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State-of-the-Art & Research Needs

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3.1 Crosswind Operations

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3.1.1 Overview

Crosswind operations rely on the simple effect that sufficiently strong crosswinds may transport wake vortices out of the flight corridor which may support temporary suspension of the need to apply wake turbulence separations between successive aircraft.

CROPS (CRosswind OPerationS) is a EUROCONTROL funded project focused on runway use optimisation by the conditional reduction of wake turbulence distance-based separation minima between arrivals on final approach by taking advantage of the effect of crosswind on the wake turbulence decay and transport, while maintaining an acceptable level of safety regarding possible wake vortex encounter (WVE). It is a natural follow-on of the completed R&D project CREDOS (Crosswind REduced separations for Departure OperationS). The main driver of CROPS is congestion at major airports and fixed ICAO separations (not weather dependent).

The scope of the CROPS project is currently limited to determination of crosswind conditions for a safe 0.5NM reduction of WT separations applied on final approach segment. This is done mainly by analysis of collected wake vortex and MET data. The results of this analysis form part of the key evidence in the safety assessment report.

Although the CROPS concept of operations for a specimen operational environment relies on current ATM procedures, without a priori need of developing specific new ATC tool, the necessary changes to ANS/ATM system to allow operational application of CROPS will need to be assessed at local implementation level. It depends on the local ATM system in place and its performance, in particular regarding wind nowcast and forecast information.

NATS incorporated the concept of operations for CROPs for arrivals within the scope for ‘Reduced Final Approach Separation’ (RFAS). RFAS considers both minimum headwind and crosswind component requirements for a 0.5NM separation reduction to selected wake constrained arrival pairs at Heathrow.

3.1.2 CROPS benefits

CROPS benefits arise from a temporary increase in runway throughput and/or reduction of airborne delays.

Emphasis is to be put on the fact that CROPS is not expected to add strategic capacity in terms of scheduled slots. The major benefits are to be achieved when a single segregated runway is used for arriving traffic and during peak periods or when queuing creates delays. The actual benefits are dependent mainly on local wind conditions, traffic mix (number of wake turbulence separated pairs), of the usage, orientation and layout of the runway(s) and standard arrival route structure. For example, a detailed benefit study (using HERMES model) with local traffic mix and wind conditions at London Heathrow (LHR) shows a maximum possible reduction of average arrival delay per aircraft from 5.9 min to 3.4 min (assuming a perfect forecast, and sustained wind conditions over periods studied). If 30 minutes stability of the wind was required, the procedure could have been applied in 17% of total operating hours at LHR airport (assuming required wind thresholds are based upon average wind conditions at the runway surface level only.

3.1.3 CROPS implementation

The CROPS implementation will consist of procedural changes to the ATM system. It is envisaged that, during temporary trial phase, wind threshold higher than the minimum required value will be applied, in order to gain confidence in CROPS application. Local implementers will determine the appropriate deployment strategy. Guidance for implementers shall be developed in 2012.

The CROPS project shall provide a transitional step towards SESAR IP2 related operational improvements to be addressed by the SJU project P6.8.1 in Phase 2 - Weather Dependent Separations (WDS).

To date the following stakeholders have expressed an interest (feedback received at EUROCONTROL's Airport Operations Team stakeholder meeting) to explore the possibilities of implementation: BAA, NATS and UK CAA (for London Heathrow), DSNA (for Paris Charles de Gaulle) and Schiphol airport, Amsterdam.

3.1.4 Current Status

The initial CROPS generic concept of operations was completed and presented at the EUROCONTROL Wake Vortex Task Force (WVTF) in June 2010. The benefit assessment results were presented to the WVTF in November 2010 and initial safety assessment results were presented to the WVTF in April 2011.

Under the NATS/EUROCONTROL TBS activities and now under the SESAR P6.8.1 TBS activities an intensive LIDAR data collection campaign has been carried out at London Heathrow airport since October 2008. The WV trajectories, circulation as well as wind intensities have been collected for NGE/IGE behaviour (October 2008 to December 2010) and is being collected for OGE behaviour (from January 2011 ongoing). The possibility of 0.5 NM WT separation reduction was assessed by comparing the probability of wake vortex persistence in calm wind conditions (0-5 kt – baseline) to the probabilities observed in crosswind conditions using the Heathrow NGE/IGE measurements. The computation of frequency & severity curves for different wind bands and comparison against baseline resulted in definition of required wind threshold criterion of 7-8 knots (runway surface wind conditions). The potential local application of this generic criterion was also evaluated at two European hubs, London Heathrow and Paris Charles de Gaulle. The resulting local thresholds were very similar to the generic threshold (min. 6 knots at EGLL and 7 knots at LFPG). The local application of the separation reduction is made possible by integrating the local wind distributions into the generic results. The identified wind criterion is consistent with the outcome of the CREDOS project and will provide the key technical evidence into the final CROPS safety assessment report. It shall not be applied without development of the local safety case.

Due to lack of resources, the safety work on CROPS has not progressed in the second half of 2011, but it is planned to resume in 2012 leading to delivery of:

- a preliminary safety assessment report to present the safety argument and supporting evidence, from wake and weather data collection and analysis, that the reduction of WT separation minima is acceptably safe when the weather-dependent conditions are satisfied and to provide a guidance to support development of safety assessment on local implementation by ANSPs; and
- an updated concept of operations for CROPS, according to the safety assessment results.

The NATS RFAS project has completed the 'Feasibility and Options' phase to assess concept viability and cost benefit. This phase lasted 12 months and has concluded that the concept is feasible from both a safety and operational concept perspective. However, the project will not be further pursued for implementation at Heathrow given the short duration of expected benefits when taking account of planned implementation of Time Based Separation (TBS) at Heathrow. Progress and achievements from the RFAS project are outlined below:

- A concept of operations was developed and refined based upon real-time simulation validations and controller workshops. This has provided a mature set of operational requirements (including procedures and HMI).
- A safety methodology has been proposed and internally agreed (at a high level) among NATS safety stakeholders. This provided a high level view of the safety performance requirements and evaluation criteria. Safety workshops and hazard identification workshops have taken place to refine the safety plans and identify, scope, and direct, the required activities.
- LIDAR analysis from the joint NATS and EUROCONTROL data collection campaign at Heathrow has been developed and undertaken (for near ground effect data) by both EUROCONTROL and NATS with complimentary results. This has provided early indications of the wind conditions required near-ground

to satisfy the safety requirements (from a wake encounter perspective). Data gathering from the measurement campaign out of ground effect continues.

- Wake modelling was scoped, and innovative methods designed to further aid wake encounter assessment at higher altitudes at Heathrow, and at glide-path intercept.
- Requirements for met monitoring and forecast were developed (based upon the above initial safety assessments). Collaborative work with the UK Met Office has established a feasible short-term solution to (potentially) meet the required objectives, and a plan developed to research, build, and test, the proposed system.
- A benefits model was developed and results provided estimates of the concept benefit (in terms of movement recovery and delay), under a range of weather conditions, and forecast success rates.

3.1.5 Lessons learned from CREDOS

The EU project CREDOS (Crosswind-Reduced Separations for Departure Operations) intended to demonstrate the operational feasibility of a concept of departure operations that uses measures of the prevailing crosswind component to allow temporary suspension of the need to apply wake turbulence separations between successive departing aircraft.

Monte Carlo simulations of the Frankfurt traffic mix with WakeScene (see §6.2.2.4, Holzäpfel & Kladetzke 2011) indicate that for current operations 66% of the potential encounters are restricted to heights below 300 ft above ground. Within this altitude range clearance of the flight corridor by descent and advection of the vortices is restricted: stalling or rebounding vortices may not clear the flight path vertically and weak crosswinds may be compensated by vortex-induced lateral transport. Further, minor peaks at altitudes of 1300 ft and at 1800 ft occur which can be attributed to flight path diversions (change of climb rate and heading) in combination with adverse wind conditions (headwind and crosswind) which increase the encounter risk compared to approximately parallel flight of the leader and follower aircraft.

Statistics of encounter frequencies and encounter conditions have been established for 60 s and 90 s departure separations and minimum crosswinds from 0 to 10 knots in 2 knot increments, respectively. The reduction of aircraft separations from 120 s to 60 s approximately triples the number of encounters, whereas the fraction of strong encounters increases due to the reduced time for vortex decay.

An investigation of wind direction effects on the encounter frequencies reveals an intriguing phenomenon: Headwind situations lead to the highest encounter probabilities because headwind transport of the wake vortices may compensate wake vortex descent or even lead to rising wake vortices with respect to the generator aircraft trajectory. This effect increases encounter frequencies because the medium weight class followers usually take off earlier and climb steeper than the leading aircraft and therefore usually fly above the wake vortices. In contrast, the encounter frequencies for tailwind situations are much lower because tailwinds support wake vortex descent.

Initially surprising, the beneficial effects of crosswinds are not symmetric. The smallest encounter frequencies are observed for crosswinds from the starboard side. Here the crosswinds close to the ground reduce encounter frequencies. With increasing height the wind direction turns on average to the right. Consequentially, a tailwind component is added to the crosswind which supports relative vortex descent and thus reduces encounter frequencies aloft. This turning of the wind direction with height is related to the concept of the Ekman spiral which describes the resulting wind direction in the atmospheric boundary layer by equilibrium of the driving pressure gradient force, the Coriolis force, and the friction force. Due to the same mechanism crosswinds from port side receive a headwind component with increasing height. As a consequence, the port crosswind situation leads to significantly more encounters than the starboard side crosswinds.

From a WakeScene-D perspective it can be concluded that for 60 s departure separations along the northern departure routes as used routinely at Frankfurt airport acceptable encounter frequencies are found for crosswinds below -6 knots (wind from starboard side) and for crosswind magnitudes above 8 knots. The respective assessment of the related encounter risks with VESA (Kauertz et al. 2012) leads to the same conclusions also for straight departure routes. Crosswind departure procedures could be refined by using only departure route combinations where the leading aircraft is flying on the downwind route.

Crosswind transport certainly is the most effective mechanism to clear a flight corridor from wake vortices. However, the applicability of purely crosswind based wake vortex advisory systems covering vertically extended domains is impeded by the veering wind with altitude. As a consequence, either the flight tracks of subsequent aircraft must be separated already at quite low altitudes such that the crosswind does not change significantly within the considered height ranges or the advisory system must also consider vortex descent and/or vortex decay either explicitly or implicitly as in the presented concept.

3.1.6 Research Needs

As the CROPS project provides only an interim step towards a Weather Dependent Separation (WDS) concept, the following key validation areas should be further researched under the SESAR WP6.8.1 Phase 2:

- Definition of the weather criteria (not only crosswind) allowing the reduction of wake turbulence separations (by 0.5 or 1.0 NM)
- Definition of the weather dependent reduced wake turbulence separations under different weather conditions
- Assessment of the wake vortex encounter risk associated to the reduction of wake turbulence separations under pre-identified weather conditions
- Assessment of the spatial and temporal stability of the weather conditions allowing the reduction of wake turbulence separations
- Assessment of the potential benefits for various airports considering the distribution of their wind conditions throughout the year
- Definition and assessment of the HMI and ATM component requirements and operational procedures allowing the air traffic controller to apply weather dependent wake turbulence separations
- Definition of the requirements and operational procedures allowing the flight crew to safely apply the controller proposed weather dependent wake turbulence separations
- Definition of the high level system, functional and algorithm requirements of the WDS tool support
- Assessment of the high level system, functional and algorithm requirements of the WDS tool support