The International Civil Aviation Organization (ICAO) separation standards for landing and take-off were implemented in the 1970s to protect an aircraft from the wake turbulence of a preceding aircraft. However, research has shown that the transport and persistence of wake vortices are highly dependent on meteorological conditions, so that in many cases the ICAO standards are over-conservative. By developing a full understanding of wake vortex (WV) behaviour in all weather categories, separations could be reduced under certain suitable conditions. The CREDOS project was studying the operational feasibility of this approach by focussing on the situation for take-off under crosswind conditions. The project used measurements of wake vortices taken at St Louis and Frankfurt airports to develop models of wake vortex behaviour. Using Monte Carlo simulation techniques these models have been used to establish safe separations under various crosswind conditions. An operational concept for crosswind departures has been developed and validated in accordance with the operational concept validation methodology.
The work of the project was divided into five work packages (WPs), as follows:

WP 1 - Data collection
The CREDOS data were mainly collected by research measurement tools deployed for the project or from systems already installed on the airport since a certain time. In addition to these research tools, operational data available at airport such RADAR data, METAR, anemometer measurements also provided relevant information for the project.

WP 2 - Data analysis and models
Two measurement campaigns for wake vortices generated by departing aircraft at Frankfurt airport have been carried out and the databases were provided through WP 1. The campaign EDDF-1 focused on aircraft departing from runway 07L where the measured 147 wake vortices were generated in a height range from 100 m to 400 m. The EDDF-2 long-term campaign measured 10 442 wake vortex tracks generated by aircraft departing from runway 25R. Due to the vortex generation height range from the ground up to 150 m, most vortices were generated in ground effect or descended into ground effect. The meteorological conditions spanned a wide range in terms of wind conditions, turbulence, and temperature stratification.

Wake vortex prediction skill has been investigated for a number of model versions employing a scoring procedure which evaluates deviations between vortex predictions and measurements. The scoring results indicate good prediction skill if the onset of rapid decay out of ground effect is delayed by one time unit. As expected the scoring results confirm that crosswinds measured by lidar yield superior prediction skill of lateral transport compared to other wind measurement devices situated further away. Peculiarities of wake vortex behaviour during departures could not be identified. A very consistent view of lateral vortex transport measured by lidar and predicted by D2P could be achieved.

This indicates that the statistics of measured lateral transport are well suited to derive crosswind thresholds sought-after in CREDOS. It further indicates that the D2P model should be well applicable for the prediction of lateral vortex transport in the Monte Carlo simulation environment WakeScene-D which is used to support the definition of crosswind thresholds for reduced aircraft separations and to contribute to the CREDOS safety case.

For both models, the vortex predicted characteristics are in the range of the LIDAR data, under the given challenging atmospheric conditions. It is concluded that the wake vortex models (DVM and D2P) both represent the wake vortex transport and decay. From the data, an opportunity is indicated that the models could be used for the transport prediction under crosswind conditions, together with the appropriate probabilistic versions (PVM and P2P) or using an appropriate safety margin to be defined and applied (a proposition being also reported).

A wake vortex detection algorithm 'Wavenda' was adapted for the detection of aircraft wake vortex encounters (WVE), both for arriving and departing aircraft, using flight data recording data (FDR). The wake vortex detection algorithm was implemented using classification functions, based on the results of a discriminant analysis applied to a set of landing cases obtained in a previous project. These cases had
Discriminant analysis applied to a set of landing cases obtained in a previous project. These cases had been visually inspected for the occurrence of a WVE. Based on the results obtained and limited performance tests it is recommended to further explore the wake vortex detection classification by including other parameters, e.g. the product of vorticity and signal-to-noise ratio SNLR, so as to hopefully increase the successful detection rate from about 78% to at least 90%.

WP 3 - Risk modelling and risk assessment
The aim of this work package was to provide a simulation environment for the assessment of wake vortex hazard under different crosswind conditions and apply it to the departure situation used in the CREDOS concept.

A trajectory generation model has been developed to generate realistic distributions of departing aircraft's flight paths for Monte Carlo simulations using the tool WakeScene-D. This trajectory model has been validated with aircraft track data delivered by DFS during the project.

Piloted simulator tests of wake vortex encounters in two flight simulators were conducted with a number of licensed commercial pilots to gain experience about wake encounters during departure. Those tests generated a large database of simulated wake encounters flown with an A320 and an A330 flight simulator during departure that can be exploited for model development and validation. The data was used within CREDOS for development and validation of a pilot behaviour model for wake encounters during departure based on a neural net architecture and advanced severity criteria for assessment of the severity of wake encounters.

Extensive analyses have been conducted on the simulation results regarding the influence of parameters like wind direction and magnitude or aircraft routing on encounter frequency and severity. The analyses revealed a significant effect of the veering of the wind with altitude, the so-called Ekman spiral, on encounter risk. This leads to the fact that crosswinds coming from the left of the departure runway on the ground generally lead to higher encounter probability above a certain altitude than crosswinds coming from the right (valid on the northern hemisphere).

All results indicate that for a scenario with straight-out departure routes a crosswind of 8 kt is needed to sufficiently reduce wake encounter risk when reducing the departure spacing between heavy and medium type aircraft from 120 s to 60 s. For a realistic departure route layout additional constraints are needed. For the Frankfurt example used in the simulations a crosswind of 6-8 kt could be sufficient if it is made sure it is coming from the right of the runway. Alternatively a restriction to using only the northerly departure routes would have a similar effect than departing straight-out, allowing a crosswind threshold of 8 kt as well.

WP 4 - CREDOS operational concept and validation
The aim of this work package was:
- the definition of the concept of operations, the refinement of this concept based on the CREDOS modelling and validation results, and requirements for the system (the procedures, user requirements, and system requirements);
- the development of the validation strategy and plan, the execution of the different validation cases (business case, environmental case, safety case, and human factors case) and other activities necessary,
The basic idea behind CREDOS is that, for departures, the wake turbulence separation criterion may be relaxed on the runway and for the first part of the climb path when the crosswind is such that the wake turbulence generated by the preceding aircraft will have been blown out of the departure track of the succeeding aircraft. The CREDOS concept has been kept as generic and as simple as possible. The concept is thus to be considered rather as guidance material than as a description of one particular endorsed solution. A number of improvements are also envisaged for the future. The different validation cases have shown that, although there is clear potential from a business case, environmental case and human factors point of view, further work in the area of safety is needed. It is also concluded that the next step for crosswind concept validation should be aimed at performing one or more local implementation cases.

WP 5 - Stakeholder communications and marketing
The aim of this WP was to manage all the mechanisms used by the project to effectively communicate the CREDOS concept to the full range of interested parties. This work package also covered the main instruments of internal communication within the project, namely the project website, OneSky Teamsite and the VDR.

Two information packages, one for air traffic controllers (ATCOs) and one for the pilots have been developed. Both information packages are presented in one single portal to encourage and facilitate the interest both the controllers and the pilots have for each other's working environment. The CREDOS portal can be accessed through the following web link: http://credos.bluskyservices.com.

A CREDOS project website was constructed and maintained, to be used for both internal and external communication of the projects achievements. It can be accessed at: http://www.eurocontrol.int/eec/credos/public/subsite_homepage/homepage.html

Related documents

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