WINDSHEAR WARNING

AEROSPATIALE APPROACH
1. SUMMARY

Although our A300, A310, A300/600 are yet automatically windshear protected by the floor system AEROSPATIALE has on study windshear warning system according to AC 25 XX and AC 120 XX.

All the numerical values used here after have not the mathematical rigour related to an exact science, they just allow us setting targets. They are milestones, they also lead to marks welcomed in our design process.

We set up targets, conservative as far as possible, and check using marks the good behaviour of the system.

We keep in mind at every moment that: the more confident the crew will be, the more flying safety will be improved.

The following paper is concerned by future onboard windshear warning system and the AEROSPATIALE approach.
2. **Milestones: Low Altitude Windshear Probability**

Several reports or study sponsored by the US Administration (NASA, FAA), Nimrod and Jaws projects, Professor T. Fujita publications, etc., makes the windshear phenomenon more comprehensive.

Some parts of the world seem to be more sensitive. They are generally situated between the two 40th parallels and more particularly in the continental areas.

Europe seems to be free of windshears. But, in France, we observed strong shears near by the mediterranean sea (Marseille, Montpellier, Perpignan, Toulouse).

All those interesting remarks cannot help us in determining an occurrence probability for a low altitude windshear.

(Slide 1) Fortunately the amount of accidents or incidents observed over a 20 years period is low, nevertheless it allows us in defining a maximum milestone in a sensitive region of the world.
3. THE MARKS : WIND MODELS

Setting up our windshear warning systems we are supported by :

3.1. Accidents, incidents wind analysis mainly issued from BOEING studies, also called historical gradients (slide 2).

Their probability are such defined.

3.2. The AC 12041 (slide 3) whose probability is unknown.

3.3. The windshear training aid wind models whose probability is also unknown.

3.4. Some three-dimensional downburst models one can fit in size and intensity. Their occurrence probability are obviously unknown.

We will try to estimate the model's probability matching them with historical gradients.

To do so, we use the severity factor (slide 4) called "SF".

Using "SF" we define the weight of the shears for taking off historical gradients (slide 5) and for landing (slide 6).

Using the same observer we weight the windfields (slides 7, 8, and 9).

We can so appreciate whatever the wind modelization is.

Now we can compare the "SF" and balance the windfields versus the historical gradients (slide 10).

The same "SF" weighting can be used for windshear training aid wind models (slide 11).

Those weightings lead to the general comparison (slide 12) between historical gradients, windfields and wind models.

The comparison slides 12 and 10 comes from a visual analysis but two observers can help us in the comparison process : "WSF" and "PSF" (slide 13).
4. THE TARGETS - AEROSPATIALE WS WARNING SYSTEM

Considering our in flight experience, and the AC 25 XX and AC 120 XX demands we set the following targets (slide 14).

4.1. Performance

We have to detect the shears whose probability is equal or lower than $1 \times 10^{-6}$. If the system does not detect such gradient we have to show that the aircraft can take off or land safely within the common safety rules.

4.2. Nuisances

Nuisance can have several origins nevertheless none of them could occur with probability greater than $10^{-4}$. Taking in account pilot training or protection of sensible areas by ground aids (LLAWS) we relax active or latent failures probabilities in accordance with AC 25 XX advices.

On the other hand, in the case of nuisance performance warning we cannot tolerate a warning rate 100 times or 1000 times greater than it could really exist.

So, as we did in the past with floor system, we are developing for the future a windshear warning as credible as possible for crews, mainly in the most critical part of the flight: the landing case.
5. WINDSHEAR WARNING SYSTEM
   THE AEROSPATIALE APPROACH

(Slide 15) WS warning is balanced by comparing longitudinal shear, vertical wind ("SF") properly filtered, actual aircraft energy with minimal aircraft safe energy.

Warning is sensitized by each headwind increase (short period) and desensitized according to the longitudinal mean wind (long period input) avoiding as far as possible the effect of mean turbulence.

The computing principle of AEROSPATIALE Windshear Warning System is as follow (slide 16): it could be implemented in digital AFCS.
6. NORMAL PERFORMANCE NUISANCE WARNING

Considering the time of exposure and the nuisance for airlines or air traffic control of frequent undue go around AEROSPATIALE focused its research on landing case, without forgetting the take off case.

In landing case AC 2057A provides us with a simple means of atmosphere modelization allowing the knowledge of wind probability and related turbulence.

Just a problem : the observed wind probabilities don't go further 10^-3 so we have to continue the model linearly maintaining the turbulence and mean wind relationship.

Results on (slide 17-1-2) allow to define a safe threshold in the world of AC 2057A. The warning threshold can be set at a point guarantizing a level of improbable nuisance warning by landing.

Similar analysis was performed for a fixed threshold (2 to 2.5 kt/s) according to a properly filtered "SF" (slide 17-3).

AC 2057A leads in that case to a nuisance warning level of 10^-3 to 10^-4 by approach.

Several piloting technics can also be implemented for decreasing the number of performance nuisance warning. Those technics such as decelerated approach, ground speed mini are not introduced in today's evaluation.

CONCLUSION

The theme we have here developed is mainly supported by engineers' assumptions considering the lack of reliable statistics.

Nevertheless we have used as far as possible the windshear phenomenon knowledge for detection with sufficient credibility.
LOW ALTITUDE WINDSHEAR

PROBABILITY

*From NTSB 28 accidents/incidents due to windshear in 1964–1983 period.

*About 3000 US AC Performs 5,000,000 take off or landing each year.

*Probability of severe low altitude windshear = $10^{-6}$
\* SHEAR SEVERITY FACTOR

\[
dE/dt = M \ast \left[ C^{\text{te}} - V_{\text{air}} \ast \dot{W}_x + g \ast W_z \right]
\]

\[
SF = \left[ \dot{W}_x - g/V_{\text{air}} \ast W_z \right]_{\text{Lim}}^+
\]

headwind < 0    downdraft < 0

SF is in Kt/s
SF IN TAKE OFF CASES

UAL 209 ORD

CO 426 DEN

PA 759 MSY

X FT FROM BRAKE RELEASE

TAKE OFF ZONE
SF IN LANDING CASES

DAL 191 DFW

-8000 -10000 -12000 -14000 X FT TO GPPIP

EA 66 JFK

EA 693 ATL

TWA 524 LGA
### AC 120-41 Wind Fields

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- + more severe
- = equivalent
- - less severe

P \(\leq 10^{-6}\)

T(W.F.)?
SF IN WINDSHEAR TRAINING AID

WIND MODEL NR 1

154

WIND MODEL NR 2

WIND MODEL NR 3

WIND MODEL NR 4

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## Windshear Training Aid

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+ more severe  - less severe
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\[
\text{WSF} = \sum_{x_{\text{start}}}^{x_{\text{stop}}} \frac{SF \cdot dx}{xF} \\
\text{PSF} = \left| \frac{\text{WSF}}{m} \right|
\]
WS Warning System Targets

Performance

- Detect $10^{-6}$ or $10^{-6}$ cases

- If no detection show the good behaviour of the aircraft

Nuisances

- Warning due to Active Failure
  AC 25 XX

- Lack of Warning due to Latent Failure
  AC 25 XX

- due to performance
  $10^{-6}$ (Landing case)
Wind Shear Warning

The Aerospatiale Approach

- Compare shear and vertical wind intensity with AC energy and safe minimal energy
- Sensitize energy thresholds when short period head wind increases
- Desensitize energy thresholds in constant wind if thresholds are sensitized
- Means angle of attack (measured or estimated (V, Weight, CLaoa, Nz...)) ground speed, true air speed, vertical speed, pitch attitude, f/s position, altitude
EAOA\textsuperscript{E} - EQUIVALENT AOA ESTIMATE

\begin{align*}
\text{Wind} & \xrightarrow{W_x} \text{derive.} & EAOA\textsuperscript{E}(\text{tailwind shear}) \\
& \downarrow & \\
& EAOA\textsuperscript{E}(\text{headwind shear}) & \longrightarrow \text{Amplitude} \\
& \downarrow & \\
& EAOA\textsuperscript{E}(\text{mean wind speed}) & \longrightarrow \text{Limitations} \\
& \downarrow & \\
& EAOA\textsuperscript{E}(\text{down vertical wind}) & \longrightarrow \text{Comp.} \\
& \downarrow & \\
A\text{OA} & \rightarrow \text{Filter} & \rightarrow \text{COMP} \\
& \downarrow & \\
& \color{red}{\text{gain } \frac{A}{Z_{RF}}} & \rightarrow \alpha_W \\
& \downarrow & \\
& \color{blue}{\text{Energy thresholds and } \alpha_w \text{comp}} & \rightarrow \text{Wind Shear} \\
& \downarrow & \\
& \text{Wind Shear Logics} &
\end{align*}

AEROSPATIALE WINSHEAR WARNING COMPUTATION PRINCIPLE
NUISANCE GRID
IN AC 20 57 A

TOWER MEAN WIND KT

10^-7
10^-6
10^-5
10^-4
10^-3
10^-2

0.05 0.1 0.5 1 10

WARNING NR / APPROACH

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NUISANCE WARNING IN LANDING CASE

WARNING THRESHOLD

TOWER MEAN WIND KT
AC 20 57 A

AEROSPATIALE WINDSHEAR WARNING SYSTEM

CONSTANT SPEED APPROACH
FROM 1000 FT TO 50 FT AGL

WARNING NR APPOACH
KIOUMARS NAJMABADI (Boeing) - I would like to know if the alert criteria is based on energy rate of change or is it based on energy margin?

J.L. BONAFE (Aerospatiale) - Both. Just a moment. [Pointing to viewgraph] The minimal energy is defined by the threshold you have here. That is right. But, you increase your energy taking your angle of attack, considering the derivative of the horizontal shear, and the vertical shear. So you increase your energy estimate by the shear estimate. You don't compare only the energy threshold and the incidence estimate. It is a, sort of, rate increase in energy. Okay?

KIOUMARS NAJMABADI (Boeing) - So what you are saying is you are estimating your energy loss based on your energy rate of loss and then you are comparing that with your margin, am I correct?

J. L. BONAFE (Aerospatiale) - Yes. This is the way it is implemented.