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WSVBS - An Advisory System for Aircraft Wake Vortices

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ABSTRACT

To tactically increase airport capacity for landing aircraft, DLR has developed a wake vortex advisory system, its Wirbelschleppen-Vorhersage- und -Beobachtungssystem WSVBS. The WSVBS is intended to dynamically adjust aircraft separations dependent on weather conditions and the resulting wake vortex behaviour without compromising safety. The system is particularly designed for the closely spaced parallel runway system of Frankfurt Airport but can be adapted to any other airport as well.

Figure 1 left delineates the components of the WSVBS and their interplay. The bottleneck of runway systems prevails in ground proximity because there stalling or rebounding wake vortices may not descend below the flight corridor. Therefore the best wake prediction skill is required in that domain which is achieved based on measurements of meteorological conditions with a SODAR/RASS system and an ultra sonic anemometer (USA). The SODAR/RASS provides 10 min averages of wind and temperature profiles with a vertical resolution of 10 m and up to 300 m AGL. The USA measures wind with a frequency of 20 Hz on a 10 m mast. Turbulence kinetic energy and dissipation rate are computed from the velocity variance spectra. Because it is not possible to cover the whole glide-path from the threshold to the final approach fix 11 NM away with such instrumentation, the meteorological conditions in the remaining area are predicted with a numerical weather prediction system (NOWVIV) leading to wake predictions with increased uncertainty bounds. NOWVIV runs twice a day on a massively parallel LINUX cluster and predicted the meteorological conditions for the Frankfurt Airport Terminal Area in intervals of 10 min. Based on the forecast and measured meteo and the glide path adherence statistics (FLIP), the probabilistic real-time model P2P predicts upper and lower bounds for position and strength of vortices of aircraft from class HEAVY (H) in 13 gates along the glide path to runways 25L/R for the next 60 min. In ground proximity the gate separation of 1 NM is reduced to 1/3 NM to properly resolve the interaction of wake vortices with the ground. The predicted bounds are expanded by the safety area around a vortex that must be avoided by follower aircraft for safe and undisturbed flight (SHAPe). The instant when these safety areas do not overlap with the flight corridor define the *minimum separation time MST* between two landing aircraft that is translated into operational procedures by the arrival manager (AMAN). The German Air Safety Provider DFS has established four operation modes to separate aircraft to be applied for the dependent parallel runway system at Frankfurt Airport under instrumented meteorological conditions (IMC) (the WSVBS translates the spatial separation into a temporal separation in brackets): (i) “ICAO” – standard procedure with 4 NM (100 s) for a HH aircraft pair and 5 NM (125 s) for a HM pair across both runways; (ii) “Staggered” (STG) – procedure where both runways can be used independently from each other but obeying the radar (minimum) separation of 2.5 NM (70 s); (iii/iv) “Modified Staggered Left/ Right” (MSL/R) – aircraft on right/left (windward) runway keep 2.5 NM separated from aircraft of left/right (lee) runway. Finally, the LIDAR monitors the correctness of WSVBS predictions in the most critical gates at low altitude. The different prediction components are adjusted to consistent probability

levels such that the WSVBS will meet accepted risk probabilities as a whole.

The WSVBS has been employed at Frankfurt Airport in the period of December 2006 until February 2007. Figure 1 right displays the full MST information as it is available in the WSVBS. In addition to the four DFS procedures, such a display allows also surveying possible reduced separations for aircraft flying in-trail and it distinguishes between aircraft combinations HH and HM. The proposed operational procedures were also displayed on controller screens for real-time simulations. We further performed fast-time simulations to obtain capacity figures for the different concepts of operation utilised by WSVBS under real world conditions. The simulations included flight plans with realistic distributions of wake vortex categories, demand peaks throughout the day, weather data, and the WSVBS proposals for a period of one month.

At Frankfurt airport, the WSVBS has demonstrated its functionality. It ran stable - no forecast breakdowns occurred; aircraft separations could have been reduced in 75 % of the time compared to ICAO standards; the predictions were correct: at least for about 1100 landings observed during 16 days no warnings occurred from the LIDAR. Fast-time simulations revealed that the concepts of operation, introduced by the German air safety provider DFS, yield significant reductions in delay and/or an increase in capacity by 3% taking into account the real traffic mix and operational constraints in the period of one month. Relaxing the DFS constraints and allowing more operation modes (e.g. reduced in-trail separations) would further increase capacity or reduce delays.

Before the WSVBS can be handed over for final adaptations to become a customized fully operational system some further steps are planned. DLR will expand the system to include landings on runways 07/L/R. The LIDAR shall be operated automatically and the traced vortex positions shall be used on-line to check for forecast errors and warn the operators in case of an increased risk. Finally, also a risk analysis needs to be pursued to convince all stakeholders of the usefulness and capabilities of our system.

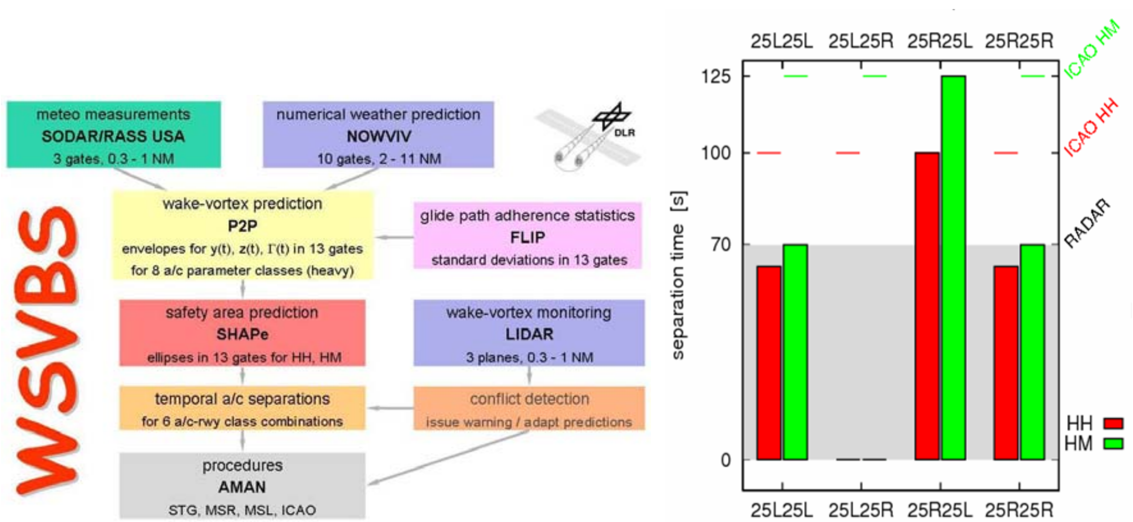

Figure 1 Left: Components and flowchart of the WSVBS, see text. **Right:** Display of Minimum Separation Time information and derived arrival procedures for Frankfurt Airport on 25. Jan.2007 at 15:10 UTC. The sketched example reads that not only the DFS procedure MSL can be used (no wake-vortex separation required for runway combination 25L25R but full ICAO separation for 25R25L), but that also aircraft which follow each other on the same runway (in-trail) can be radar-separated. The meteorological reason for that case is a strong northerly crosswind that clears both runways quickly from vortices of the leading aircraft.