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AIRBUS AIRBORNE WINDSHEAR SYSTEM AND WINDSHEAR WARNING DESIGN PROCESS

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ABSTRACT

Since the early 70th Airbus get in mind the necessity of windshear protection on all its designed airplanes. The following paper summarizes the actual knowledge of windshear phenomenon, shows the evolution in Airbus protection and explains the design process developed in Airbus new patented windshear warning.

A - AIRBUS - AIRBORNE WINDSHEAR SYSTEM

A.1 - WINDSHEAR

Shear, in engineering terms, is a type of deformation in which parallel planes in a body remain parallel but are relatively displaced in a direction parallel to themselves. Windshear is an abrupt change in the speed and direction of the wind at constant height or as height above ground varies in the boundary between 2000 ft and the surface.

Over 60 % of the accidents to aircraft occur along the path between some 15 miles on approach and a similar distance along the climb out path. Within this zone the pilot has many preoccupations and may miss any warning that may be read in the sky.

A.2 - DOWNBURST

It is a shear with both vertical and horizontal components, a strong down-draught which induces an outburst of damaging winds on or near the ground. Damaging winds either straight or curved are highly divergent. A microburst or macroburst can vary from a kilometre to several tens of kilometres and last 5 to 30 minutes, with winds as fast as 150 kts (Figure 1).

The forces involved may be beyond the recovery capacity of any aircraft, since horizontal windshear can reach more than 5 kts/sec. The effects on aircraft performance are dramatic because tailwind (20 kts) and downflow (20 kts i.e. 2000 ft/mn) can reduce lift by 25 % each at a normal take off angle of attack.

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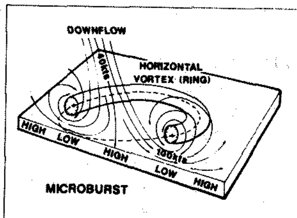

Figure 1

A.3 - DETECTION AND WARNING

Low Level Windshear Alerting Systems have been installed by the FAA at a 100 airports in the USA. They are anemometers separated by 1,5 nm which record wind velocity at 10 seconds intervals, but they only detect what is partially on top of them.

Today no ground based or airborne system exists that will provide crews with reliable warning of windshear and enable them to adopt the safest solution : keep well away from it. The responsibility for coping with windshear, if encountered, therefore remains within the aircraft itself.

Windshear is often met out of the blue, where there is no black line or rain. If windshear is encountered, the necessary pilot reactions are not all instinctive, neither the rapid and large change of pitch attitude required. 3 dimensional mathematic models of downburst have been developed, from recorded data, for pilot simulator training.

A.4 - SURVIVAL TO WINDSHEAR ENCOUNTER

Coping with windshear needs : identification, maximum power, maximum lift. Airborne systems have been developed to give the best chance of survival in a windshear encounter. The principles of the system logic and guidance law results of the following analysis.

The only options available to the pilot to cope with windshear, once it is encountered, are setting maximum available thrust and trading kinetic energy at some rate for an increase in climb gradient. The optimum strategy, for the most part, is to delay reducing airspeed until at least level flight is no longer possible with maximum available thrust applied. This procedure saves the available kinetic energy as long as possible in the event the windshear becomes more severe. The rate of airspeed reduction should not be greater than that needed to prevent a loss of altitude. This procedure also delays the loss of kinetic energy as long as possible in the hopes that the shear conditions can be exited, and reduces the exposure time to airspeeds at or near the airplane stall warning. Also, this delays flying the airplane at an increasingly adverse lift-to-drag ratio as long as possible.

A.5 - AIRBORNE SYSTEMS

Since 1974, every airbus aircraft that has entered service has been equipped to counter windshear by generating automatically the high lift and high thrust necessary.

A.6 - ALPHA-FLOOR PROTECTION

A characteristic of flight through windshear by large aircraft is that airspeed and ground speed vary in opposite senses ; the inertia is such that rapid wind fluctuations cause large instantaneous airspeed change but slow change in groundspeed. The alpha-floor protection system detects by comparison the acceleratins to which the aircraft is being subjected, and beyond a threshold which is programmed, it automatically commands maximum thrust at the earliest possible moment.

A.7 - SPEED REFERENCE SYSTEM

The Speed Reference System computes the aircraft's potential flight path corresponding to the take-off speed of normal engine configuration or with an engine failing and provides pitch guidance.

In a windshear encounter, the system trade airspeed and pitch demand to increase lift in order to maintain a slightly positive climb gradient. With the fly-by-wire concept excursions outside the flight envelope are not possible, and with the side stick pulled right back, the computer will control the maximum angle of attack corresponding to the maximum lift coefficient.

A.8 - MINIMUM GROUND SPEED TECHNICS (autothrust system)

The key element in fighting low level horizontal windshear is to provide the aircraft with sufficient kinetic energy prior to the actual encounter. During approach a speed increment is automatically computed, based on real time wind variations from the inertial system and the surface wind entered in the flight management system.

The autothrust system automatically prevent the aircraft to fly below the minimum ground speed target all the way down to touchdown.

A.9 - CONCLUSION

Windshear, in its extreme forms, can unleash forces greater than the recovery capacity of any aircraft however high its power, weight ratio and lift generating capability. The best answer is still : do not enter windshear. Providing a timely warning is important, but once it is encountered, the airbus systems provide detection and continuous pitch guidance for escape manoeuvre.

B - WINDSHEAR WARNING DESIGN PROCESS

B.1 - SUMMARY

Although our A300, A310, A300/600 are yet automatically windshear protected by the alpha-floor system AEROSPATIALE developed on board windshear warning system according to AC 25 12 and AC 120 41.

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 welcome 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 onboard windshear warning system and the AEROSPATIALE approach.

B.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.

Fortunately, the amount of accidents or incidents observed over a 20 years period is low, nevertheless it allows us in defining a maximum milestone : Probability of severe low altitude windshear encounter : 10^{-6} in a sensitive region of the world (from NTSB reports).

B.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.
According to NTSB reports, their probability are such defined : 10^{-6}.

3.2 - The AC 12041 (figure 2) whose probability is unknown.

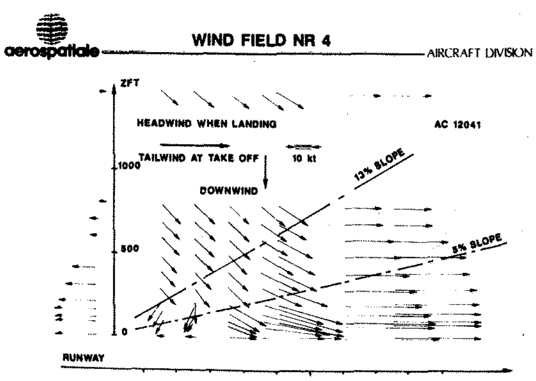

FIGURE 2

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 estimator * called "SF".

$$dE/dt = M \times (Cte - Vx_{air} * Wx + g * Wz)$$

$$SF = |Wx - g/Vx_{air} * Wz| \; Lim_0$$

headwind 0 downdraft 0

SF is in Kt/s

Using "SF" we define the weight of the shears for taking off historical gradients and for landing.

Using the same observer we weight the windfields (figure 3).

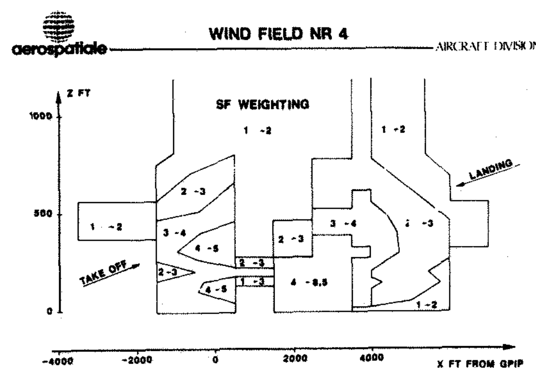

FIGURE 3

We can so appreciate whatever the wind modelization is.

Now we can compare the "SF" and balance the windfields versus the historical gradients (figure 4).

The same "SF" weighting could be used for windshear training aid wind models.

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

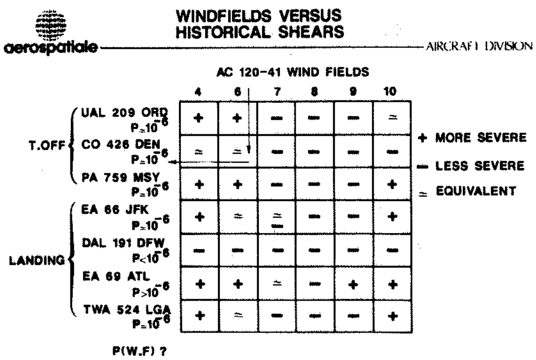

FIGURE 4

B.4 - THE TARGETS - AEROSPATIALE WS WARNING SYSTEM

Considering our in flight experience, and the AC 25-12 and AC 120-41 demands we set the following targets.

4.1 - Performance

We have to detect the shears whose probability is equal or lower than 1.10^{-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^{-6}. Taking in account pilot training or protection of sensible areas by ground aids (LLAWS) we relax active or latent failure probabilities in accordance with AC 25-12 advices.

On 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 alpha-floor system, we developed for the future a windshear warning as credible as possible for crews, mainly in the most critical part of the flight : the landing case.

B.5 - WINDSHEAR WARNING SYSTEM THE AEROSPATIALE APPROACH

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 follows ; it is now implemented in digital AFCS (figure 5).

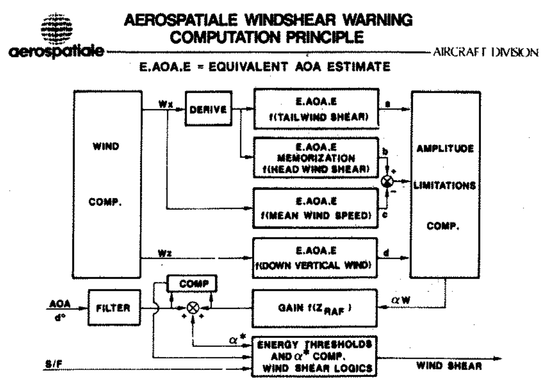

FIGURE 5

B.6 - NORMAL PERFORMANCE NUISANCE

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 2057 A 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 Figure 6 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.

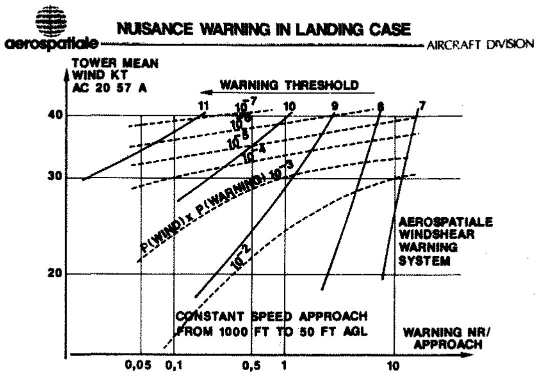

FIGURE 6

Similar analysis was performed for a fixed threshold (2 to 2,5 kt/s) according to a properly filtered "SF".

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

Such a result is not in accordance with the confidence level needed by the crew in a windshear warning. It is why AEROSPATIALE and AIRBUS patented a system enhancing credibility in windshear warning considering airplane's energy and "SF".

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.

B.7 - 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.