Flight Operations Briefing Notes

Adverse Weather Operations

Windshear Awareness

I Introduction

Flight crew awareness and alertness are key factors in the successful application of windshear avoidance and escape / recovery techniques.

This Flight Operations Briefing Note provides an overview of operational recommendations and training guidelines for aircraft operation in forecast or suspected windshear or downburst conditions.

II Background Information

II.1 Statistical Data

Adverse weather (other than low visibility and runway condition) is a circumstantial factor in nearly 40 percent of approach-and-landing accidents.

Adverse wind conditions (i.e., strong cross winds, tailwind and windshear) are involved in more than 30 percent of approach-and-landing accidents and in 15 percent of events involving CFIT.

Windshear is the primary causal factor in 4 percent of approach-and-landing accidents and is the ninth cause of fatalities.

These statistical data are summarized in **Table 1**.

Factor	% of Events
Adverse weather	40 %
Adverse wind (all conditions)	33 %
Windshear	4 %

(Source: Flight Safety Foundation - Flight Safety Digest - Vol. 17/Vol. 18 - 1998-1999)

Table 1

Weather factors in Approach-and-landing Accidents

II.2 Defining Windshear

Windshear is defined as a sudden change of wind velocity and/or direction.

Windshear occurs in all directions, but for convenience, it is measured along vertical and horizontal axis, thus becoming vertical and horizontal windshear:

- Vertical windshear:
  - Variations of the horizontal wind component along the vertical axis, resulting in turbulence that may affect the aircraft airspeed when climbing or descending through the windshear layer
  - Variations of the wind component of 20 kt per 1000 ft to 30 kt per 1000 ft are typical values, but a vertical windshear may reach up to 10 kt per 100 ft.
- Horizontal windshear:
  - Variations of the wind component along the horizontal axis (e.g., decreasing headwind or increasing tailwind, or a shift from a headwind to a tailwind)
  - Variations of wind component may reach up to 100 kt per nautical mile.

Windshear conditions usually are associated with the following weather situations:

- Jet streams
- Mountain waves
- Frontal surfaces
- Thunderstorms and convective clouds
- Microbursts.

Microbursts combine two distinct threats to aviation safety (**Figure 1**):

- The downburst part, resulting in strong downdrafts (reaching up to 6000 ft/mn of vertical velocity)
- The outburst part, resulting in large horizontal windshear and wind component shift from headwind to tailwind (horizontal winds may reach up to 45 kt).

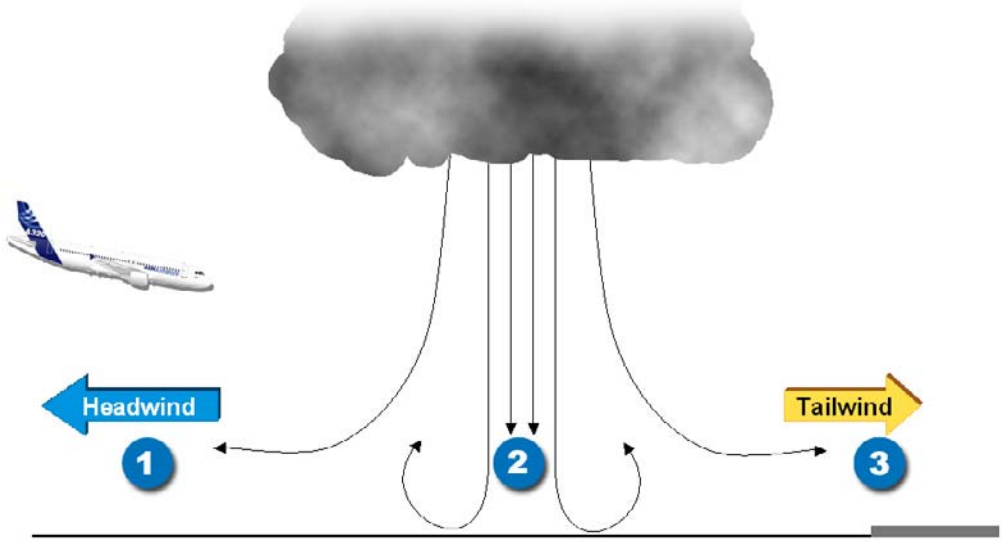

Figure 1

Microburst caused by a Cumulonimbus

II.3 Influence of Windshear on Aircraft Performance

The flight performance is affected as:

- Headwind gust instantaneously increases the aircraft speed and thus tends to make the aircraft fly above intended path and/or accelerate (see **Figure 1**, item 1).
- A downdraft affects both the aircraft Angle-Of-Attack (AOA), that increases, and the aircraft path since it makes the aircraft sink (see **Figure 1**, item 2).
- Tailwind gust instantaneously decreases the aircraft speed and thus tends to make the aircraft fly below intended path and/or decelerate (see **Figure 1**, item 3).

Windshears associated to jet streams, mountain waves and frontal surfaces usually occur at altitudes that do not present the same risk than microbursts, which occur closer to the ground.

Four cases can be observed depending on the position of the aircraft relatively to the microburst:

- **Microburst in front of the aircraft**

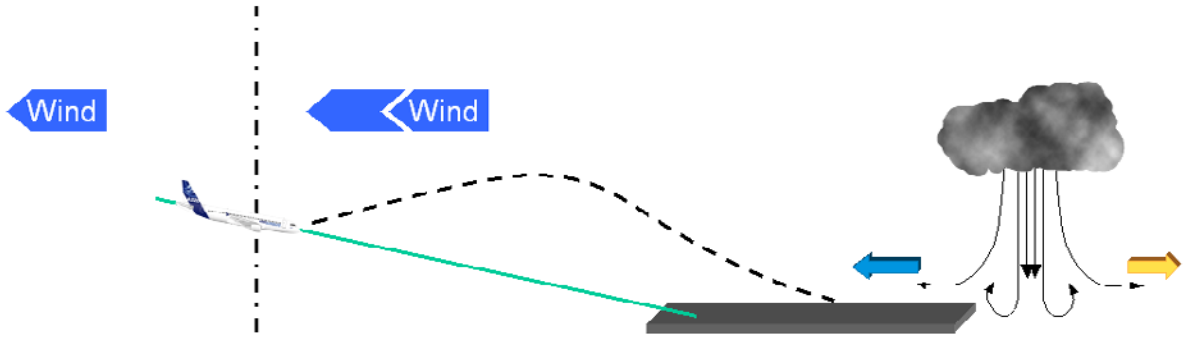

Figure 2

Microburst in front of the aircraft

The crews do not always perceive an increase of the headwind as a risk. But such a headwind gust de-stabilizes the approach of the aircraft, which will tend to fly above path and/or accelerate, if the pilot does not react adequately.

If the headwind shear occurs at takeoff, the resulting aircraft performance will increase. Once out of the shear, the indicated airspeed decreases thus leading to an AOA increase which might trigger the alpha-floor protection and/or stick shaker activation.

- **The aircraft flies through a microburst downdraft**

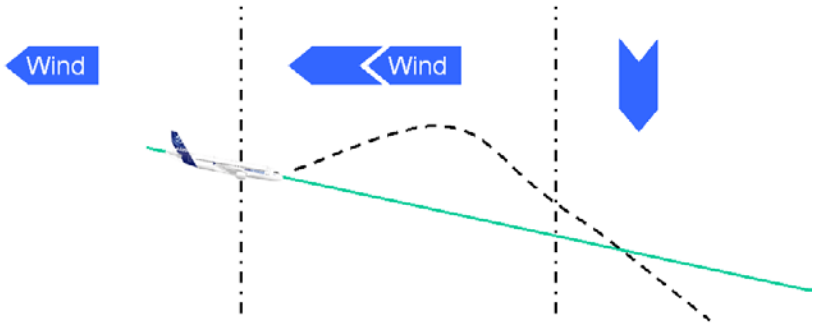

Figure 3

The aircraft flies through a microburst downdraft

Vertical downdrafts are usually preceded by an increase of the headwind component (see **Figures 1 and 3**). If the pilot does not fully appreciate the situation, he/she will react to the headwind gust effects to regain the intended path by

reducing the power and by pushing on the stick. At that point, a vertical downdraft will increase the aircraft sink rate, which will bring the aircraft below the intended path.

- **Microburst appearing behind the aircraft**

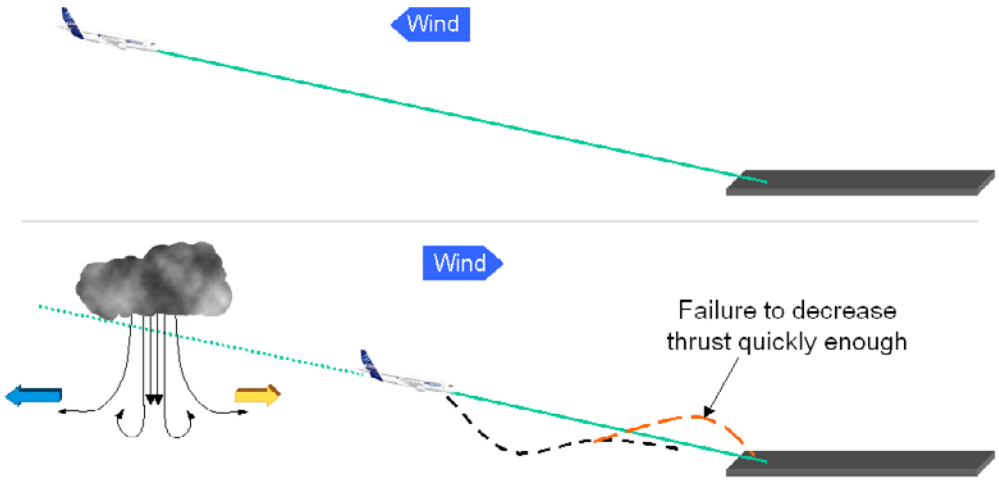

Figure 4

Microburst appearing behind the aircraft

In case of a sudden increase of the tailwind, the aircraft airspeed decreases instantaneously. The lift decreases and the aircraft tends to fly below the intended approach path.

If the pilots pulls on the stick to recapture the path without adding sufficient thrust, the AOA will increase significantly and the aircraft will sink down.

If sufficient thrust is set to regain the intended path, but the pilot's reaction is then slow to reduce the thrust once back on the path, the aircraft will fly above the path and/or will accelerate.

- **The aircraft flies through a microburst**

The worst case is the addition of the previous three cases:

- Headwind gust
- Downdraft
- Tailwind gust.

This is what an aircraft encounters when it flies through a microburst (see **Figure 1**).

II.4 Windshear Awareness and Avoidance

Avoidance

The following information should be used to avoid areas of potential or observed windshear:

- Weather reports and forecast:

  Some airports are equipped with a Low Level Windshear Alert System (LLWAS) and/or a Terminal Doppler Weather Radar (TDWR).

  LLWAS consists of a central wind sensor (sensing wind velocity and direction) and peripheral wind sensors. It enables controllers to warn pilots of existing or impending windshear conditions.

  An alert is generated whenever a difference in excess of 15 kt is detected.

  LLWAS may not detect downbursts with a diameter of 2 nm or less.

  TDWR enables to detect approaching windshear areas and, thus, to provide pilots with more advance warning of windshear hazard.

- Pilot's reports:

  PIREPS of windshear in excess of 20 kt or downdraft / updraft of 500 ft/mn below 1000 ft above ground level should draw the attention of the crews.

- Visual observation:

  Blowing dust, rings of dust, dust devils (i.e., whirlwinds containing dust and stand), or any other evidence of strong local air outflow near the surface often are indication of potential or existing windshear.

- On-board wind component and ground speed monitoring:

  On approach, a comparison of the headwind or tailwind component (as available) and the surface headwind or tailwind component indicates the potential and likely degree of vertical windshear. This monitoring increases the situational awareness.

- On-board weather radar

- On-board predictive windshear system.

Recognition

Timely recognition of a windshear condition is vital for the successful implementation of the windshear recovery/escape procedure.

The following deviations should be considered as indications of a possible windshear condition:

- Indicated airspeed variations in excess of 15 kt

- Ground speed variations
- Analog wind indication variations: Direction and velocity
- Vertical speed excursions of 500 ft/mn
- Pitch attitude excursions of 5 degrees
- Glide slope deviation of 1 dot
- Heading variations of 10 degrees
- Unusual autothrust activity or throttle levers position.

Predictive and Reactive Windshear Warnings

An optional WINDSHEAR warning is available on most aircraft models.

The windshear warning is based on the assessment of current aircraft performance (flight parameters and accelerations). The windshear warning is generated whenever the energy level of the aircraft falls below a predetermined threshold.

The windshear warning system associated to the Speed Reference System (SRS) mode of the flight guidance constitute the Reactive Windshear Systems (RWS), since both components react instantaneously to the current variations of aircraft parameters.

To complement the reactive windshear system and provide an early warning of potential windshear activity, some weather radars feature the capability to detect windshear areas ahead of the aircraft.

This equipment is referred to as a Predictive Windshear System (PWS).

PWS provides typically a one-minute advance warning. RWS and PWS characteristics are summarized in **Figure 5**.

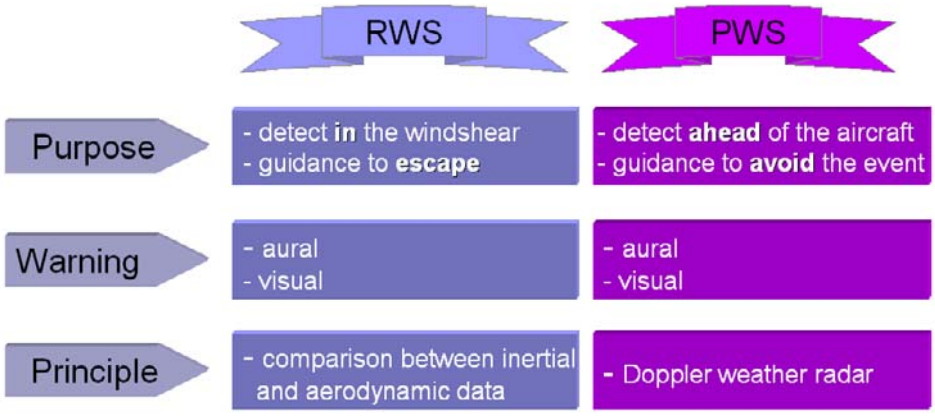

Figure 5

RWS and PWS compared characteristics

PWS generates three levels of windshear alert, depending on:

- The distance and angular position between the aircraft and the windshear
- The altitude of the aircraft
- The flight phase.

Colored patterns and icons are displayed on the weather radar display (ND) to indicate areas of windshear activity (as illustrated by **Figure 6**).

Figure 6

Example of predictive windshear display on ND

III Operational Standards

As a general rule, if windshear is suspected, or is detected by the PWS, delay the takeoff.

If windshear is detected by RWS during takeoff or approach, recover with maximum thrust and follow SRS guidance.

Note:

Applicable recovery procedures are published in the FCOM and QRH.

III.1 Cockpit Preparation – Departure Briefing

Flight crew should consider all available windshear-awareness items and:

- Assess the conditions for a safe takeoff based on:
  - Most recent weather reports and forecast
  - Visual observations

  - Crew experience with the airport environment and the prevailing weather conditions; or,

- Delay the takeoff until conditions improve, as warranted.

III.2 Takeoff and Initial Climb

Windshear suspected

If windshear conditions are suspected during takeoff, the flight crew should:

- Consider delaying the takeoff
- Select the most favorable runway, considering the location of the likely windshear/ downburst
- Select the minimum flaps configuration compatible with takeoff requirements, to maximize the climb-gradient capability
- Use the weather radar (and the predictive windshear system, as available) before commencing the takeoff roll to ensure that the flight path is clear of hazard areas
- Select the maximum takeoff thrust
- Closely monitor the airspeed and speed trend during the takeoff roll to detect any evidence of windshear.

Recovery Technique for Windshear Encounter during Takeoff

If windshear is encountered during takeoff roll, apply the following recovery techniques without delay:

- Before V1:
  - Reject the takeoff only if unacceptable airspeed variations occur and the pilot assesses there is sufficient runway remaining to stop the aircraft.

- After V1:
  - Maintain or set the thrust levers to the maximum takeoff thrust (TOGA)
  - Rotate normally at VR
  - Follow the Flight Director pitch orders, or set the required pitch attitude if FD is not available (as recommended in the applicable FCOM).

Note:

If a windshear occurs during takeoff roll, V1 may be reached later (or sooner) than expected. In this case, the pilot may have to rely on his/her own judgment to assess if there is sufficient runway remaining to stop the aircraft, if necessary.

Note:

Recovery technique during initial climb is described in the paragraph "Recovery technique for windshear encounter during initial climb, approach and landing" (see page 11).

III.3 Descent and Approach

Windshear suspected

Before conducting an approach in forecast or suspected windshear conditions, the flight crew should:

- Consider delaying the approach and landing until conditions improve or divert to a suitable airport:
  - When downburst / windshear conditions are anticipated based on pilot's reports from preceding aircraft or based on an alert issued by the airport Low Level Windshear Alert System (LLWAS), the landing should be delayed or the aircraft should divert to the destination alternate airport.
- Assess the conditions for a safe approach and landing based on:
  - Most recent weather reports and forecast
  - Visual observations
  - Crew experience with the airport environment and the prevailing weather conditions.
- Select the most favorable runway, considering:
  - The location of the likely windshear / downburst condition
  - The available runway approach aids.
- Use the weather radar (or the predictive windshear system, as available) during the approach to ensure that the flight path is clear of hazard areas
- Select less than full flaps for landing (to maximize the climb-gradient capability) and adjust the final approach speed (i.e. V_{APP}) accordingly
- If an ILS is available, engage the autopilot for a more accurate approach tracking
- If gusty wind is expected, increase V_{APP} displayed on the FMS CDU up to a maximum of minimum approach speed (i.e. V_{LS}) + 15 knots
- Compare the headwind component or tailwind component aloft and the surface headwind or tailwind component to assess the potential and likely degree of vertical windshear

- Closely monitor the airspeed, speed trend and ground speed during the approach to detect any evidence of imminent windshear:
  - A minimum ground speed should be maintained, to ensure a minimum level of energy to the aircraft, and to ensure proper thrust management during the approach, in case of sudden headwind to tailwind change. This is automatically performed on Airbus fly-by-wire aircraft by the Ground Speed mini function, when the speed target is managed and the A/THR function is engaged.
- Be alert to respond immediately to:
  - Any predictive windshear advisory, W/S AHEAD caution or W/S AHEAD warning
  - A reactive WINDSHEAR warning.

Recovery Technique for Windshear Encounter during Initial Climb, Approach and Landing

If windshear is detected (by the pilot, or by the PWS or RWS) during initial climb, approach or landing, the following recovery techniques should be implemented immediately:

- Set and maintain the Takeoff / Go-Around thrust (TOGA)
- Follow the FD pitch orders or set the pitch attitude target recommended in the FCOM (if FD is not available)
- Applying full back stick on Airbus fly-by-wire aircraft, or flying close to the stick shaker / stall warning Angle-Of-Attack (AOA) on aircraft models that do not have full flight envelope protection, may be necessary to prevent the aircraft from sinking down
- Do not change the flaps and landing gear configuration until out of the windshear condition
- If AP is engaged, keep it engaged. If AP is not engaged, do not engage it
- Level the wings to maximize climb gradient, unless a turn is required for obstacle clearance
- When out of the windshear, let the aircraft accelerate in climb, resume normal climb and clean aircraft configuration.

IV Factors Affecting Windshear Awareness

The following factors may affect the windshear awareness and avoidance capability:

- Aircraft equipment:
  - Absence of reactive and/or predictive windshear system(s).

- Airport equipment:
  - Absence of a Low Level Windshear Alert System (LLWAS) detection and warning system
  - Absence of a Terminal Doppler Weather Radar (TDWR).
- Training:
  - Absence of windshear awareness program
  - Absence of simulator training for windshear recovery.
- Standard Operating Procedures:
  - Inadequate briefings
  - Inadequate monitoring of flight parameters
  - Incorrect use of or interaction with automation.
- Human Factors and CRM:
  - Absence of cross-check (for excessive parameter-deviations)
  - Inadequate back-up (callouts)
  - Fatigue.

V Prevention Strategies

Prevention strategies and lines-of-defense should be developed to address these adverse factors (as possible and practical).

Standard Operating Procedures (SOP)

SOP should emphasize the following windshear-awareness items:

- Windshear awareness and avoidance:
  - Takeoff / departure and approach / go-around briefings
  - Approach hazards awareness.
- Windshear recognition:
  - Task sharing for effective cross-check and back-up, particularly for excessive parameter-deviations
  - Energy management during approach
  - Elements of a stabilized approach and approach gates.
- Windshear recovery / escape procedure:
  - Readiness and commitment to respond to a reactive or predictive windshear advisory or warning, as available.

Pilot's reports

In all cases, after a windshear encounter, it is important that the crew makes a detailed report of the event to the ATC, to increase other aircraft's crews awareness. This report should contain:

- The words "pilot report"
- Windshear intensity
- Windshear vertical and horizontal position.

Training

A windshear awareness program should be developed and implemented, based on the contents of:

- The industry-developed Windshear Education and Training Aid

The windshear recovery / escape procedure should be trained in a full-flight simulator, using realistic windshear profiles recorded during actual windshear encounters.

VI Summary of Key Points

The following key points and recommendations should be considered in the development of company strategies and initiatives enhancing windshear awareness.

Key points are grouped into the three domains associated with windshear awareness; Avoidance, Recognition and Recovery / Escape:

- Avoidance
  - Assess the conditions for a safe takeoff or approach-and-landing, based on all the available meteorological data, visual observations and on-board equipment
  - Delay the takeoff or the approach, or divert to a more suitable airport
  - Be prepared and committed for an immediate response to a predictive windshear advisory/caution/warning or to a reactive windshear warning.
- Recognition
  - Be alert to recognize a potential or existing windshear condition, based on all the available weather data, on-board equipment and on the monitoring of the aircraft flight parameters and flight path
  - Enhance instruments scan, whenever conditions for potential windshear exist.
- Recovery / Escape
  - Follow the FD windshear recovery / escape pitch-guidance or apply the recommended FCOM recovery / escape procedure.

VII Associated Flight Operations Briefing Notes

The following Flight Operations Briefing Notes provide expanded information on related subjects:

- **Optimum Use of the Weather Radar**
- **Being Prepared for Go-around**
- **Conducting Effective Briefings**

VIII Airbus References

- A300/A310/A300-600 Flight Crew Operating Manuals (FCOM) – Procedures and Techniques – Inclement Weather Operations – Operation in Windshear/Downburst Conditions
- A300/A310/A300-600 FCOM Bulletins – Windshear Phenomenon
- A318/A319/A320/A321 & A330/A340 FCOM – Abnormal and Emergency - Windshear Procedures
- A318/A319/A320/A321 & A330/A340 Flight Crew Training Manuals – Supplementary Information – Adverse Weather – Windshear.

IX Regulatory References

The following regulatory references are provided to assist the reader in a quick and easy reference to the related regulatory material:

- ICAO – Windshear (Circular 186)
- ICAO – Annex 6 – Part I, 6.21 – Recommendation – Forward-looking Windshear Warning System
- FAA – AC 00-54 - Pilot Windshear Guide.

X Additional Reading Materials

- The industry-developed Windshear Training Aid should be used to further illustrate and complement the information contained in this Flight Operations Briefing Note.

Note:

This two-volume Windshear Training Aid is available from: U.S. National Technical Information Service (NTIS) – **www.ntis.gov**.

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