Airport Radar Monitoring of Wake Vortex in all Weather Conditions

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***Abstract*— To assess maturity and capability of X-band radars to monitor wake roll-ups in all weather conditions, Radar data were collected on airports, near runway at ORLY airport and just under its ILS Interception Area. Additional trials took place on Paris-CDG Airport to benchmark Lidar & Radar Technologies. Continuous Detection, characterization and profiling capabilities of wake vortices, up to a range of 2000 m, have been proved in clear air and rainy weather. Recorded data have been correlated with electromagnetic and fluid mechanical models of Wake Turbulences for better and more accurate understanding of roll-ups radar cross section (RCS) and Doppler signature. X-band Radar has been proved to be a full-fledged alternative, which can make a significant contribution to a wake vortex alert system, but to achieve as much reliability as possible, collaborative Electro-optical & electromagnetic sensors solution is envisaged encapsulated in a Wake Vortex Advisory System. These sensors could be used to permanently monitor wake turbulence on runways.**

I. Introduction

Aircraft creates wake vortices in different flying phases. To avoid jeopardizing flight safety by wake vortices encounters, time/distance separations have been conservatively increased, thus restricting runway capacity. The concern is higher during taking off and landing phases, as aircraft are less easy to manoeuvre. These vortices usually dissipate quickly (decay due to air turbulence or transport by cross-wind), but most airports operate for the safest scenario, which means the interval between aircraft taking off or landing often amounts to several minutes. However, with the aid of accurate wind data and precise measurements of Wake Vortex, more efficient intervals can be set, particularly when weather conditions are stable. Depending on traffic volume, these adjustments can generate capacity gains which have major commercial benefits.

Wake vortices are a natural by-product of lift generated by aircraft and can be considered as two horizontal tornados trailing after the aircraft. A trailing aircraft exposed to the wake vortex turbulence of a lead aircraft can experience an induced roll moment (bank angle) that is not easily corrected by the pilot or the autopilot. However these distances can be safely reduced with the aid of smart planning techniques of future Wake Vortex Advisory Systems based on Wake Vortex detection/monitoring and Wake Vortex Prediction (mainly transport estimation by cross-wind), significantly increasing airport capacity. This limiting factor will be significantly accentuated soon with the arrival of new heavy aircrafts: Airbus A380 and the new stretched version of Boeing B747-8.

Radar Sensor is a low cost technology with highly performing wake-vortex detection capability in all weather conditions compared to Lidar sensor that suffers of limited one in adverse weather like rain or fog. Radar is a promising sensor for turbulences remote sensing on airport, for all kinds of aviation weather hazards (wake vortex, wind-shear, micro-bursts, atmospheric turbulences) with ability to work operationally in different severe weather conditions like fog, rain, wind, and dry air.

II. Physics of Wake Vortex Hazards

In this section, we will describe physics of Wake Vortex hazard and the origin of Wake Vortex radar cross section in clear air. These elements are important to analyze and understand Doppler Radar signature.

The Wake Vortices shed by an aircraft are a natural consequence of its lift. The wake flow behind an aircraft can be described by near field and far field characteristics. In the near field small vortices emerge from that vortex sheet at the wing tips and at the edges of the landing flaps.

After roll-up the wake generally consists of two coherent counter-rotating swirling flows, like horizontal tornadoes, of about equal strength: the aircraft wake vortices.

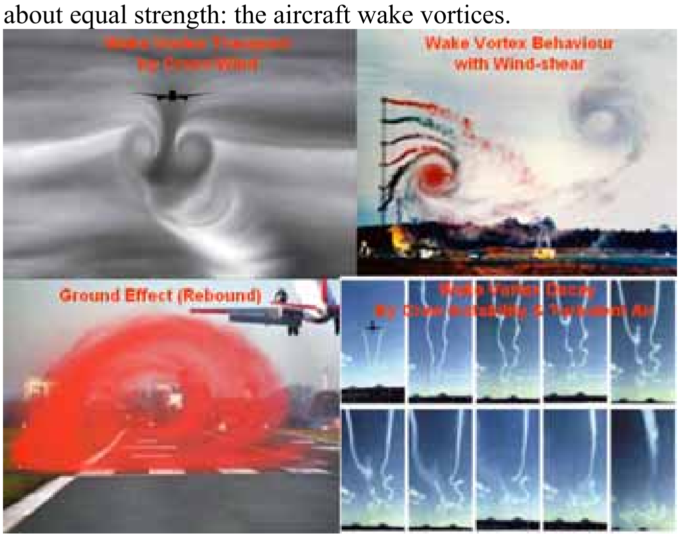

Fig. 1 : Wake-Vortex Dynamic & behavior

Fluid dynamic of wake turbulence is modeled by Navier equations, that have been expressed in a new form by Jean Leray [1] that can be used for radar wake vortex signature analysis because new Leray's equation only depends on velocity u and no longer on pressure p. At $t = 0$, if we