

The Airbus Safety Magazine

January 2015

#19

# Safety first



# Safety first

**The Airbus magazine contributing to the enhancement of the safety of aircraft operations by increasing knowledge and communication on safety related topics.**

Safety first is published by the Product Safety department. It is a source of specialist safety information for the restricted use of flight and ground crew members who fly and maintain Airbus aircraft. It is also distributed to other selected organisations.

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# editorial



**YANNICK MALINGE**

SVP, Head of Product  
Safety

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There are things we do so repeatedly that we sometimes lose sight of why we do them and why in such a specific way. We also often lose sight of the meaning of the limits we comply with and why they are there. Most situations don't really require that we even get close to them. However, when the situation is slightly different from usual, or when the pressure increases, we don't necessarily have the time to stand back and think about the essentials.

Something similar happens in situations that we encounter infrequently in our daily lives. We tend to forget how to handle them because we are not able to recall the underlying rationale.

This issue of Safety first magazine will take you behind the scene of safety, back to fundamentals. It will revisit the why behind the how to handle some situations safely. Take the time to read these articles. They will give you some key pointers and advice to help you to be prepared. I hope you will find your reading interesting.

At this time of challenge to safety, our thoughts are with the QZ8501 victims and their families. Despite this sad context, I wish you and your relatives all the very best for this New Year.

A handwritten signature in black ink, appearing to read 'Y Malinge', with a horizontal line underneath.



## A makeover for Safety first!

Your magazine now features a new layout to improve the reading experience and to ease the identification of subjects of interest:

**Sections:** each article is now allocated to one specific, colour coded section:

- **Procedures**
- **Aircraft**
- **Training**
- **Operations**
- **General**

**Domains:** pictograms at the beginning of each article characterize the domain(s) addressed:



Flight operations



Engineering



Maintenance



Ground operations

The entire Safety communication team hopes that you will enjoy these changes, and wishes you a happy reading!

## SAVE THE DATE



### 21<sup>st</sup> FLIGHT SAFETY CONFERENCE – 2015

Another year has nearly passed since our last Flight Safety Conference in Dubai. All the Airbus people who were present enjoyed very much the opportunity to network with our customers and to share ideas and news. This was also confirmed by all the feedback we received from airlines delegates who valued this great opportunity for sharing safety information.

We are pleased to announce that the 21<sup>st</sup> Flight Safety Conference will take place in Paris, France, from the 23<sup>rd</sup> to the 26<sup>th</sup> of March 2015. The Flight Safety Conference provides an excellent forum for the exchange of information between Airbus and its customers. To ensure that we can have an open dialogue to promote flight safety across the fleet, we are unable to accept outside parties.

The formal invitations with information regarding registration and logistics, as well as the preliminary agenda have been sent to our customers in January 2015. For any information regarding invitations, please contact

Mrs. Nuria Soler, email [nuria.soler@airbus.com](mailto:nuria.soler@airbus.com)

This year the conference will “major” on the importance of applying judgments to available data, as we drive forward across the industry with further safety advances and further information sharing programs. The whole subject will be being brought to life with real operational examples of when data and judgment has or has not been handled optimally and what best practice looks like in this regard. So, there will be lots to share and lots of opportunities to learn from each other.

As always, we welcome presentations from our operators. You can participate as a speaker and share your ideas and experience for improving aviation safety. If you have something you believe will benefit other operators and/or Airbus and if you are interested in being a speaker, please provide us with a brief abstract and a bio or resume at [nuria.soler@airbus.com](mailto:nuria.soler@airbus.com)

# Flight safety conference

Paris, 23-26 March 2015







# Safety first #19



Flight operations



Maintenance



Engineering



Ground operations

## OPERATIONS

P06 - Tidy cockpit for safe flight



P12 - Landing on contaminated runways



P26 - Understanding weight & balance



P38 - Wind shear: an invisible enemy to pilots?





THE “CLEAN COCKPIT” PHILOSOPHY

# Tidy cockpit for safe flight

One would not normally think of everyday life objects, apparently as inoffensive as a pen or a cup of coffee, as being a real threat to the safe operation of a commercial flight. Yet, leaving them unsecured or forgotten in a cockpit could rapidly turn them into real trouble makers...



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Flight Operations Safety  
Enhancement Manager



At the beginning of 2014, the crew of a cruising A330 and their passengers unintentionally lived a new flying experience at negative g by night... The culprit? A digital camera left between the Captain's side stick and the seat arm rest that led to inadvertent nose down inputs as the PF seat was adjusted forward.

## LOOSE ITEMS IN THE COCKPIT: UNINVITED GUESTS!

**Common sense generally instructs anyone in a cockpit to maintain an orderly environment. However, over the past decade, serious incidents involving unsecured or forgotten items have continued to happen. For the most part, being complacent is not intentional. It just happens. But in view of the possible consequences, truly the cockpit must remain clean and tidy at all time during flight.**

### The resulting consequences

Investigations into the cited 2014 event showed that the camera had been left unsecured between the Captain's side stick and the seat arm rest, such that when the pilot moved his seat forward, it pushed the camera forward too, and eventually, the side stick.

The aircraft dutifully answered this side stick motion and abruptly pitched its nose down for around 20 seconds, reaching a maximum 15 000 feet a minute descent rate. When the aircraft

entered this steep descent, the Captain was alone in the cockpit, in a night environment; therefore these 20 seconds were necessary indeed for him to analyse the situation properly, remove the camera, and eventually recover by pulling the stick back and stabilising the aircraft at a safe attitude.

4 000 feet were lost in altitude during the dive, after which the flight continued uneventfully, but a few passengers and crew members were injured in the process.



## OPERATIONS

Tidy cockpit for safe flight

This event is just one in too many operational incidents over recent years where a loose item left unsecured or forgotten in the cockpit is involved. The following incident summaries for example, illustrate some common – and preventable – scenarios related to unsecured or forgotten items:

- During an aircraft landing, the roll-out jerks caused the pilot's cap to fall off right onto the Park Brake handle because it was hung too loosely. A jump seat rider present in the cockpit at that time, was quick to react and while attempting to secure the hat, he inadvertently turned the Park Brake handle and set it ON. This obviously led to a rather abrupt stop and the aircraft tires to burst. Thankfully no one was injured in this event.
- On another aircraft in cruise, documentation that had been left on the center pedestal moved and interfered with the rudder trim knob. This resulted in a sudden rudder movement and unexpected aircraft yaw, from which the pilot managed to recover. Again thankfully no one was injured.
- An aircraft with moving throttles was approaching the Top Of Climb (TOC). At TOC, when thrust

reduced, an iPad the Pilot had left on the throttles control module became jammed between the throttles and the fuel levers. When the Pilot removed his iPad, both fuel levers were activated, thus shutting down the two engines. The crew managed to recover the situation safely and no one was injured.

Other common situations are regularly heard of:

- Coffee cups placed on the glare shield or pedestal: unexpected turbulence or unintentional bumping by the crew causes fluid to be spilled onto the cockpit control panels. Beverage spill onto electronic equipment may not necessarily have an immediate effect on the flight, but at best, it can lead to an early and expensive overhaul of the equipment.
- Books placed on the glare shield or pedestal: these fall off and may operate some switches or pushbuttons, such as a fuel lever being pushed off, or even de-select a radio frequency.
- Forgotten pens, cutlery (during meals) or clipboards: as small as they can be, they can get jammed in the controls – typically the rudder pedals – when they fall on the floor and move during flight.

**Each one of the above incidents must serve as important reminders of the critical need to ensure that items are properly stowed and secured before AND during flight.**



## The culprits

Establishing an exhaustive list of all potential candidates that may interfere with the controls would be too long and ineffective. These items can include aviation-related items such as portable GPS units, clipboards; non-aviation-related Portable Electronic Devices such as personal cell phones or laptops; and personal items such as clothing or carry-on items.

Following are the most common objects that can be found unsecured or forgotten in a cockpit:

- iPad
- Laptop
- Cell phone
- Digital camera
- Spectacles and sunglasses
- Scattered papers
- Pen
- Clipboards
- Meal tray
- Coffee or any beverage cup
- Pocket calculator
- Lighter

This list could be longer, but it gives an idea of the kind of common equipment likely to create hazards when left loose in a cockpit.

The aircraft cockpit ergonomics are designed to be as robust as possible against these kind of threats. Where relevant, Airbus has developed modifications to prevent the ingestion of foreign objects into the controls. The flap lever mechanism for instance is protected by a brush covering the lever slot, thus efficiently preventing foreign objects ingress.

However, even a perfectly well-designed cockpit can never be fully protected against the malicious behaviour of unsecured objects. For this reason, prevention is essential and discipline in the cockpit is paramount. ■

“ Prevention is essential and discipline in the cockpit is paramount ”



# PREVENTION: A PLACE FOR EVERYTHING, AND EVERYTHING IN ITS PLACE...

**The 2014 event could have resulted in far worse consequences, had the aircraft been at a lower altitude. This was a strong reminder to the flight crew that they should never under-estimate the potential for harm of everyday life objects, when left unsecured!**

In fact, the solution against such events lies in one word: discipline.

To help efficiently curb the number of operational incidents involving a loose item in the cockpit, pilots need to be vigilant and ordered.

First, items that are brought in a cockpit must be put and stowed in their dedicated compartment:

- Cups in the cup holders
- Headsets not in use, on the hook stowage
- Books and paper, if any, in the lateral stowage
- Trash in the waste bin in the lateral console
- Meal trays on the floor behind the flight crew. The flight attendants should collect the meal trays as soon as possible.
- Personal equipment properly secured in the various stowage areas. The Pilot Pocket in particular, is the answer to where to stow valuable items such as a portable GPS or cell phone.
- Flight bags should be kept closed after obtaining whatever was necessary.

Then, we encourage flight crews to incorporate the following simple checks in their preflight actions in order to ensure their working environment is well secured for a flight:

- Inspect the cockpit for forgotten or misplaced items before take-off and ensure all are properly secured and isolated from other equipment in the cockpit. This also helps assure their availability throughout the flight.
- Make sure all your personal items such as hats and jackets, iPads or luggage are secured.
- If necessary, remind jump seat riders not to create distractions and to adopt the same measures and same discipline against unsecured items.

And maintain this attitude and level of alertness prior to AND during flight, putting a particular emphasis on the preparation for the approach phase during the approach briefing prior to descent. ■



## DID YOU KNOW

Airbus Clean cockpit philosophy is available in FCTM NO-010 GENERAL-Clean cockpit.



Loose items in a cockpit environment are not welcome: they can too easily drive a crew into a hazardous, and yet easily preventable, operational situation.

To efficiently curb the number of incidents related to unsecured or forgotten items, pilots need to be vigilant and adopt a clean and tidy cockpit philosophy from preflight through to landing and arrival at the gate.

When entering the cockpit, ask yourself these questions: is all of the luggage secure? How about my own flight bag and my iPad? And just remember: a place for everything, and everything in its place...



THE QUESTION OF PERFORMANCE

# Landing on contaminated runways

Landing performance is a function of the exact landing runway conditions at the time of landing. A simple statement for a more complex reality. Indeed, knowing what exact contamination is or remains on the runway at a given point in time is often challenging.



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Performance expert –  
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Landing on a contaminated runway may be an almost daily experience for some pilots or a more exceptional one for others. In any case, doing it safely requires some background understanding and thinking on a variety of questions, especially: What does the term “contaminated runway” actually mean? How are contaminated runway conditions reported to pilots? How to translate the reported runway condition terminology into a safe assessment of the aircraft landing performance? How to prepare for a safe landing and then perform it?

## CONTAMINATED RUNWAY: WHAT DOES IT MEAN IN REALITY?

**If weather can to some extent be anticipated, the runway surface conditions with natural contamination may be more difficult to forecast. Indeed, runway surface conditions depend on a variety of factors including state changes due to surface temperature effects, chemical treatment, or run-off and removal.**

### A variety of contaminants

The most common and natural contaminants are limited in number:

- compacted snow (solid contaminant, its depth is irrelevant),
- dry or wet snow, depth at or more than 3 mm - 1/8 inch (\*)
- water, slush, depth at or more than 3 mm - 1/8 inch (\*)

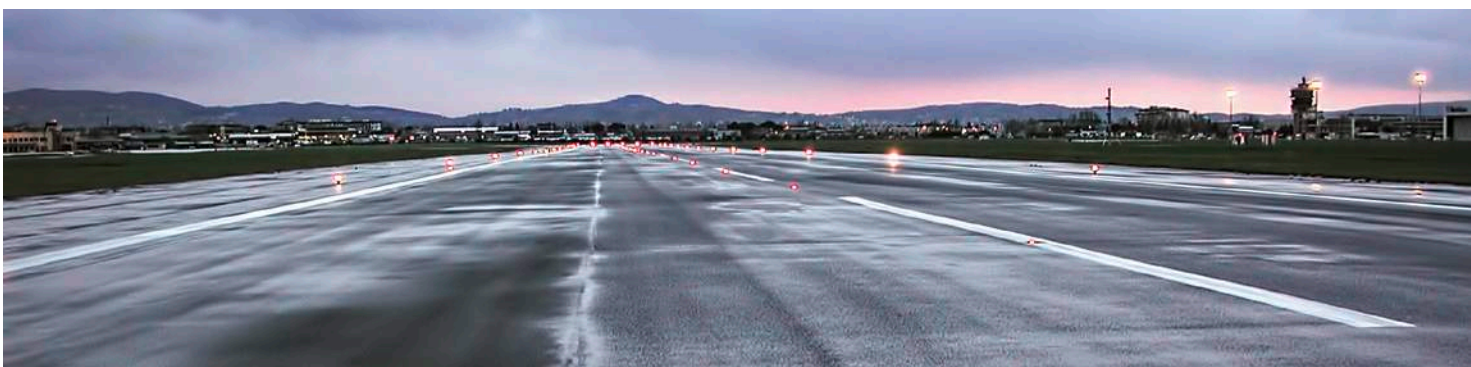
- ice (solid contaminant, its depth is irrelevant).

They are the ones for which sufficient historical data has been gathered and safe performance levels defined by EASA, assuming a homogeneous condition of the contaminant along runway length.

(\*) DRY and WET normal runway conditions, without abnormal contamination by rubber or other pollution, are by aeronautical language convention classed as “non-contaminated”.

Dry or wet snow, water and slush of a depth less than 3 mm - 1/8 inch or frost are considered equivalent to a wet runway (non-contaminated).

A wet runway excessively contaminated by rubber, reported by NOTAM as “Slippery when Wet” as defined by ICAO, is a contaminated runway. It is considered to have the same performance as snow (MEDIUM).



## OPERATIONS

Landing on contaminated runways

“ The most common contaminants for which aircraft performance level can be defined have been synthesized into the Runway Condition Assessment Matrix that permits deterministic classification of the expected landing performance. ”

In some situations though, the contaminant reported to be present on the runway may not make it possible to identify the corresponding performance level just by considering the contaminant type and depth. It is the case particularly when the contaminant is:

- **too variable as to its impact on aircraft performance:** e.g. volcanic ash, hydraulic fluid spillage. Operations cannot, in general, be supported with specific performance information;
- **a common natural one, but outside of the temperature conditions where its characteristics are well known:** e.g. compacted snow if the outside air temperature subsequently raises above  $-15^{\circ}\text{C}$ . Indeed, compacted snow is a specially prepared winter runway when temperature is very low, at or below  $-15^{\circ}\text{C}$ . Above that, there is a risk that some

of the contaminant be no longer true compacted snow. A downgrade of performance should then be considered as risk mitigation to support safe operations.

- **a piling up of layers of different contaminants:** the few cases documented water on top of compacted snow, water on top of ice (or wet ice), or dry/wet snow over ice, have shown unacceptable impact on aircraft performance and operations cannot be supported, even adoption of the most conservative contaminant, i.e. ice, for snow over ice condition might be unsafe.

Eventually, the most common contaminants for which aircraft performance level can be defined have been synthesized into the Runway Condition Assessment Matrix that permits deterministic classification of the expected Landing Performance.





Runway Surface Conditions		Observations on Deceleration and Directional Control	Related Landing Performance		Maximum Crosswind (Gust included)
Runway State or / and Runway Contaminant	ESF* or PIREP**		Code	Level	
Dry	-	-	6	DRY	38kt
Damp	Good	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.	5	GOOD	38kt
Wet Up to 3 mm (1/8") of water					29kt
Slush Up to 3 mm (1/8")					
Dry snow Up to 3 mm (1/8") Wet snow Up to 3 mm (1/8") Frost					
Compacted Snow OAT at or below -15°C	Good to Medium	Braking deceleration and controllability is between Good and Medium.	4	GOOD TO MEDIUM	29kt
Dry Snow More than 3 mm (1/8"), up to 100 mm (4") Wet Snow More than 3 mm (1/8"), up to 30 mm (6/5") Compacted Snow OAT above -15°C Slippery when wet	Medium	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be reduced.	3	MEDIUM	25kt
Water More than 3 mm (1/8"), up to 12.7 mm (1/2") Slush More than 3 mm (1/8"), up to 12.7 mm (1/2")	Medium to Poor	Braking deceleration and controllability is between Medium and Poor. Potential for Hydroplaning exists.	2	MEDIUM TO POOR	20kt
Ice (cold & dry)	Poor	Braking deceleration is significantly reduced for the wheel braking effort applied. Directional control may be significantly reduced.	1	POOR	15kt
Wet ice Water on top of Compacted Snow Dry Snow or Wet Snow over ice	Nil	Braking deceleration is minimal to non-existent for the wheel braking effort applied. Directional control may be uncertain.	-	-	-

\*ESF: Estimated Surface Friction  
 \*\*PIREP: Pilot Report of Braking Action

## A dynamic weather

Weather conditions evolve quickly and elude a forecast accurate enough to be compatible with the sensitivity of landing performance. As an example, Landing performance is defined as GOOD when the runway is normally wet (runways quickly drain water during showers with normal precipitation rates). It might drop to MEDIUM TO POOR with standing water accumulation (the 3 mm water depth criterion is a necessary simplification to represent this phenomenon). Likewise, the estimated runway condition and resulting landing performance may be sensitive to temperature. It is the case especially when

the temperature leads to a change of state of the contaminant: landing performance is poor on dry ice, but can become non-existent if ice surface is melting (here again, the -3°C temperature criterion is a necessary simplification). Determining precisely when the precipitation accumulation will become critical or when the ice will start melting in significant proportion is already a challenge when nothing interferes with it. Yet in reality, a number of other factors do interfere with this weather dimension and make it even more difficult to determine the actual runway condition, not to mention an anticipation of it.

### A large runway surface area

Although runways vary in size, 3 km long and 45 m wide give a representative indication of the surface area of a runway. On such a surface, the exact contamination may vary from one place to another. As an illustration, “patchy snow and ice” may be reported in some airports as representing less

than 25% of runway coverage.

Whatever the actual state of the runway and its variability, it needs to be simplified to make a landing performance computation. Indeed, landing performance models can only consider a single contaminant evenly distributed on the runway.

### Airport operations

Beyond these intrinsic difficulties of having an accurate representation of the runway condition, **operations taking place on the runway modify the runway condition at least in some places of the runway.** An aircraft landing on a runway may change the depth of a contaminant if not its nature. Indeed, it can for example induce a change of state at the touch-down point or along its deceleration path. The contamination will remain unchanged though on the un-trafficked last part of the runway or further away

laterally from the landing gear.

An aircraft taking off might also induce changes in the runway contamination along its take-off roll, thereby increasing as well the heterogeneity of the contamination throughout the runway surface.

A more obvious case of impact of airport operations on runway contamination is any runway management action such as cleaning or de-icing. In many cases, de-icing fluids are applied only to a limited width along the runway axis. ■



# HOW ARE RUNWAY CONDITIONS REPORTED TO PILOTS?

**For pilots, the main reason why runway contamination needs to be considered is because of its impact on the performance of the landing.**

Although this sounds obvious, it means that what pilots need to know is not the very physical details of the runway conditions but rather how the performance of the aircraft might be affected, thus what they will need to do to still perform a safe landing. In other words, what pilots really need is a translation of the runway condition into its practical effects on the aircraft.

Yet today, the information provided to pilots on runway condition is not directly a level of performance. One of the main challenges for pilots is to translate from their vantage point in the cockpit of an approaching aircraft the sometimes complex information provided to them on runway surface condition into a single classification of the runway condition landing performance level.

This translation is done by means of the Runway Condition Assessment Matrix (RCAM) introduced earlier. The RCAM includes, beyond DRY, WET and thin contaminants that are equivalent to WET, 4 discrete levels of contamination, each of which is associated with a landing performance level.

The information provided to pilots of runway condition may vary from one country to another and from one airport to another. Let's review the three categories of possible information pilots may get on runway condition before discussing how they can be integrated to come up with a single, representative, performance level.

“What pilots need is a translation of the runway condition into its practical effects onto the aircraft.”

## Contaminant type & depth

In accordance with ICAO standards, all airports around the world should provide this information to pilots prior to landing. It is the primary information about runway contamination (this reporting is even more essential for take-off).

Currently, the description of contaminants in SNOWTAMs is done through a combination of codes and free text/plain-language remarks. There is no clear distinction between performance relevant contaminants and other runway surface conditions provided for situational awareness. The ICAO SNOWTAM codes correspond to a set of generic contaminants, thus are different from the RCAM landing performance codes

agreed by the Takeoff and Landing Performance Assessment Aviation Rule-making Committee (TALPA ARC, see article Safety First 10).

Providing the contaminant type & depth to pilots relies on measurements, especially that of contaminant depth. Performing these measures in a way that provides a representative view of the real depth is a challenge to airports. More generally, measuring runway contamination, whether it is to determine contaminant depth or to estimate the surface friction coefficient (see next section), can become challenging for a variety of reasons (see insert *The challenge of providing measures on runway contamination*).

“ There is no established meaningful correlation on most contaminants between estimated surface friction established by ground measurement devices and aircraft performance. ”

### Estimated surface friction (ESF)

ICAO and national authorities have progressively shied away from reporting measured friction to pilots. In fact, there is no established meaningful correlation on most contaminants between estimated surface friction established by ground measurement devices and aircraft performance. Therefore, reporting ESF is strongly discouraged by ICAO on contaminants for which it is now known that it may be dangerously biased (fluid winter contaminants as snow or slush, i.e. dry or wet snow or slush). (see insert *The challenge of providing measures on runway contamination*). Yet, it is a secondary information pilots may get in some areas of the world.

ESF can be reported in different formats. Either under the terminology: GOOD / GOOD TO MEDIUM / MEDIUM / MEDIUM TO POOR / POOR by third of runway length, or through a figure e.g. 26 $\mu$ . When the surface friction is expressed through a figure, it may give the illusion that it is an accurate measurement although it still remains of limited practical use in characterizing winter runway conditions for aircraft operations. Indeed, no related landing performance level can reasonably be derived from the sole figure.

### Pilot Reports of Braking Action (PiRep of BA)

The last secondary information pilots may get on runway conditions, although its use largely varies regionally, is through the air traffic controller in the form of a Pilot Report or PiRep of Braking Action. PiRep of BA are encouraged in some countries. These reports are individual perceptions that may be influenced by a number of factors: whether the pilot is familiar with contaminated runways and this particular type of conditions or with the type of aircraft or the use of deceleration devices. It is also easy for a pilot to mistake aerodynamic and reverse thrust deceleration forces for braking forces. However, the usefulness of such subjective reports should not be underestimated, as they often (but not always) provide the most recent information available under dynamic weather, and resulting runway surface

conditions. PiReps should always be communicated to the approaching pilots with a time and emitter of the report including the airline and the aircraft type.

PiReps of Braking Actions are also reported using the terminology: GOOD / GOOD TO MEDIUM / MEDIUM / MEDIUM TO POOR / POOR, and can also be reported by third of runway length.

In countries where PiReps of Braking Action are transmitted to following traffic, it is the sole responsibility of the pilot performing the In-Flight landing performance assessment to determine whether the transmitted information can be considered reliable or not.





### Integrating the various types of information on runway surface condition

Eventually, pilots need to integrate all the pieces of information they receive in relation to runway contamination to come up with a single level of landing performance. They can receive up to three different information types, coming from different sources:

- Runway contaminant type and depth: mandatory as primary information;
  - Estimated Surface Friction (ESF): not systematic as secondary information;
  - Pilot Report of Braking Action (PiRep of BA): not systematic as secondary information.
- used to determine the Related Landing Performance Level for in-flight landing performance assessment (downgrade). When ESF is higher than the performance associated to contaminated type and depth in the RCAM, its use to determine the Related Landing Performance Level is not supported (no upgrade).

Some rules do exist for pilots to integrate these various types of information.

As a general rule, the Related Landing Performance level derived from the primary information (contaminant type & depth) prevails if considering other sources of information would lead to being less conservative than EASA regulation.

When ESF is lower than the performance associated to contaminant type and depth in the RCAM, it should be

When PiRep of BA is lower than the performance associated to contaminant type and depth in the RCAM, it should be used to determine the Related Landing Performance Level for in-flight landing performance assessment (downgrade). When PiRep of BA is higher than the performance associated to contaminated type and depth in the RCAM, its use to determine the Related Landing Performance Level is not supported (no upgrade) by EASA, but under pilot responsibility in USA. ■





## **THE CHALLENGE OF PROVIDING MEASURES ON RUNWAY CONTAMINATION**

Providing quantitative information on runway contamination combines two major challenges. The first one is to perform accurate and representative measures. As for the second one, it relates to the validity of the measurement with time.

### **Interfering with operations on an active runway**

Performing measures on a runway requires sending a measurement vehicle on the runway (except for few airports equipped with contaminant depth automatic measurement devices). For any airport, this could induce a risk for active runways.

### **The time needed to perform the measures**

Even if the number of measurements performed to assess the runway condition must remain limited despite the runway surface area, it takes some time to perform them. On an airport that has infrequent winter weather events and thus has limited equipment and personnel available, the time for a runway condition assessment and runway cleaning may be very similar. Yet, when weather “piles up”, both are needed. The measurements then allow for validating the success of the cleaning operations.

### **The limitation of measurement tools**

#### **» Contaminant depth**

Measuring the contaminant depth is done by means of tripods put on the ground, or lasers, or FOD cameras or in very few airports so far, sensors built into the runway surface. Whatever the tool, very dynamic weather conditions make it difficult to perform an accurate measure. Heavy rainfalls are among these conditions,

except for the few airports in the world equipped with above mentioned automatic measurement devices for real-time water depth.

#### **» Runway friction**

Airport runway friction assessment can be performed using a variety of devices and vehicles that are based on an equally wide palette of measurement principles and ways of implementing these. They are all subject to limitations that affect the accuracy and reproducibility of measurements. The correlation of data produced with them with aircraft performance is challenged by factors such as test wheel size and inflation pressure, load on the test wheel, and last but not least testing speed, which are all at least an order of magnitude different from those of the aircraft. Airport runway friction assessment should thus at best be considered as a way to monitor trends rather than determine absolute values. It can in no way be used as primary information to directly derive landing performance from.

### **The sustainability of the values measured**

Measures are performed on a discrete basis not only space wise but also time wise. In other words, a measure is representative of whatever it measures at the time of the measure. Yet, actual conditions may quickly drift from a measurement performed at a given point in time.

## **PERFORMING A SAFE LANDING ON A CONTAMINATED RUNWAY**

**Performing a safe landing on a contaminated runway involves a number of dimensions, including lateral control, max X-wind... However, for simplification purposes, this section will put the emphasis on aircraft performance. Beyond the dispatch calculation of the landing performance, preparing to land on a contaminated runway also relies on a number of activities in-flight.**

### **Reevaluating landing performance calculation in-flight**

Even if under EASA regulation, landing performance is calculated based on the probable contamination before dispatch, it is necessary to re-evaluate the landing performance prior to landing. Dispatch considerations will most probably no longer apply to the actual conditions at the time of landing. In addition, should the conditions be exactly the ones anticipated, the most recent in-flight landing performance models can lead to longer distances. Indeed, the in-flight landing performance models used today rely on more realistic assumptions thus allow for deriving more realistic, though often more conservative, landing distances.

The model used for all Airbus aircraft for In-Flight Landing Distance assessment is based on the comprehensive work of the TALPA-ARC group. This work relies itself on the contaminants

characteristics described in EASA CS25.1591 (see SAFETY FIRST n° 10 August 2010 P8-11). Airbus concurs with the FAA in recommending a minimum margin of 15% on these distances, achievable in line operations when no unexpected variations occur from reported outside conditions and assumed pilot technique.

The improvements brought by the RCAM are so widely recognized that they allowed EASA, in combination with a minimum margin of 15%, to accept a new still safe but more realistic (better) performance level for POOR. This level is consistent with ICE (COLD & DRY) rather than with WET ICE (as previously), for which the RCAM prohibits operations. These new computation options have started to appear at the end of 2014 on the Airbus fleet and will continue progressively.







## OPERATIONS

Landing on contaminated runways

“ Anticipate all the realistic degradation or aggravating factors and determining the thresholds below which a safe landing can still be performed ”

### Assessing realistic worst conditions in which landing is still safe

While performing the in-flight check on landing performance, anticipating all the realistic degradation or aggravating factors and determining the thresholds below which a safe landing can still be performed is a way to cope with the uncertainty of the information available in approach, hence remove a potential element of surprise should one or more parameters evolve by the time you actually land. For example, if it is snowing and the latest airport report states less than 3

mm (1/8 inch) of snow, asking yourself: “is it going to exceed the critical depth of 3 mm (1/8 inch)? If it does, am I still safe?” is a way to proactively get prepared to a safe landing. Likewise if it is raining, “what is the maximum cross-wind under which I can still perform a safe landing” is the kind of question that contributes to a good preparation to a safe landing.



## Understanding the margins

As mentioned earlier and illustrated in SAFETY FIRST n°10 fig.5, a 15% margin is to be integrated in the calculations of In-Flight Landing performance, on DRY, WET and on contaminated runways (Factored In-Flight Landing performance), except in case of failure. This margin is meant to cover some uncertainty related to a variety of aspects:

- Pilot achievement of the assumed touch-down location and touch-down ground speed
  - Pilot timely activation of deceleration devices assumed (brakes if no Auto-Brake, reversers)
  - Lower performance than expected (even if friction models of CS25.1591 are generally conservative)
- If the 15% margin is fully “eaten” by the sole effect of runway conditions worse than expected, there is no margin left for any other deviation as a slightly long flare or slight pilot lag in applying deceleration means. ■



## BEST PRACTICE

### MANAGEMENT OF FINAL APPROACH, TOUCH-DOWN AND DECELERATION

With the rationale for the recommended 15% safety margin in mind, the management of final approach, touch-down and deceleration appear as key factors that deserve special attention upon landing on a contaminated runway. The following tips are worth keeping in mind:

- Consider diversion to an uncontaminated runway when a failure affecting landing performance is present
- Land in CONF FULL without speed additives except if required by the conditions and accounted for by appropriate in-flight landing performance assessment, with the auto-brake mode recommended per SOPs
- Monitor late wind changes and GA if unexpected tailwind (planning to land on contaminated runway with tailwind should be avoided)
- Perform early and firm touchdown (early as runway behind you is no use, firm to ensure no delay in ground spoiler extension, brake physical onset, and reverse extension by sluggish wheel spin-up and/or delayed flight to ground transition of the gear squat switches)
- Decelerate as much as you can as soon as you can: aerodynamic drag and reverse thrust are most effective at high speed, then moderate braking only at low taxi speed after a safe stop on the runway is assured
- Do not delay lowering the nose wheel onto the runway (it increases weight on braked wheels and may activate aircraft systems, such as auto-brake)
- Throttles should be changed smoothly from Reverse max to Reverse idle at the usual procedure speed: be ready to maintain Reverse max longer than normal in case of perceived overrun risk
- Do not try to expedite runway vacating at a speed that might lead to lateral control difficulty (Airport taxiway condition assessment might be less accurate than for the runway)



# Understanding Weight & Balance

To “feel” the aircraft response through the flight controls as being “heavier or lighter” than anticipated at take-off can result from a weight & balance inaccuracy. In fact, when the CG is out of the operational limits, the safety consequences can be far more critical than just a strange feeling.



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What does actually lie behind the aircraft weight and the %RC or %MAC mentioned on the load and trim sheet? What do these limits account for? Beyond the compliance with regulatory requirements dimension, let's take a journey through the underlying physical phenomena at stake. But first let's take a look at what can happen when the loading and C of G is incorrect or becomes out of limits.

## A VARIETY OF EVENTS, A COMMON ORIGIN

**Images of airplanes sitting on their tail or experiencing a severe tail strike or even stalling right after take-off unfortunately do not all belong to the past. In recent years, commercial aviation has faced multiple accidents or serious incidents related to weight & balance issues.**

### Tail strike at take-off

While taking-off for the second leg of a flight, a single aisle aircraft experienced a tail strike. Despite significant damage, the aircraft was able to turn back and land at departure airport. The first leg had been uneventful. During the intermediate stop over, some of the passengers disembarked the aircraft and their luggage was offloaded. No new passengers boarded nor was any new cargo

loaded. The investigation revealed that the passengers proceeding to the second destination airport were all seated at the back of the cabin and their luggage was loaded in the aft cargo bay. No movement of passengers between legs took place. The load sheet had been prepared for the first leg only. The CG position for the second leg turned out to be outside of the safe envelope: it was too far aft.

### Unexpected pitch-up during climb

The next story is based on a real event with a wide body cargo aircraft. The aircraft was carrying several similar heavy pieces of special cargo. During climb, the aircraft experienced an unexpected pitch-up when the

cargo detached and moved aft. The CG warning alert went off and the AP disconnected. The pilot successfully manually controlled the aircraft and eventually landed safely.

### Tail tipping

While being unloaded, a wide body cargo aircraft tipped up on its tail. It turned out that a less than optimum shift handover had taken place, and

lack of training of the load master on the aircraft type contributed to the non-compliance with the correct unloading sequence.



### DID YOU KNOW

Among the accidents related to a weight and balance issue\*:

- 21% are due to overweight
- 35% are due to a CG which exceeds the certified limits

\*National Aerospace Laboratory (NLR) study for the period 1997-2004

## Tail strike and take-off after runway end

A long-range aircraft type failed to take-off within the runway length, and experienced a significant tail strike whilst ultimately managing to take-off way outside the runway limits. The aircraft was severely damaged but fortunately, was ultimately able to make a successful landing. The investigation revealed that the aircraft weight entered into the system to compute the take-off speed was incorrect. One digit was incorrectly entered. While the aircraft weight was 362 tons, the take-off performance data were calculated for a 262 tons aircraft, thus the expected performance was significantly over estimated. The real aircraft performance was much worse than that which had been calculated.

## Stall and crash

Right after take-off, a long-range wide-body cargo aircraft experienced a violent pitch-up that couldn't be recovered by the crew. The rapid decrease in airspeed led to the aircraft stalling and crash. It turned out that the load had broken free and had shifted aft just after take-off.

Four recent events, one safety lesson: the impact of weight & balance issues on a flight can range from merely a "strange feeling" to a fatal accident. ■



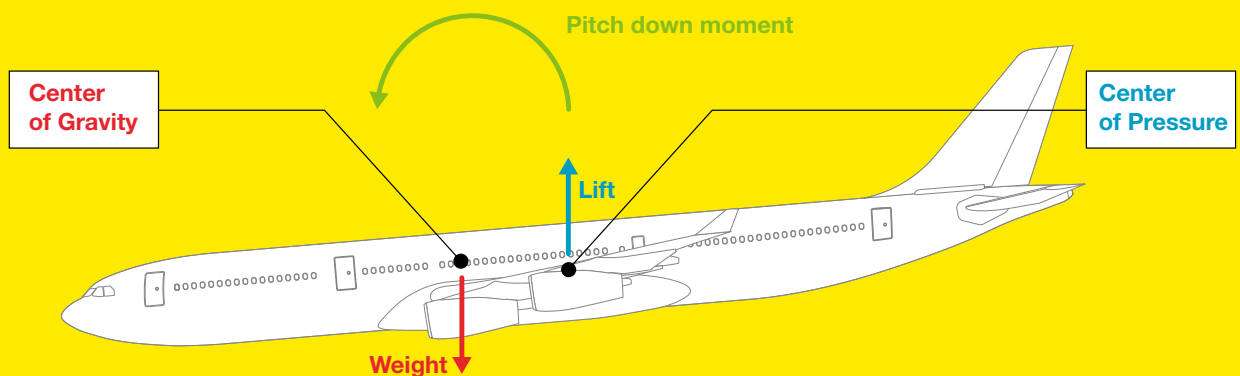
## WEIGHT & BALANCE: WHAT IS IT ABOUT?

In order to well understand the impact of weight and balance on the stability and maneuverability of the aircraft, it is worth getting back to the forces that apply to the aircraft, and more specifically to focus on the vertical ones.

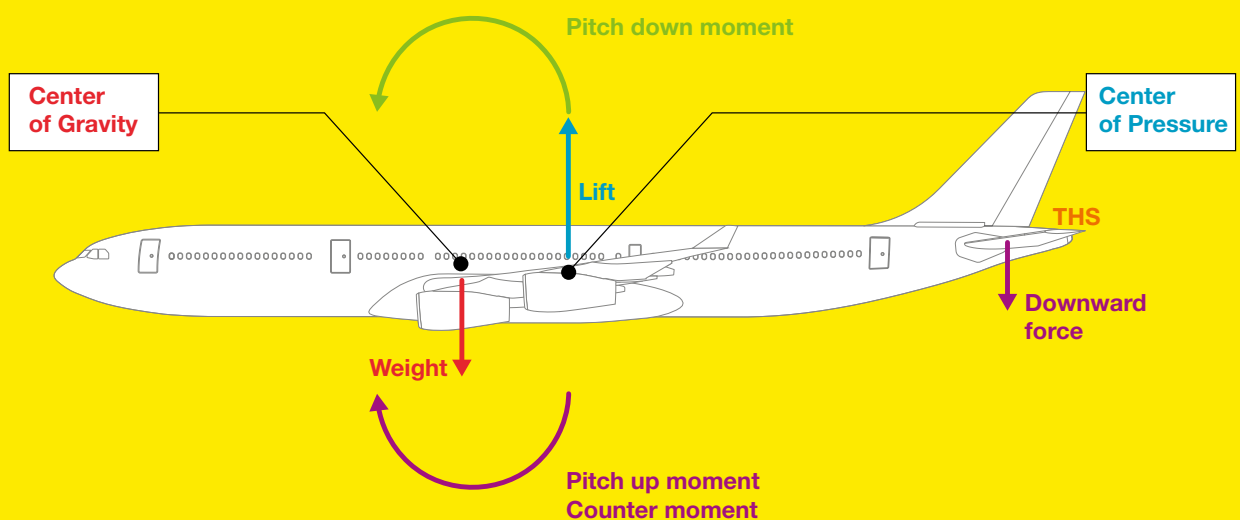
There are two of them, applying at distinct points along the aircraft longitudinal axis:

- The Weight of the aircraft, applied at the Center of Gravity (CG) of the aircraft;
- The Lift, applied at the Center of Pressure (CP).

The CG is further forward than the CP for aircraft stability reasons. Thus, the more distant the two points, the bigger the pitch-down moment.



The distance between the CG and the CP induces a pitch down moment that needs to be compensated for to keep the aircraft level. This is done through the Trimmable Horizontal Stabilizer (THS) that exerts a downward force. This force applies at the THS, thus far from the CG; therefore it creates a big pitch-up moment, but also increases the required overall lift to keep the aircraft level at the same time.



## KEEPING THE CG WITHIN THE OPERATIONAL ENVELOPE: A MUST FOR A SAFE FLIGHT

**The influence of the CG position on aircraft performance, stability and maneuverability varies along the flight, depending on the phase of flight. The main safety issues related to an inappropriate position of the CG depend on whether the CG is forward or aft as developed hereafter.**

### CG forward

As explained earlier, the more distant the CG and the CP, the bigger the pitch-down moment. Since for aircraft stability reasons the CP is always located behind the CG, a forward CG

increases the distance between the CP and the CG. A CG position further forward than the most forward position of the operational envelope can affect the safety of the flight in many ways.

#### » Impact on aircraft maneuverability at all phases of flight

A CG position that is too far forward induces such a big pitch-down moment that the aircraft maneuverability can no longer be guaranteed.

Indeed, the more forward the CG, the bigger the horizontal stabilizer and elevator deflections needed to give the aircraft a pitch-up attitude to compensate for the pitch-down moment. However, at some point of CG forward position, the horizontal stabilizer and elevator maximum deflections are reached, and the aircraft cannot

be maneuvered any more.

As an example for take-off, if the CG position is too far forward, the aircraft has such a “heavy nose” that the correct take-off rotation rate using the elevator becomes impossible to reach. The impact of an excessively forward CG position on aircraft maneuverability applies at all phases of flight. However, it is most noticeable at low speed due to the reduced effectiveness of the elevators.

“ A CG position that is too far forward induces such a big pitch-down moment that the aircraft maneuverability can no longer be guaranteed. ”





### » Impact on aircraft performance at all phases of flight

A CG exceeding the most forward CG position of the envelope is also the most penalizing situation in terms of aircraft performance.

Indeed, the take-off and landing per-

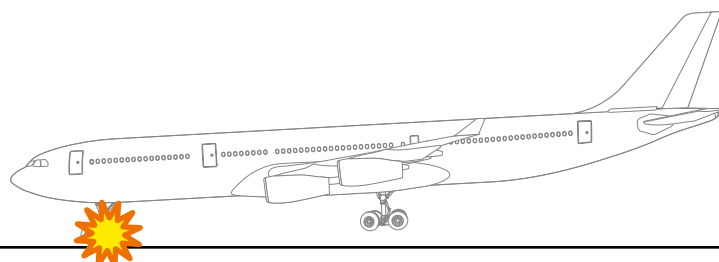
formance is calculated based on the most forward CG position within the envelope. Therefore, if the CG position is even more forward, the actual aircraft performance will be lower than the calculated one.

### » Impact on aircraft structure at take-off

On the ground, the total weight of the aircraft is supported by both the nose and main gears, the further forward the CG, the bigger the proportion of total weight is carried by the nose landing gear. At high weights (TOW),

if the CG position exceeds the most forward CG position of the envelope, the aircraft structural limits of the nose landing gear can be reached with a consequent risk of damage.

“ A CG exceeding the most forward CG position of the envelope is also the most penalizing situation in terms of aircraft performance. ”



### CG aft

A CG aft position brings the CG close to the CP. Yet, exceeding the most aft position of the envelope can lead to a variety of safety issues.



#### » Impact on aircraft controllability at ...

##### ... Go-around

In case of go-around, setting TOGA power induces a significant pitch-up moment that needs to be compensated for. The more aft the CG, the bigger the pitch-up moment. If the CG is too far aft, and outside the envelope, the pitch-up moment induced by initiating the go-around may be too big to be compensated for.

At low speed, high angle of attack and TOGA power, the pitch-up moment increase due to having a CG position too far aft, may also trigger the alpha floor protection, thus prevent its sufficient compensation.

##### ... Take-off

At lower take-off weight (for example for a positioning flight or short leg flight), a CG position too far aft impairs the nose wheel controllability during taxi and at the beginning of the take-off run. Indeed, the weight of the aircraft being mostly on the main gear, the adherence of the nose wheel to the ground is limited. This is especially true on wet or contaminated runway surfaces. Until the aircraft reaches a sufficient speed for the rudder to be effective, nose wheel steering is the only way to control the aircraft. The nose wheel adherence is even further reduced when full power is applied for take-off due the induced pitch-up moment.

This “very light nose” effect of too aft a CG position also makes the rotation so easy that it could as easily lead to a tail strike (**fig.1**). In some cases, the aircraft will “self rotate” without any action by the pilot.



**(fig.1)**

Tail strike at take off

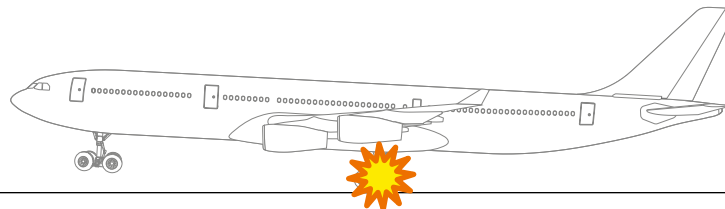


### » Impact on aircraft structure at take-off

As mentioned earlier, on the ground, the total weight of the aircraft is supported by both the nose and main gears. Therefore, the further aft the CG, the bigger the weight on the main landing gears. At high weights (TOW), if the CG position exceeds the most aft CG position of the envelope, the aircraft structural limits of the main

landing gear can be reached with a consequent risk of damage.

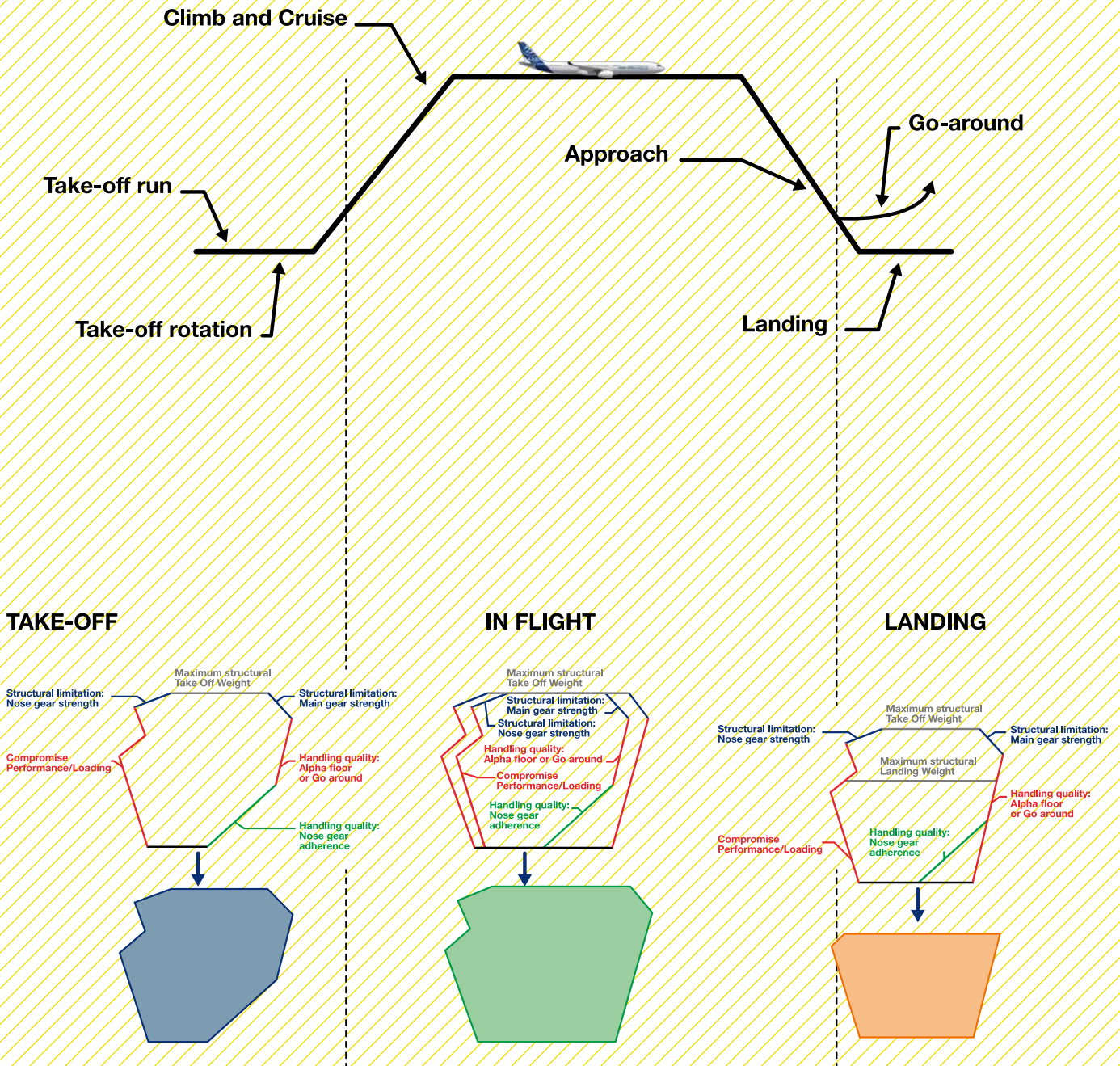
Likewise, in such high TOW conditions, the load on the wings may exceed their structural limit. This is the reason why the speed is limited during taxi for turns.



**Eventually, a CG outside the operational envelope may significantly impair the aircraft capabilities, and thus ultimately jeopardize the safety of the flight. ■**

“ A CG outside the operational envelope may significantly impair the aircraft capabilities, and thus ultimately jeopardize the safety of the flight. ”

### Summary along the flight path of the main safety impacts of an ill-located CG



# HOW TO MAKE SURE THE CG IS AND REMAINS WITHIN A SAFE ENVELOPE THROUGHOUT THE FLIGHT?

**Both the CG position and the safe envelope evolve throughout the flight. Indeed, the weight of the aircraft evolves mainly as fuel is burned. As for the CG, its position is sensitive to various phenomena ranging from landing gear, flaps and slats position to passengers or cabin crew movements from one end of the cabin to the other.**

Although there were attempts at developing systems to measure the aircraft weight and CG position, no robust solution has yet been found. The best way to make sure the CG remains within a safe envelope throughout the flight is to both define

an operational envelope that includes safety margins and to perform a correct CG calculation. Indeed, as explained in the previous section, an excursion of the CG outside of its operational envelope could lead to dramatic consequences.

## Understanding the safety margins

Determining the CG safe envelope results from calculations based on a number of assumptions. These assumptions are simplifications of the actual but evolving aircraft situation. They include inaccuracies and uncertainties that need to be compensated for. This is the purpose of the safety margins taken to define the operational envelope. Among the sources of inaccuracies and uncertainties are:

- **The determination of the dry operating weight of the aircraft:** This weight is based on the aircraft weighing results and on assumptions on the weight of items on board such as catering or crew. From one weighing to another the aircraft weight may evolve;
- **Weight of passengers and their hand luggage:** In the CG determination a single average passenger weight is taken into account to reflect as much as possible the reality.
- **Passengers embarkation:** Some changes in passengers seating may occur either before or during the flight. Their impact on the aircraft
- **actual CG position is usually limited.** In case of free seating though, some significant difference may exist between the actual and the calculated CG positions with potential impact on safety (see insert *Free seating section*);
- **Moving parts of the aircraft:** The CG position is calculated based on a given aircraft configuration. Yet, in the course of the flight, the aircraft configuration evolves: flaps and slats are retracted, landing gear moves up...;
- **In-flight cabin movements:** A single passenger moving from one end of an aircraft to the other is sufficient to affect the CG position.



## DID YOU KNOW

On an A320 37,57m long, the maximum distance along which the CG position may move is 1.34m i.e 4%.

On an A380 72.57m long, it is 1.97m i.e 3%.



## DID YOU KNOW

On an A320, a duty free trolley of 150kg rolling from the back end to the front of the aircraft moves the CG by more than 5cm out of a 1.34m leeway.

- **Cargo loading:** Although there are relatively few errors on the cargo weight there may be some in the distribution of containers;
- **Fuel weight and distribution:** The fuel density used to perform the calculation is not always the actual density. It is indeed quite sensitive to temperature. A tank full in volume doesn't always correspond to the same weight. In some cases, the difference may require to fill in the trim tank with a significant impact on the CG. The fuel logic of the A340-500/600, A380, 350 is based on weight rather than volume. Therefore these aircraft types are less sensitive to this aspect;
- **Calculation method:** The figures used to calculate the CG position are rounded off.

### FREE SEATING: FREEDOM UNDER CLOSE SCRUTINY

As a passenger, choosing your seat at the very last minute, when entering an aircraft relatively empty may be exciting. From a weight and balance viewpoint, it is another story. Free seating means uncertainty in terms of CG position, thus special caution to make sure the CG is within operational limits. Indeed, if free seating doesn't affect the total weight of the aircraft, it affects weight distribution, even more so if the cabin is not fully occupied.

In order to determine the aircraft CG position, the aircraft cabin is divided and modeled in several sections, usually 2 to 4. The aircraft CG position is calculated based on each section's weight and relative CG position. The assumption is that passengers are at the barycenter of the section.

When less than 80% of the seats are occupied in the cabin, not knowing where the passengers are seated may lead to a difference between the actual CG and the calculated one that can reach 2 to 3%. This translates into a significant difference between the actual and expected aircraft behavior.

The pilot will trim the aircraft for take-off using the calculated CG. If at take-off, the actual aircraft behavior is different from the expected one, the risk is that the pilot overreacts to this discrepancy. The type of reaction will depend whether he/she feels the aircraft nose too heavy or too light.

In order to prevent this, except for A318/319 where the cabin is small enough, it is needed to split the cabin into at least 3 sections to have sufficient precision.

### Ensuring consistency between actual operations and load and trim sheet calculations

For each flight, a load and trim sheet is to be developed to ensure the CG will remain within the operational envelope. A number of assumptions are made when doing so. Ensuring that the calculated CG corresponds to the actual aircraft CG requires consistency between these assumptions and the actual operational framework and practices. Among the aspects that can challenge this consistency are:

- **Assumptions on the weight of passengers and their hand luggage:** The average weight to be considered for a passenger and his/her carry-on luggage is mentioned in regional regulations. Yet, in some regions, the assumptions date back from quite a long time whereas a variety of sociological evolutions have taken place. The average weight of passengers tends to increase. So does the weight of carry-on luggage with new items commonly taken onboard such as computers, cameras, cell phones...;
- **Last minute changes:** To load a container at the last minute is an operational practice that may significantly impact the aircraft weight and balance. If not updated accordingly, both the weight of the aircraft and the CG position calculated are incorrect (see insert *Last minute changes*);

- Fuel burned during taxi:** In reality, the impact of the fuel burned for taxiing on the CG position is very limited. The fuel mainly comes from the inner tanks. For a while, some people in the industry held a serious mis-conception as they believed that the fuel burned first was that of the tank filled last, namely the trim tank (for aircraft equipped), which is not the case in reality.

Eventually, if the calculation underlying assumptions are realistic, the calculated CG position is as good an estimate as possible. Still, in order to compensate for a number of inaccuracies, safety margins are required to make sure that the CG will remain within a safe envelope throughout the flight. These margins are the ones that allow for defining the operational envelope.

**LAST MINUTE CHANGES**

To load a container at the last minute, because “there is room for it” is tempting for an airline. Recalculating the weight and CG position “at the last minute” is no option from an operations viewpoint for the delay it would induce. Yet, from a safety standpoint, a last minute change involves not only an increase in weight but also a change in the CG position that need to be considered carefully to avoid an excursion of the CG outside the safe envelope in the course of the flight. A good compromise that allows for reconciling the two perspectives is to calculate the maximum impact of LMCs and integrate it into the safety margins calculation.

**Keeping the CG within a safe envelope throughout the flight: a collective effort**

As mentioned earlier, the CG safe envelope depends on the aircraft weight. As for the CG position, it depends on the weight distribution along the aircraft. In practice, making sure the CG remains within the operational limits relies on a wide range of actors and actions that can be summarized as follows:

Actor	Actions
<b>Airbus</b>	Provide the aircraft weight at delivery, and raw data on positions and maximum weight of elements that can be loaded. Provide also the CG and Weight limits applicable to the aircraft
<b>Airline ops</b>	Determine the operational limits (one for Take-off and another one for Zero Fuel).
<b>Load planner</b>	Prepare a load sheet ensuring the CG remains within the operational limits: one per segment/flight.
<b>Load master</b>	Load and secure the cargo at the anticipated places. Load and unload according to the predefined sequence.
<b>Pilots</b>	During the walk around, visually “notice” the contraction/extension of the landing gear oleos and also the angle of any nose wheel steering link to carry out a gross error check for loading normally. Type in the correct values into the aircraft systems to compute aircraft performance. Cross-check aircraft performance with the other pilot. Check the CG is within the operational limits.



# Wind shear: an invisible enemy to pilots?

Weather plays a significant role in aviation safety and is regularly cited as a contributing factor in accidents or major incidents. Wind shear in the form of microbursts particularly, can be a severe hazard to aircraft during take-off, approach and landing.



**JEAN DANÉY**

Director Flight Safety –  
Accident Investigator



**XAVIER LESCEU**

Experimental Test Pilot



As commercial aviation began to develop in the middle of the last century, we knew very little about wind shear. The detection and reporting of wind shear related events was actually really poor. Yet, in its many forms, although actual encounters with severe wind shear are fairly remote in a pilot's career, this phenomenon can change a routine approach into an emergency recovery in a matter of seconds.

As research and technology progressed, we have learned to identify, prevent and if necessary, handle such events.

We will look at the effects of wind shear on an aircraft and at piloting techniques for coping with a shear situation, focusing more particularly on microbursts.

## UNDERSTANDING WIND SHEAR

### Definitions

#### >> Wind shear

Wind shear can be defined as a sudden change in wind velocity and/or direction over a short distance. It can occur in all directions, but for convenience, it is considered along vertical and horizontal axis, thus introducing the concepts of vertical and horizontal wind shear:

- Vertical wind shear consists of wind variations along the vertical axis of typically 20 to 30 knots per 1000 ft. The change in velocity or direction can drastically alter the aircraft lift, indicated airspeed, and thrust requirements when climbing or descending through the wind shear layers.
- Horizontal wind shear consists of variations in the wind component along the horizontal axis – e.g.

#### >> What is a microburst?

A microburst clearly creates the most dangerous forms of wind shear. It consists of a small column of exceptionally intense and localized sinking air, which descends to the ground (called “the downdraft”) and upon contact with the earth’s surface, diverges outwards in all directions, thus forming a ring vortex. It is capable of producing powerful winds near ground level.

decreasing headwind or increasing tailwind, or a shift from a headwind to a tailwind – of up to 100 knots per nautical mile. **(Fig.1)** shows how a penetration would appear as an aircraft crosses a cold front.

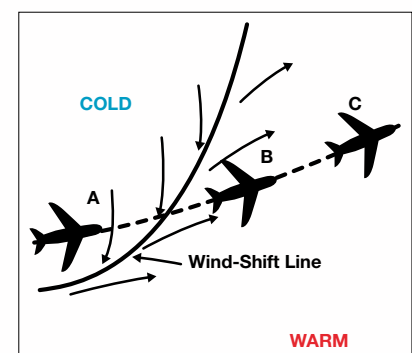
This weather phenomenon can occur at many different levels of the atmosphere; however it is most dangerous at the lower levels, as a sudden loss of airspeed and altitude can occur.

It is usually associated with the following weather conditions: jet streams, mountain waves or temperature inversion layers, frontal surfaces, thunderstorms and convective clouds or microbursts, occurring close to the ground.

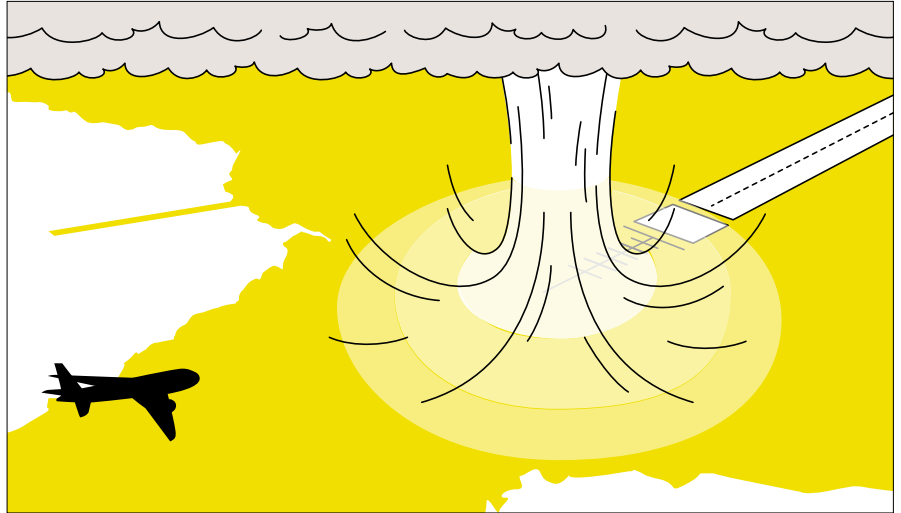
Microbursts are either dry (i.e. little or no rain reaches the ground) or wet (usually within a downpour). They typically form under or close to thunderstorms and cumulonimbus clouds in particular **(fig.2)**.

The radial pattern means winds of various directions within a small area, and hence considerable wind shear near the ground, for up to several minutes.

“ The change in velocity or direction can drastically alter the aircraft lift, indicated airspeed, and thrust requirements when climbing or descending through the wind shear layer. ”



**(fig.1)**  
Horizontal wind shear



**(fig.2)**

Microburst caused by a cumulonimbus

### Typical characteristics of microbursts

Size	Covers an area less than 2.5 nautical miles in diameter.
Intensity	Downdrafts are 40 knots (4000 ft/minute), horizontal winds between 45 and 100 knots.
Duration	Approximately 15 minutes.
Visual signs	Often associated with heavy thunderstorms, embedded in heavy rain.

### Microbursts: a threat to aviation safety

From a safety perspective, microbursts bring a threat to aircraft due to the scale and suddenness of this phenomenon. To put it briefly, microbursts combine two distinct threats to aviation safety **(fig.3)**:

- The **downburst part**, resulting in strong downdrafts that rapidly push the aircraft downward. The power of the downburst can actually exceed aircraft climb capabilities.
- The **outburst part**, resulting in large horizontal wind shear and wind component shift from headwind to tailwind. This sudden change from headwind to tailwind reduces the lift of the aircraft, which may force the aircraft down, typically during take-off or landing.

An aircraft actually encountering a microburst in the vicinity of an airfield while it is about to land or take-off, may be flying through 3 different and difficult phases of wind conditions at a critical phase of flight, at low altitude. For example, an aircraft flying through a microburst at landing should expect to encounter the following phases:

#### >> Phase 1: Headwind

- When first entering a microburst, the pilot notices a performance enhancing headwind gust, which instantaneously increases the aircraft airspeed, thus causing lift and the aircraft to rise above its intended path and/or accelerate (see **(fig.3)**, items 1 and 2).
- To descend the aircraft back on its descent path and decrease speed, the pilot will naturally retard the engines and push the side stick, thereby forcing the aircraft to descend.

>> **Phase 2: Downdraft**

- As the aircraft continues into the microburst, it meets a sudden surge of downdraft affecting both the aircraft flight path and then the Angle-Of-Attack (AOA): the aircraft will sink and the AOA will increase (see **(fig.3)**, item 3).
- The pilot, now traveling at a lower speed and pushed downwards, will attempt to regain the original trajectory by initiating a climb.

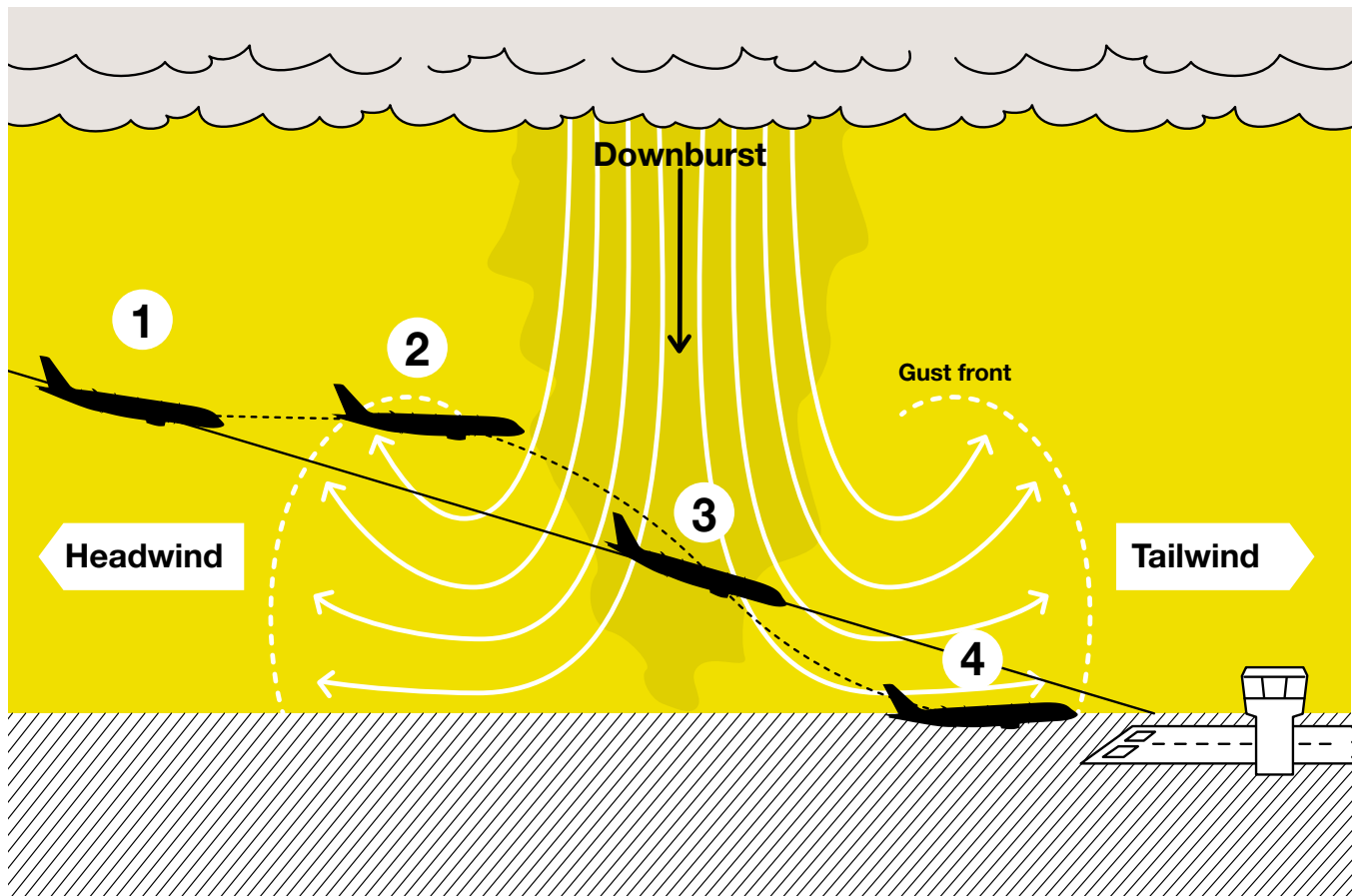
>> **Phase 3: Tailwind**

- As the pilot attempts to climb to recover his/her altitude, the aircraft now experiences a change in wind direction and encounters a tailwind.
- The tailwind gust instantaneously decreases the aircraft lift and airspeed and thus, it tends to make the aircraft fly below its intended path and/or decelerate(see **(fig.3)**, item 4).

A microburst is a serious threat to flight because of its direct and aggressive impact on the aircraft airspeed, altitude, Angle-Of-Attack, and thus, lift capability. ■

“ A microburst is a serious threat to flight because of its direct and aggressive impact on the aircraft airspeed, altitude, Angle-Of-Attack, and thus, lift capability. ”

**(fig.3)**  
Effects of a microburst on aircraft performance



## **PREVENTION: HOW TO DETECT AND AVOID WIND SHEAR**

**Wind shear has a negative effect on aircraft performance and is therefore a real threat to the safe conduct of flight. The best line of defence against such hazards is: detection and avoidance.**

Since the discovery of the effects of wind shear on aircraft performance in the early 1980's, different tools have been developed to help pilots recognize these events, and take appro-

appropriate actions. In practice, flight crew awareness and alertness are key factors in the successful application of wind shear avoidance techniques.

### **Wind shear awareness and detection means**

The best ways a pilot can prevent an encounter with wind shear is to know wind shear is there and to avoid it where possible. However, should an encounter be unavoidable, it is important to know the likely magnitude of the change, and be prepared to react immediately. Although there is no absolutely reliable way to predict the occurrence, different tools and information can be used to detect areas of potential or observed wind shear, and thus be able to develop efficient avoidance strategies.

#### **>> Weather reports and forecast**

Many airports – particularly those that are prone to microburst and wind shear – are now equipped with a Low Level Wind shear Alerting System (LLWAS) and/or a Terminal Doppler Weather Radar (TDWR).

These devices are able to detect microbursts and warn aircraft of their occurrences by sending an alert to ATC. In this respect, a good communication between flight crews and ATC is essential.

“A good communication between flight crews and ATC is essential.”



## **INFORMATION**

The LLWAS is comprised of a central anemometer (sensing wind velocity and direction) and peripheral anemometers located approximately two nautical miles from the center. Central wind sensor data are averaged over a rolling two-minute period and compared every 10 seconds with the data from the peripheral wind sensors.

There are two LLWAS alerting modes: wind shear alert and microburst alert. A wind shear alert is generated whenever the wind speed loses 15 to 29 knots, or gains more than 15 knots. Microburst alert condition is when the wind speed loses more than 30 knots. LLWAS may not detect downbursts with a diameter of 2 nm or less. This system enables Air Traffic Controllers to warn pilots of existing or impending wind shear conditions.

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



### >> Crew observations

Blowing dust, rings of dust, dust devils (i.e. whirlwinds containing dust and sand), intense rainfall or any other evidence of strong local air outflow near the surface often are good indications

of potential or existing downburst. A large difference between actual wind (on ND) and wind reported by tower can also be a good indication. Therefore it is better to avoid these areas.

### >> Pilots' reports (PIREPS)

PIREPS of wind shear in excess of 20 knots or downdraft / updraft of 500 ft per minute below 1000 ft above ground level are all good indications of severe conditions and should be avoided at any time.

Considering that these conditions develop, change or dissipate rapidly, those reports should however be interpreted with great care and judgement. A pilot must consider the amount of time since the report was made. Indeed, knowing that micro-

bursts intensify for several minutes after they first impact the ground, the severity may be higher than that initially reported. Conversely, the microburst reported may well have dissipated by the time the aircraft plans to cross the incriminated area.

Therefore it is very important to remember that the aircraft ahead may experience vastly different conditions than the following one will encounter in the same airspace.

### >> On-board weather radar

Generally microbursts are accompanied by heavy rainfalls, which can be detected and identified using the

on-board weather radar. Those areas should be avoided.

“ Remember that the aircraft ahead may experience vastly different conditions than the following one will encounter in the same airspace. ”



**(fig.4)**

“W/S AHEAD” predictive caution display on PFD

### >> On-board predictive wind shear system

Today, most aircraft models have predictive wind shear equipment to warn pilots of possible threats via aural and visual means.

To provide an early warning of potential wind shear activity, some on-board weather radars feature the capability to detect wind shear areas ahead of the aircraft, based on a measure of wind velocities ahead of the aircraft both vertically and horizontally.

This equipment is referred to as a Predictive Wind shear System (PWS). This system is active and provides reliable indications between 50 and approximately 1000 feet above the ground surface.

### >> Summary

Flight crew should consider all available wind shear awareness means and assess the conditions for a safe take-off or safe descent, approach and landing based on:

- Most recent weather reports and forecast. Pay a careful attention to ATC indications in particular.
- Visual observations.
- Crew experience with the airport environment and the prevailing weather conditions.

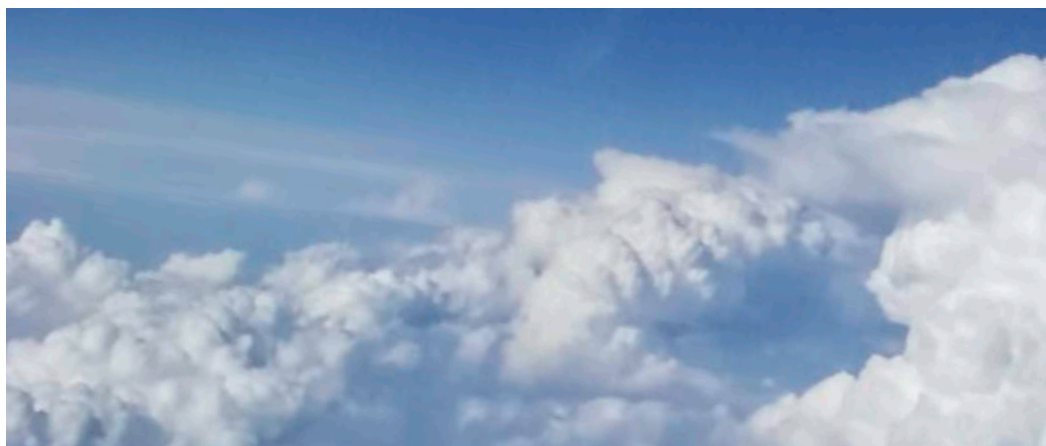
The PWS provides typically a one-minute advance warning by showing first an amber “W/S AHEAD” message on the PFD **(fig.4)**.

If conditions worsen and the wind shear location gets closer to the aircraft, the “W/S AHEAD” amber caution turns into a red warning and is associated with an aural synthetic voice “WIND SHEAR AHEAD, WIND SHEAR AHEAD” during take-off, or “GO AROUND, WIND SHEAR AHEAD” at landing. This is a possible indication that the aircraft is approaching a microburst.

- Weather radar implemented at airports. These systems serve to detect microbursts in close proximity to the airport and send out alerts to both pilots and ATC alike.
- On-board weather radar to ensure that the flight path is clear of hazard areas.
- On-board Predictive Wind shear System (PWS).

## Operational best practices: how to avoid wind shear and get prepared altogether

The wealth of tools and indications listed previously should allow crews to gather sufficient knowledge about the weather conditions ahead, and thus plan accordingly. But how can these pieces of information be best used to be prepared to react and effectively avoid an actual encounter with wind shear? Here are a few tips.



## >> Take-off

- Consider delaying the take-off until conditions improve. Remember a downburst is not a long-lasting phenomenon and can clear within minutes.
- Select the most favourable runway and initial climb out path, considering the location of the likely wind shear / downburst. This may involve asking ATC for “an immediate left or right turn after take-off to avoid”.
- Use the weather radar (and the predictive wind shear system, as available) before commencing the take-off roll to ensure that the flight path is clear of hazard areas.
- Select the maximum take-off thrust.
- Closely monitor the airspeed and speed trend during the take-off roll to detect any evidence of wind shear.

## >> Descent and approach

- When downburst / wind shear conditions are anticipated based on pilots' reports from preceding aircraft, or based on an alert issued by the airport LLWAS, the approach and landing should be delayed until conditions improve, or the aircraft should divert to a more suitable airport.
- Select the most favourable holding point, approach path and runway, considering the location of the likely wind shear / downburst condition, and the available runway approach aids.
- 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 a gusty wind is expected, consider an increase in  $V_{APP}$  displayed on the FMS CDU (a maximum of minimum approach speed (i.e.  $V_{LS}$ ) + 15 knots is allowed).
- Closely monitor the airspeed, speed trend and ground speed during the approach to detect any evidence of imminent wind shear. If the presence of wind shear is confirmed, be prepared for a possible missed approach and escape maneuver. 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.
- In anticipation of a possible wind shear event, be alert to respond immediately to any predictive wind shear advisory, “W/S AHEAD” caution or warning. And be prepared to perform a missed approach or go-around if necessary. ■



## BEST PRACTICE

**If wind shear is suspected, or is detected by the Predictive Wind shear System (PWS), delay the take-off.**



## BEST PRACTICE

**If wind shear is suspected, or is detected by the Predictive Wind shear System (PWS), delay the approach until conditions improve, or divert to a more suitable airport.**



# RECOVERY: HOW TO RECOGNIZE AND HANDLE ACTUAL WIND SHEAR CONDITIONS

**Despite the available prevention means, an actual encounter with wind shear can happen. A timely recognition of this weather phenomenon is crucial to allow enough time for the crew to decide on the next course of action.**

As far as wind shear is concerned, the best course of action is almost always avoidance. But in case of an actual encounter, piloting techniques exist for coping with a shear situation.

## Recognition

As rare as an actual encounter with severe wind shear may be, timely recognition of this condition is key for the successful implementation of wind shear recovery / escape procedures.

### >> How to strengthen the wind shear situational awareness

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

- Indicated airspeed variations in excess of 15 knots
- Ground speed variations
- Analog wind indication variations: direction and velocity
- Vertical speed excursions of 500 ft/minute
- Pitch attitude excursions of 5 degrees
- Glide slope deviation of 1 dot
- Heading variations of 10 degrees
- Unusual autothrust or auto throttle activity.

### >> On-board reactive wind shear system

A reactive wind shear warning system is available on most aircraft models.

This system is capable to detect a wind shear encounter based on a measure of wind velocities, both vertically and horizontally. When it activates, the audio “WIND SHEAR” is repeated 3 times, and a red “WINDSHEAR” warning appears on the PFD **(fig.5)**.

The wind shear warning system associated to the Speed reference System (SRS) mode of the flight guidance constitute the Reactive Wind shear System (RWS), since both components react instantaneously to the current variations of aircraft parameters.



**(fig.5)**

“WINDSHEAR” reactive warning display on PFD



## Recovery technique for wind shear encounter

The aircraft can only survive severe wind shear encounters if it has enough energy to carry it through the loss-of-performance period. It can sustain this energy level in the following three ways:

- Carry extra speed. The aircraft does this automatically when in approach in managed speed (Ground speed mini).
- Add maximum thrust. The aircraft does this automatically with alpha

### >> During take-off

If a wind shear is detected by the RWS or by pilot observation during the take-off roll, V1 may be reached later (or sooner) than expected. In this case, the pilot may have to rely on his/her own judgement to assess if there is sufficient runway remaining to stop the aircraft, if necessary.

In any case, the following recovery techniques must be applied without delay:

#### • Before V1:

Reject the take-off if unacceptable airspeed variations occur (not

floor protection, even if TOGA was already selected (do not forget to disconnect the Autothrust in this case, when out of alpha floor).

- If possible, trade height energy for speed. Any aircraft can do this.

Proper pilot technique helps in this process, providing the following few recommendations are duly followed, in a timely manner.

exceeding the target V1) and the pilot assesses there is sufficient runway remaining to stop the aircraft.

#### • After V1:

- Maintain or set the thrust levers to the maximum take-off thrust (TOGA);
- Rotate normally at VR;
- Follow the Flight Director (FD) pitch orders if the FD provides wind shear recovery guidance, or set the required pitch attitude as recommended in the FCOM.





## BEST PRACTICE

If wind shear is detected by the Reactive Wind shear System during take-off or approach, recover with maximum thrust and follow the Speed Reference System (SRS) guidance.

### >> During initial climb, approach and landing

If a wind shear is detected by the pilot, or by the RWS, during initial climb or approach and landing, the following recovery technique must be applied without delay:

- Set the thrust levers to the maximum take-off thrust (TOGA);
- If the Auto Pilot (AP) is engaged and provides wind shear recovery guidance, keep the AP engaged; or, if the AP is not engaged, do not engage it. Follow the FD pitch command if the FD provides wind shear recovery guidance, or set the required pitch attitude, as recommended in the FCOM;
- Level the wings to maximize the climb gradient, unless a turn is required for obstacle clearance;
- 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 wind shear condition;
- Closely monitor airspeed, airspeed trend and flight path angle (if flight path vector is available and displayed to the PM);
- When out of the wind shear, let the aircraft accelerate in climb, resume normal climb and clean aircraft configuration. ■



## NOTE

To recover from an actual wind shear encounter, recovery measures are indicated in the FCOM ABNORMAL AND EMERGENCY PROCEDURES. Refer to PRO-ABN-80, or FCOM Increment Weather Operations on A300/A310/A300-600.

### RWS and PWS compared characteristics

	RWS	PWS
PURPOSE	- Detect <b>in</b> the wind shear - Guidance to <b>escape</b>	- Detect <b>ahead</b> of the aircraft - Guidance to <b>avoid</b> the event
WARNING	- Aural - Visual	- Aural - Visual
PRINCIPLE	- Comparison between inertial and aerodynamic data	- Doppler weather radar

# SUMMARY: OPERATING IN WIND SHEAR CONDITIONS

Considering the threat that a severe wind shear represents to safety, the best option is always to avoid it whenever possible. Nevertheless, in the case of an actual encounter with wind shear, it is essential to recognize it and then, recover from it.

The following key points and recommendations on avoidance, recognition and recovery can be considered for the development of company strategies and initiatives aiming to enhance wind shear awareness.

## Avoidance

- Assess the conditions for a safe take-off or approach-and-landing based on all the available meteorological data, visual observations and on-board equipment.
- As far as possible, delay the take-off or the approach, or divert to a more suitable airport.
- Be “go-around minded” when flying an approach under reported wind shear conditions.
- Be prepared and committed to respond immediately to a predictive wind shear caution or warning.

## Recognition

- Be alert to recognize a potential or existing wind shear condition based on all available weather data, on-board equipment indications and on the monitoring of the aircraft flight parameters and flight path.
- Scan instruments for evidence of impending wind shear.



## NOTE

To safely operate an aircraft in wind shear or downburst conditions, best recommendations are indicated in the FCOM SUPPLEMENTARY PROCEDURES.

## Recovery

- If a wind shear warning occurs, apply the recommended FCOM recovery / escape procedure i.e. set maximum thrust and follow the FD wind shear recovery / escape pitch guidance.
- Make maximum use of aircraft equipment, such as the flight-path vector (as available). ■

Wind shear can be a serious threat to aviation safety. Thanks to extensive research into the understanding of the phenomenon, efficient equipment is now available to assist pilots in identifying, avoiding and if necessary, handling wind shear conditions. With the technology, flight crew awareness and alertness are key factors in the successful application of avoidance techniques and recovery / escape procedures.

But above all, remember that avoidance is undoubtedly the best defence against the hazards of wind shear.

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