spreads radially on the ground. A microburst has a vertical component - a powerful downdraft, and a horizontal component at the surface, and ahead and around them are vortices of circulating winds. Microbursts are associated with convective weather, cumulus congestus and cumulonimbus clouds, and grow in strength as storm clouds mature. The downbursts can normally be expected below thunderstorm clouds, but the downburst may be at an angle which adds to the unpredictability of the downburst location.

When the downburst hits the earth's surface it radiates, and the strength of the horizontal winds may also be asymmetrical. There could be a greater flow in one direction and a lesser flow in the other

direction. Around the divergent area, vortices form that can have an upper limit of nearly 2000 feet above ground level, and they feed currents of air back into the cloud. The horizontal outflow area is usually from 1 to 2 nautical miles (NM), about 2 to 3.6 km. The thunderstorm related downburst is usually a few hundred feet to a few thousand feet in diameter, about 100m to 1000m. (See Fig. 1)



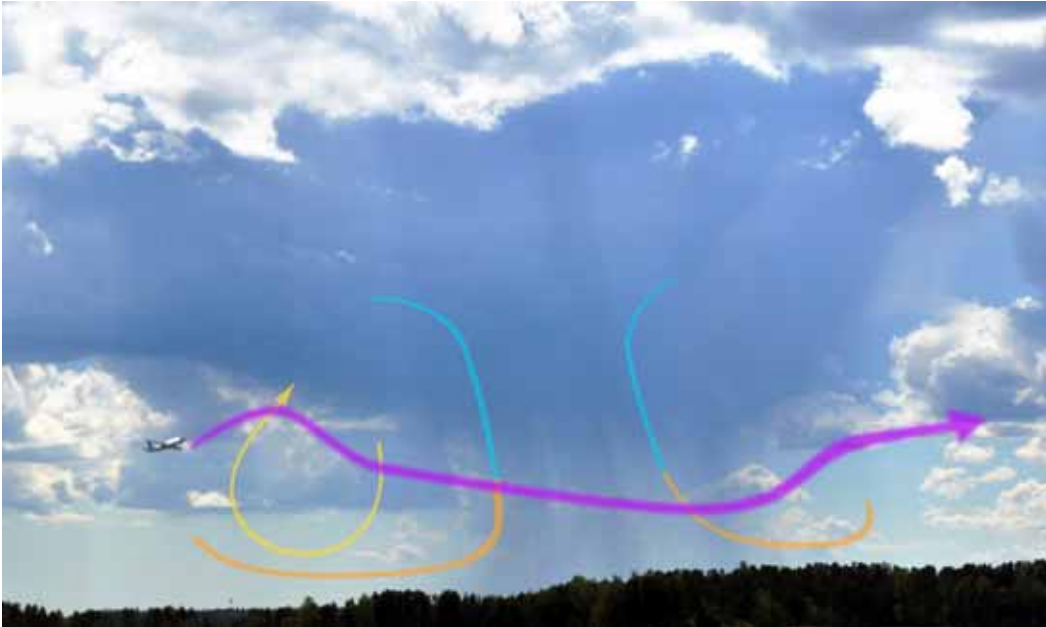
The strength of the downburst is exacerbated by precipitation. Regardless of whether the precipitation is rain, hail or virga, during their descent some moisture evaporates absorbing energy from the surrounding air. This causes the air to cool, to become denser, and thus the heavier air falls faster. The additional weight of large hail stones also contributes to the acceleration of the downburst. The life span of a microburst is associated with that of the mature stage of the thunderstorm, and is usually about 15 to 20 minutes, rarely longer than 30 minutes. They are known to generate winds of greater than 145 knots, 75 m/s or 270 km/h.

Microbursts can also be jet streams that have been diverted down to the surface, by thunderstorm convection currents.

*Fig. 1 Elements of a microburst, showing downburst, area of divergence and horizontal outflow of wind, an example of vortices, and virga.*

## **Aircraft aerodynamics and wind shear**

The wings of an aircraft are designed to be at the optimum angle of attack for straight and level flight. That means that optimum lift in ratio to speed is attained. When the speed of the air over the wing changes or if the angle of attack changes the ratio of lift changes. So, if an aircraft suddenly passes through a downburst, the angle of attack of the wing to the airflow becomes negative, a pocket low pressure forms below the wing, and the wing falls to fill it. The aircraft now only has forward speed, but is losing very rapidly in height. Should this occur close to the ground, during the descent to land, there is practically no time to recover before hitting the ground. See Fig. 2



*Fig. 2 This image shows how the flight path of an aircraft is affected by the various elements of a microburst. Here the aircraft first encounters updrafts, followed by downdrafts of the vortices, and then enters the main downburst. The changes in height are dramatic and could be fatal if the aircraft were closer to the ground for example while approaching to land.*

During take-off, the aircraft is usually fully laden, and then a good headwind is favorable for take-off. If a microburst is over the centre or the end of the runway, then the outflow will be seen as a good headwind. The aircraft takes off with the wings in an angle for optimum climb. Climb is effective as long as the headwind holds steady, but if the aircraft should pass through the downburst at this critical phase, climb is lost, the aircraft is stuck for a while at that level, and then it is hit by an equally strong tailwind. With the loss of climb and headwind, and in quick procession followed by a strong tailwind the aircraft goes down. Yet again, the chance of recovery is minimal.

### ***Identifying the incidence of wind shear***

A thunderstorm in the vicinity of an airport is a visible clue of the possibility of wind shear, but not all convective storms spell wind shear. Normally anvil-head storm clouds are clear indicators of wind shear, but pin-pointing the downburst area is not that simple. It is easy to assume that closer to the ground, the horizontal flow of wind is away from the cloud, but can one assess at what speed?

At airports, a dense network of wind sensors helps to see anomalies in wind speed and direction. If the data from these sensors are shown on separate displays, it requires that the air traffic controller (ATC) checks all of them to assess the possibility of wind shear. Normally, the ATC gives wind shear readings to the pilot in conjunction with the clearance to land. Pilots need to be vigilant, and to take note of wind readings given to aircraft landing and taking-off ahead of them, in order to prepare themselves for the variable wind conditions.

In cases of severe wind shear, the wind shear information can be transmitted by the airport's Automatic Terminal Information Service, (ATIS). In any case, as wind shear cannot be predicted, the start of the event, when the down draft hits the ground and outflow begins, it surprises everyone,

ATC and pilots alike. If, for example, the aircraft's tailwind tolerance is 10 knots, a typical microburst wind shear of even 40 knots, would be devastating as a downdraft or a tailwind.

### ***Wind shear alerting is necessary***

The unpredictability of wind shear complicates the ATC's role while controlling air traffic. The rapid changes in wind, as the microburst sweeps across or past the airport, may lead to quick runway changes, which interferes with traffic patterns and Air Traffic Management (ATM) processes. The danger of a sudden, dramatic loss in height during landing and take-off could cause a serious accident, so it is important to avoid situations that threaten the safety of aircraft. Instead of merely issuing pilots with wind shear data at landing and take-off, with better data, the ATC could take more informed and pro-active decisions.

Efficient handling of air traffic in and out of an airport, with tools that improve airport safety installed, increases traffic figures and profitability. Having wind shear data conveniently at hand, eases the ATC's burden, and increases the pilot's confidence in flying at that airport.

How could ATC be alerted of wind shear the instant it begins? One solution would be a system that gathers wind data from a network of wind sensor sets, analyses the data, and alerts ATC when significant variability in wind speed and direction is detected.

### ***Countering wind shear***

In 1985, the FAA funded a second initiative, the Classify, Locate, and Avoid Wind Shear (CLAWS) project <sup>5</sup>, which developed an algorithm for a Low-Level Wind Shear Alert System (LLWAS).

The LLWAS was specifically designed to determine wind shear of 15–30 knots and microbursts of over 30 knots up to 1000 feet above ground level. The LLWAS comprises wind speed and direction sensors sited around the runway area, connected to a data collection unit, on site. The data collection unit powers the anemometers, collects data and transmits it, on request, to the LLWAS main computer. The LLWAS algorithm creates sets of triples (triangles) and pairs (edges) using the anemometer sites. The filtered wind data from these sets are interpreted by the LLWAS in order to identify divergence or convergence, and to estimate the effects of the wind shear on aircraft. The sensors are placed high enough to avoid local wind interference, 15 to 30 m above the ground. The wind shear data can be displayed in one of two formats – either as text or graphically. Wind shear alerts are presented visually and audibly. The graphical display depicts the areas of wind shear in relation to the active runway(s). See Fig. 3

The advent of the weather radar in the early 1980s introduced an alternative method of detecting weather elements which quite quickly developed to include the detection of wind and wind shear. Doppler weather radar can provide wind shear detection and reflectivity data to air traffic controllers. Doppler weather radar rapidly scans boundary-level winds within the area of coverage at an airport. This allows the radar to provide graphical and numerical data on wind shear events. The use of Doppler weather radar has played a significant part in the reduction of wind shear related accidents at airports. The wind shear alerts from Doppler weather radar may be merged with LLWAS alerts to increase probability of detection while lowering the incidence of false alarms.

A third method of detecting wind shear is by wind profiling. A wind profiler is a Doppler radar which provides vertical profiles of horizontal wind speed and direction, and vertical wind velocity up to an altitude of 3 to 16 km above ground level (depending on the type of wind profiler). Wind profilers have the benefit of indicating vertical wind shear, due to the vertical profile of the wind data. Wind profilers provide wind measurements within their scope of measurement, but they do not detect or provide horizontal wind shear alerts.

A combination of systems provides a greater range of information on wind shear. The selection of one or more systems is reliant on the site and its environmental factors, also the types of wind shear that most commonly occur at the site should be considered. Obstacles at the site may be the cause of wind shear, and obstacles may also interfere with wind shear detection. Depending on the circumstances at the site and its environs, weather radar data merged with wind profiler data may provide all the data needed, while in other circumstances a combination of an LLWAS with weather radar would be more appropriate.

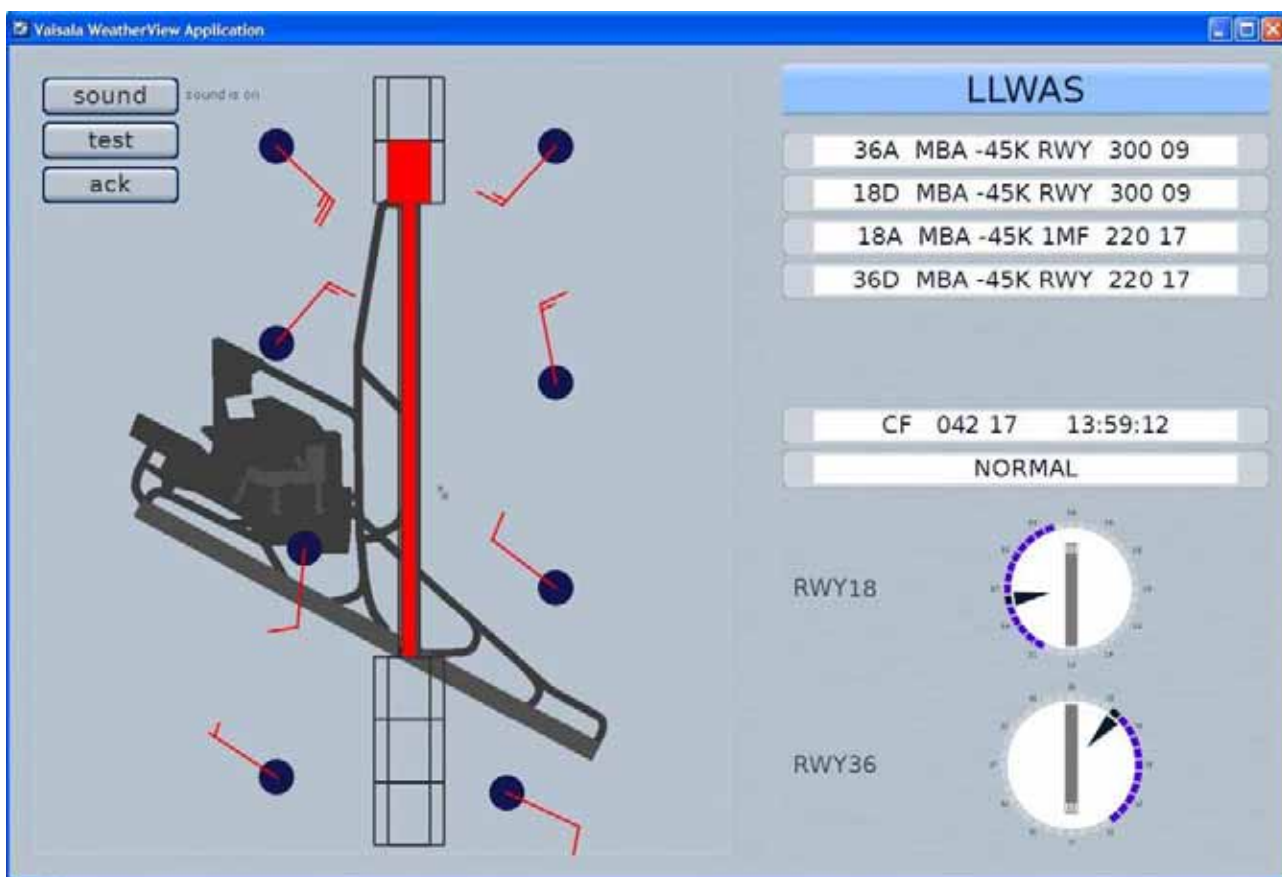


Fig. 3 This image shows the LLWAS display, showing the sensors, and wind shear information. (Screen capture by courtesy of Vaisala)

### **The effects on airport and airline business**

In the USA, between 1964 and 1985, over 25 accidents were attributed to wind shear, incurring 625 deaths and 200 injuries<sup>6</sup>. Following the CLAWS project, the FAA installed LLWASs at all major airports in the USA. This contributed to the safety of flight and dramatic reductions in wind shear

related incidents and accidents were recorded in the following decades, in the USA. In contrast, the statistics for the rest of the world did not show reduction, even though reductions occurred in Europe and Japan, where LLWASs had been installed. One can surmise that installing an LLWAS, significantly reduces the risks related to low level wind shear.

If the potential risk of suffering losses, due to accidents or delays, is reduced it can be seen as a clear benefit for airline business and airport operations. Installing an LLWAS is an investment against disaster, at worst, and against delay-related cumulative costs, at best.

## **References**

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