MINUTES of the
1st WakeNet3-Europe Workshop
on
Wake Turbulence Safety
in Future Aircraft Operations

Thales University
Jouy-en-Josas, near Paris, France
January 8th & 9th, 2009

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v1	20-MAR-009	none	none	1st version
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1. Executive Summary

The first WakeNet3-Europe workshop was held at Thales University in Jouy-en-Josas, near Paris, France, on January 8-9, 2009.

WakeNet3-Europe is the European Coordination Action for Aircraft Wake Turbulence. It is funded by the European Commission, composed of 12 beneficiaries plus Eurocontrol as Third Party and started on April 1st, 2008. WakeNet3-Europe is coordinated by Airbus Deutschland GmbH.

24 aerospace professionals presented during the workshop. And with more than 100 registered attendees the workshop attracted an unprecedented number of participants. Participants came from all across Europe, the United States, Russia, China, Japan, Canada and Azerbaijan. The audience included representatives from airlines, pilot unions, airports, aviation authorities, air traffic service providers, aircraft & system manufacturers, research organisations, and universities.

The presentations covered the following five main topics:

- Wake Vortex Concepts in SESAR and NextGen
- Operational Detection and Prediction of Wake Vortices
- Wake Vortex related Safety Cases for Operational Implementation
- Wake Advisory & Warning Systems
- Towards Recategorisation of Wake Turbulence Separations

The workshop highlighted that relevant progress with regard to Wake Vortex topics has been achieved over the past three years or since the 3rd and last workshop of WakeNet2-Europe (held at Eurocontrol Experimental Centre, Bretigny sur Orge, France, November 29-30, 2005).

This progress is exemplified by the maturity of wake prediction models, by the further improved physical understanding of the wake vortex phenomenon, as well as by the enhanced and new wake detection and measurement technologies. Also, a number of wake vortex related safety cases have been accepted by the authorities over the past years: the Airbus A380 entry into service has been accompanied by a dedicated wake vortex safety assessment and subsequent classification by ICAO. Less noticeable to the general public - but also challenging - some operational changes requiring wake vortex related safety assessments have been introduced recently with more to follow.

The wake vortex topic remains of significant interest in the future. Wake turbulence separations are an important safety aspect and continue to limit capacity. Wake vortex safety is explicitly taken into account in the European and US programs for the modernisation of Air Traffic Management (SESAR and NextGen, respectively) with several projects to be expected in the SESAR Joint Undertaking (SESAR-JU) starting in 2009. Airbus is continuing the assessment of wake vortex safety in the context of A380 operations based on a unique data base of wake encounter flight tests. New wake advisory and warning systems are under development, related standardization activities are under way and work has started in earnest to replace the proven but rigid system of fixed wake turbulence separations.

Past and future wake vortex activities require multi-disciplinary exchange between professional stakeholders and WakeNet3-Europe will continue to provide a forum for these exchanges. Also, the WakeNet3-Europe Coordination Areas and Tasks Groups will help in networking and are planned to conduct specialised, dedicated workshops.

2. Final Agenda – Day 1 - January 8th, 2009

08:30	**Registration**
09:00	**Welcome & Introduction** Andreas REINKE, Coordinator - WakeNet3-Europe, Airbus Thierry BEAUVAIS, VP Research and Technologies, THALES AIR SYSTEMS Dietrich Knörzer, Scientific Officer DG Research, European Commission
09:30	**Topic 1 : Wake Vortex Concepts in SESAR and NextGen** Chair: Jean-Luc MARCHAND / EUROCONTROL
09:30	**SESAR Overall Framework and Concept** Robert GRAHAM / EUROCONTROL
10:00	**Wake Vortex Topics in SESAR** David BOOTH / EUROCONTROL, Andrew HARVEY / EUROCONTROL
10:30	**Wake Vortex in the Context of NextGen** Steven LANG / FAA, Jeff TITTSWORTH / FAA
11:00	**Standardization Activities for Wake Vortex Data Link Services** Laurence MUTUEL / Thales Avionics, Wayne BRYANT / FAA, Ernie DASH / FAA
11:30	**Break**
12:00	**Topic 2 : Operational Detection and Prediction of Wake Vortices** Chair: Sebastian KAUERTZ / Airbus
12:00	**Some reflections on the achievable quality of operational wake vortex prediction using operational met and a/c inputs** Gregoire WINCKELMANS / UCL
12:25	**On the maturity of wake vortex observation, prediction, and validation** Frank HOLZÄPFEL / DLR
12:50	**Lunch**
14:25	**Near-field evolution of trailing vortices and initialization of far-field models** Jeffrey CROUCH / Boeing
14:50	**Pulsed 1.5 µm LIDAR for aircraft wake vortex detection and monitoring** Agnes DOLFI-BOUTEYRE / ONERA
15:15	**Wake vortex X-band radar monitoring: Paris-CDG airport 2008 campaign results & perspectives** Frederic BARBARESCO / Thales Air Systems
15:40	**Break**
16:10	**First approach to wake vortex prediction and detection integrated fusion filters** Shanna SCHOENHALS / TU Braunschweig, Meiko STEEN / TU Braunschweig
16:35	**Wake vortex detection using Flight Data Recorder data registered on board aircraft** Henk HAVERDINGS / NLR
17:00	**FAR-Wake: Fundamental Research on Aircraft Wake Phenomena** Thomas LEWEKE / IRPHE CNRS
17:25	**End of Day 1**

3. Final Agenda – Day 2 - January 9th, 2009

08:00	**Opening**
08:30	**Topic 3 : Wake Vortex related Safety Cases for Operational Implementation** Chair: Tim FOWLER / Det Norske Veritas
08:30	**Worst-case analysis of wake vortex risk of 700ft vertical separation** Gerben VAN BAREN / NLR
08:55	**Wake vortex severity assessment - a core element of the safety case** Carsten SCHWARZ / DLR, Frank HOLZÄPFEL / DLR, Thomas GERZ / DLR, Klaus-Uwe HAHN / DLR
09:20	**Development of the Safety Case for the CREDOS operation** Lennaert SPEIJKER / NLR
09:45	**Break**
10:15	**Airbus wake vortex flight test campaigns and general conclusions** Claude LELAIE / Airbus, Andreas REINKE / Airbus
10:40	**National Rule Change and Follow-on** Steven LANG / FAA, Jeff TITTSWORTH / FAA
11:05	**Wake turbulence safety assessment of the arrival and departure segregated operation in Paris CDG** Vincent TREVE / EUROCONTROL
11:30	**Developing Local Wake Turbulence Separation Standards (Never Ending Story)** Isa ALKALAY / Skyguide
11:55	**Lunch**
13:00	**Topic 4 : Wake Advisory & Warning Systems** Chair: Peter ERIKSEN / EUROCONTROL
13:00	**ATC-Wake: Integrated ATC Wake Vortex Safety and Capacity System** Lennaert SPEIJKER / NLR
13:25	**Wake Vortex Advisory System** Jean-Francois MONEUSE / Thales Air Systems
13:50	**Technologies and procedures for wake vortex flight safety in the Russian next-generation air navigation system** Eduard FALKOV / GosNII AS
14:15	**Break**
14:35	**Topic 5 : Towards Recategorisation of Wake Turbulence Separations** Chair: Prof. Robert LUCKNER / Technische Universität Berlin
14:35	**Model-based recategorisation - options and challenges** Andreas REINKE / Airbus
15:05	**RECAT Phase 1: Towards the Identification of new Static Wake Turbulence Categories along with their Associated Wake Turbulence Separation minima** Elsa FREVILLE / EUROCONTROL, Steven LANG / FAA, Jeffrey TITTSWORTH / FAA, Catalin Lepadatu / EUROCONTROL
15:35	**Workshop Wrap-up** Bram ELSENAAR / NLR Retired, Andreas REINKE / Airbus
16:00	**End of Workshop**

4. Workshop Presentations and Q & A

Welcome & Introduction

Andreas REINKE, Coordinator - WakeNet3-Europe, Airbus

Andreas REINKE welcomed all participants and introduced them to the WakeNet3-Europe Coordination Action project which is funded by the European Commission within the 7th framework programme and includes 12 beneficiaries plus Eurocontrol as Third Party. The project started on April 1st, 2008, and is expected to run for three years. This workshop is the first of three major workshops planned within WakeNet3-Europe.

Reference: *WN3E_WS1_Intro_1_Reinke.pdf*

Thierry BEAUVAIS, VP Research and Technologies, THALES AIR SYSTEMS

Thierry BEAUVAIS also welcomed all participants in his function of local host to the workshop which takes place at Thales University in Jouy-en-Josas, near Paris Versailles. Mr. Beauvais presented the involvement and activities of Thales Air Systems related to Air Traffic Management, which includes provisions for Wake Vortex prediction and detection in the Thales Air Systems solutions for airports.

Reference: *WN3E_WS1_Intro_2_Beauvais.pdf*

Dietrich KNÖRZER, Scientific Officer, European Commission

Dietrich KNÖRZER also welcomed all participants in his function as representative of the funding organisation, the European Commission. The presentation by Mr. Knörzer addressed EC funding opportunities within the 7th Framework Programme and international cooperation within and beyond Europe.

Topic 1 - Wake Vortex Concepts in SESAR and NextGen

New air traffic management concepts are planned to be introduced in Europe via the European Air Traffic Management modernisation program (SESAR) and in the USA (NextGen). These shall enable the safe and efficient increase in air traffic in the future. The topic shall provide an overview of the SESAR and NextGen projects and specifically highlight those new procedures and concepts that are affected by wake turbulence separation requirements.

- How is wake turbulence safety addressed in SESAR and NextGen?
- What are the related projects? How are they harmonised and how can other activities be harmonized with SESAR and NextGen?
- Are there any concepts requiring additional consideration of wake vortex safety?
- Which advances in wake vortex technologies are required to fulfil the expectations of SESAR and NextGen?

The first session was chaired by Jean-Luc MARCHAND, Eurocontrol, former scientific officer of the EC and involved with WakeNet3-Europe during the proposal phase.

SESAR Overall Framework and Concept
Robert GRAHAM / EUROCONTROL

Bob GRAHAM presented the SESAR JU work programme and timeline as well as some of the key concepts driving the work programme.

Reference: *WN3E_WS1_Topic1_1_Graham.pdf*

Comments, Questions & Answers:

Q: When is a unique and globally accepted definition of 4D trajectory to be expected?
A: When we have collected and agreed-on definitions; more precisely it is likely to take place after the first 2 years in SESAR. This common definition is a must have to proceed with trajectory based operations.

Q: What seemed to be missing from the presentation were the objectives of the work programme.
A: Because it was an overview, up to now significant amount of work was done to arrive at version 4 of the description of work which defines what has to be achieved. The objectives remain however high level but for all, research has to be achievable. At the end of the project it has to move to implementation and not go to research once more.

Q: Where were the wake vortex concepts in SESAR? They seem to be rather spread in many work packages in SESAR, hence it is difficult to get a coordinated concept. How to ensure the end result is a coordinated effort?
A: It is indeed spread. The concepts brought many diverse ideas and it was not coordinated at the time of definition of work, thus it has to be done within the early stages of SESAR. All pieces have to be pulled together, which should normally happen via the Work Breakdown Structure of SESAR. It is weary that many different concepts exist uncoordinated; they should be assembled, integrated and coordinated, which is the job of the JU.

Q: Can you explain the different Implementation Packages of SESAR?
A: They are timeframes, basically:
- IP1: current situation – no R&D – what is handed over to implementation
- IP2: where SESAR focuses on. Ensuring that different concepts can be implemented. Usually depicted as capabilities or services to be provided.
- IP3: future beyond 2020.

Wake Vortex Topics in SESAR
David BOOTH / EUROCONTROL and Andrew HARVEY / EUROCONTROL

The presentation covered the wake vortex related contribution to SESAR from Eurocontrol, which includes Time Based Separations, Closely Spaced Parallel Runways, Crosswind Operations and Recategorisation of Wake Separation Minima (SESAR project 6.8.1).

Reference: *WN3E_WS1_Topic1_2_Booth_Harvey.ppt*

Comments, Questions & Answers:

Q: The SESAR WP6.8.1 timetable goes beyond 2013 but it was thought that implementation would start in 2013. Is the timeline correct?
A: SESAR lifetime is about 7 to 8 years. It is SESAR IP1 that should start implementation in 2012-2013; WP6.8.1 is an IP2 activity.

Q: While work in CREDOS is of great value, can we agree that the best improvement is to use mixed mode because then all problems would disappear?
A: This is mostly true but for various reasons (e.g. regional specifics) mixed mode is not always possible and so we do need alternate methods.

C: By not mentioning in the presentation mixed mode but only the alternate methods, the vision of the workshop attendee can be skewed.

Wake Vortex in the Context of NextGen
Steven LANG / FAA

Reference: *WN3E_WS1_Topic1_3_Lang.pdf*

Comments, Questions & Answers:

Q: The presentation was quite negative about wind measurement up to 4000ft although it is working at Frankfurt airport.
A: It is acknowledged.

Q: Wake turbulence research history 10 years ago was famous to work on advisory systems. Now you have success in implementing procedures. Do you foresee to go back to the previous approaches?
A: Yes, mid-term. Some of the approaches are in drawers. For the short term only procedural changes were viable and we had to go with this.

Q: Could you clarify about ADS-B implementation?
A: The issue is driven by equipage and there is no mandate today. The issue lies then with the airlines and whether they want to bear the cost, which is not forced on them. The problem is to find solutions also adapted to current equipage. Implementation horizon is 2020.

Q: An ADS-B solution still has a lot of unknown in the transmission, how about visualisation of wake vortices as was reported in the US academy report?
A: Cannot comment on the academy report that discussed wake visualisation. Sensor work has been carried out worldwide to reach alerting ranges of 30s. Research is ongoing but most likely it is not a short-term solution.

Standardization Activities for Wake Vortex Data Link Services
Laurence MUTUEL / Thales Avionics

Reference: *WN3E_WS1_Topic1_4_Mutuel_Bryant_Dash.pdf*

Comments, Questions & Answers:

Q: You are presenting the need for standards, don't you think the hazard metrics should be defined first?
A: The definition of hazard metrics (i.e. what is an acceptable encounter) is of paramount importance. Nevertheless, the ongoing standardisation activities like wake parameters in ADS-B and datalink services can proceed without the hazard metrics being defined because of their scope. But the international effort on the hazard metrics definition shall be set in place rather quickly as today no one can provide a clear definition of an equivalent of severity factor for the wake vortex hazard.

Q: The downlink is an important element, why is it not standardised?
A: Within the standardisation group dealing with datalink services, downlink is within the scope but not much as been done mostly for lack of expertise within the group. The examples available were AMDAR for the downlink of aircraft atmospheric parameters and within FLYSAFE the request from the aircraft to the ground system for wake information was defined. Beyond this, we were not knowledgeable.

Q: What physical means do you envisage?

A: The standardisation of datalink services does not purposely consider the physical layer but only addresses the services. There are initiatives in the world using VDL-2, -4, Satcom, UAT… but we pursue the standardisation of services independently from them.

Q: Does the standardisation address current or future datalink?
A: Both. Some products for wake vortex concepts are so new they might require future datalink. There will be work in SESAR addressing future communication needs with a long-term implementation horizon (20-30 years) but the speaker is not knowledgeable about the details of these future means.

Topic 2 - Operational Detection and Prediction of Wake Vortices

Direct measurement as well as model-based prediction of wake vortices has significantly improved in the last decade. Research activities towards further improvements are ongoing with the aim to provide more reliable, more capable, and operational systems, on the ground and for airborne applications.

- What are the requirements on measurements and models for decision making and/or safety monitoring?
- What is the current quality of wake detection and characterisation by sensor?
- Which sensor capabilities are feasible and when could they become operational?
- Are new sensor technologies emerging?
- What is the current quality of model-based predictions? What are the required inputs and how is the quality affected by the availability / quality of the inputs?
- How can operational wake prediction models be validated?
- How can models and measurements be fused?

The second session was chaired by Sebastian KAUERTZ, Airbus, CREDOS Work package 3 ("Risk modelling and risk assessment") leader and engaged in wake vortex R&D since 2003.

Some reflections on the achievable quality of operational wake vortex prediction using operational met and a/c inputs

Gregoire WINCKELMANS / UCL

Reference: *WN3E_WS1_Topic2_1_Winckelmans.pdf*

Comments, Questions & Answers:

Q: It is understood that the uncertainty in the wake prediction volume is driven by nature and the measurement uncertainty. Do you see a possible reduction in the uncertainty via the reduction of measurement uncertainty?
A: In CREDOS, the declared measurement uncertainty is not corrected when compared to the measured data. There is work to be done to correct and/or minimize this.

Q: Can you distinguish the allocation to measurement errors or naturally fluctuation in the physics?
A: In general not, but in some cases with no wind or by using the knowledge of wake behaviour the attribution to measurement error was possible. It is the responsibility of the data provider to minimize the error in the data, it is not the responsibility of the wake vortex modeller.

On the maturity of wake vortex observation, prediction, and validation

Frank HOLZÄPFEL / DLR

Reference: *WN3E_WS1_Topic2_2_Holzaepfel.pdf*

Comments, Questions & Answers:

Q: We have heard two presentations with contradicting conclusions. Do you have any experiment in mind in order to prove the 3D vortex evolution really takes place?
A: Smoke visualisation has been used. However there are cases where it is very difficult to understand what is going on. So it cannot be fully proven.

Q: The aspect of probable exposure time was mentioned. The probability of severity should be going with the time spent in the vortex but how about the initial jerk?
A: There is related research in the ongoing German project Weather & Flying.

Q: Do you think the maturity level achieved by the models today is sufficient to be used operationally for safety in replacement of Lidar measurements, or is it still as supporting evidence?
A: The speaker thinks that models can be used for multiple purposes but other people need to be convinced. He favours the use of the models as the time when they were not credible enough is behind us; the user must however understand the uncertainties.

C: Models can do a lot of things, but at the end of the day the model explain for the generator but do not give an idea of the impact of the follower. That is the next step and that is really important.
A: Indeed, the models discussed here are for the understanding of the wake vortex behaviour.

Near-field evolution of trailing vortices and initialization of far-field models

Jeffrey CROUCH / Boeing

Reference: *WN3E_WS1_Topic2_3_Crouch.pdf*

Comments, Questions & Answers:

C: Note that there are other loadings than elliptical for the b/b_g value shown in the presentation.
A: Sure but they could be close to elliptical.

Q: Do you think the engine jet may play a role? Did you perform CFD methods on this issue?
A: Totally agree, we did CFD to allow to include the jet. We do with and without to quantify the jet effect; the jet affects how the vortices stay together or not.

Q: Are there any buoyancy effects?
A: Buoyancy effects have not been isolated as such.

Q: Can you explain how B757 developed stronger wake vortices then other aircraft?
A: Probably this assessment is more an artefact of its weight being higher and this airplane going to smaller airports instead of a result of its configuration.

Pulsed 1.5 µm LIDAR for aircraft wake vortex detection and monitoring
Agnès DOLFI-BOUTEYRE / ONERA

Reference: *WN3E_WS1_Topic2_4_Dolfi-Bouteyre.ppt*

Comments, Questions & Answers:

Q: There have been numerous measurement campaigns within EU projects. Now could you imagine to have a system installed permanently?
A: Further work is needed to develop unattended systems to have longer campaigns.

Q: FIDELIO has further work to increase the Lidar detection distance?
A: FIDELIO has been completed so further work could be done on the Lidar.

Q: Is it destined as an airborne Lidar? Longitudinal detection is feasible?
A: Slight off axis detection is easier than being completely aligned with the vortex core.

Wake vortex X-band radar monitoring: Paris-CDG airport 2008 campaign results & perspectives
Frederic BARBARESCO / Thales Air Systems

Reference: *WN3E_WS1_Topic2_5_Barbaresco.pdf*

Comments, Questions & Answers:

Q: Concerning the complementarities of Lidar and Radar: did you make a one to one comparison? Also: at the CDG picture it looked like there was a metal pole in front of the radar, how to declutter?
A: Radar has a blind range of 400m so the Radar was not perturbed by the pole. On the comparison, yes there was a one to one comparison: the Radar data was fit in the Lidar format and the data was transmitted to Eurocontrol for analysis. Results are still in process. We would like to have longer campaigns pushed via SESAR and also the possibility to use different modes of the weather radar. These Thales funded trials were done to de-risk the usability of the radar in all weather conditions and to assess complementarities.

Q: You mentioned that circulation can be estimated from Radar, can you estimate how accurate these estimations are?
A: The equation used links the radar parameter proportionally to the circulation. It is not known how the Lidar was calibrated for its circulation computation, but the radar could be calibrated similarly. The formula has been used in the US with a RASS benchmark.

Q: Doppler entropy parameter was mostly used for the roll-up, is that the highest gain parameter or the most meaningful one?
A: The Doppler entropy used is a special definition of Doppler entropy taken from Thales military experience. In the far field it is simple Doppler that is used as there is no more roll-up.

First approach to wake vortex prediction and detection integrated fusion filters
Shanna SCHÖNHALS / TU Braunschweig

Reference: *WN3E_WS1_Topic2_6_Schoenhals.pdf*

Comments, Questions & Answers:

Q: Can you give additional details on the processes inside the integration box, i.e. the fusion filter?

A: The concept presented in loosely coupled. The fusion filter predicts the errors in circulation and trajectory prediction and feeds them to the model for correction.

Q: In reality the Met data refreshment rate is quite low. The Met profiles are typically provided every 3 minutes, SODAR every 10 minutes. These timescales are longer than the wake vortex life, how do you intend to address that constraint?
A: Using indirect measurements from the sensor could be provided almost real-time and be entered via the fusion filter. The model still uses as inputs the Met data.
The corrections inside the filter are not correcting 100% as the uncertainty in the sensors are taken into account, algorithm tuning is necessary to optimize the uncertainty in both elements.

Q: This is just starting, when could results be seen?
A: Work started 8 months ago, this is an overview of possible concepts. One or two years should be necessary. Modellers are currently invited to participate, the vortex behaviour is not yet included in the process.

C: The low maturity of the results was known to the WN3E Coordination Board. The board still believed to include the presentation since we have conclusive research on models and sensors independently but not in combination. The concept of fusion of sensor and models is of great interest and we feel there is a R&D gap here.

Wake vortex detection using Flight Data Recorder data registered on board aircraft

Henk HAVERDINGS / NLR

Reference: *WN3E_WS1_Topic2_7_Haverdings.pdf*

Comments, Questions & Answers:

C: The use of open path integral in the cross plane is a powerful tool and could additionally be taken into consideration.

Q: What do you mean by vorticity in your method?
A: Just considering the rotational of a flow. It is the effect on the aircraft that is evaluated.

C: In a potential flow as indicated in your drawings there should be no vorticity.

Q: Happy to see that somebody is interested in what happens to the follower. Not a lot of events are reported. How do you know which aircraft produced a vortex?
A: With the FDR approach you cannot. The interest is only in what happened to the follower, the generator info is not available, except from ATC. This information is however important for spacing.

Q: If better aircraft data was available for processing, how would it improve your detection rate?
A: The algorithm is quite robust, what is more important is the values for the derivatives element, however having done quick sensitivity studies the impact seems to be minor.

FAR-Wake: Fundamental Research on Aircraft Wake Phenomena

Thomas LEWEKE / IRPHE CNRS

Reference: *WN3E_WS1_Topic2_8_Leweke.pdf*

Comments, Questions & Answers:

(Nothing recorded)

Topic 3 – Wake Vortex related Safety Cases for Operational Implementation

Any changes potentially affecting wake turbulence safety need to be thoroughly evaluated in dedicated safety cases. Examples of such changes are the introduction of RVSM, the introduction of new large aircraft (e.g. A380, B747-8), changes to approach wake turbulence separations (e.g. time based separation) as well as the introduction of additional safety nets (e.g. airborne alerting).

- In the absence of specific regulatory requirements and prescribed means of compliance, how can wake turbulence safety be evaluated?
- What is the role of safety monitoring and what are the latest experiences with incident reporting and analysis?
- Is the current situation sufficiently safe to serve as reference in relative safety assessments?
- How is the current level of safety defined? Is it possible to strictly distinguish between relative and absolute safety assessments?
- How has wake vortex safety been addressed in recent developments, what is planned in ongoing activities?

The third session was chaired by Tim FOWLER, Det Norske Veritas. Tim FOWLER is a safety case expert who was involved in the writing of the A380 Safety Case (LiDAR based) and currently is engaged in the WIDAO project (Wake turbulence safety assessment of the arrival and departure segregated operation in Paris CDG).

Worst-case analysis of wake vortex risk of 700ft vertical separation
Gerben VAN BAREN / NLR

Reference: *WN3E_WS1_Topic3_1_VanBaren.pdf*

Comments, Questions & Answers:

Q: When you say separation of today of 1000ft is safe, I disagree. There have been simulations where the aircraft crashes. Typically when the aircraft is at high speed, 6NM is not acceptable. For the A380 8NM is asked. The presented separation is not considered safe from my point of view.
A: It depends on the definition of safe.

C: A negative load factor is not safe for example.

Q: 5.5g is a bit overkill as a threshold for assessment: the aircraft aerodynamics will not allow this, something bad will happen well before this value. Has the aerodynamics of such light aircraft been taken into account in the modelling?
A: The computations used where quite simplified.

Q: How did you do the variations analysis? What was the reference worst case?
A: No stratification, no turbulence was considered the worst case.

C: 5.5g is indeed hard to reach with a light plane. However the safety aspect is mitigated by the airspace allocation, e.g. heavies fly higher than lights.

C: If the current vertical separation would not be safe, then the whole airspace today would not be safe.

C: Concern is more the distance, not the vertical separation; I would never fly into a Heavy's wake with a Light aircraft at 6 NM.

Wake vortex severity assessment - a core element of the safety case
Carsten SCHWARZ / DLR

Reference: *WN3E_WS1_Topic3_2_Schwarz.pdf*

Comments, Questions & Answers:

Q: One should be worried to associate the Lidar in its current state with "safety net" quality. A safety net requires other capabilities than that of the Lidar, e.g. real-time operations. The approach shown here does not include Lidar-issued warnings being transmitted to controller.
A: If we consider an operational concept, the Lidar was indeed not part of it. It was validation for the campaign data analysis.

C: You should be careful about computing wake vortex down to the very end of the ILS, close to the ground. In ATC-Wake the same approach was developed, here it is rather the DLR tools than a DLR approach that is presented.

Q: It was assumed straight vortex lines as worst case?
A: Right now also the dynamic evolution of vortices, e.g. forming of rings, is addressed.

Development of the Safety Case for the CREDOS operation
Lennaert SPEIJKER / NLR

Reference: *WN3E_WS1_Topic3_3_Speijker.pdf*

Comments, Questions & Answers:

Q: Are the high safety objectives related to accidents? The described hazards do not necessarily lead to an accident.
A: They do not directly relate to accidents, but they "could" lead to accidents.

Q: Do you have any idea of the frequency with which such a system would be usable?
A: That is part of another specific study in CREDOS that looks at how often the favourable wind conditions occur in Europe, but it will also depend on the threshold for the wind criterion to be used. We have some figures based on assumptions on this criterion: 2-5% reduction in delay assuming that wind constraints are the most relevant parameter and other constraints like runway occupancy are less relevant.

Airbus wake vortex flight test campaigns and general conclusions
Claude LELAIE / Airbus, Andreas REINKE / Airbus

Reference: *WN3E_WS1_Topic3_4_Lelaie_Reinke.pdf*

Comments, Questions & Answers:

Q: I relate to slide13: have you ever executed the whole chain of processing for a single event? Lidar measurements are typically close to the ground where flight tests are difficult.
A: There are tests that have been made with Lidar IGE and OGE. At high altitudes the same vortex was measured by Lidar and then encountered by our aircraft.

Q: Ideally we would like to run each pair of aircraft and for each variable but that is not possible in flight tests. Just saying what is available at the moment is only "paper" aircraft and posing this against flight tests is limiting.

A: Of course a flight test validation of all possible cases is not possible, just a few representative cases would be sufficient (representative in terms of aircraft types and atmospheric conditions). The models used to assess all the other variables are good, but need to be validated.

Q: Based on the huge work done, does Airbus have in mind to propose new regulations based on the data that authorities can accept?
A: Airbus is ready to do everything that is required and to share the acquired database. However, until the A380 situation has been clarified within its dedicated group, the database cannot be shared.

National Rule Change and Follow-on
Edward JOHNSON / FAA

Reference: *WN3E_WS1_Topic3_5_Johnson_Lang.pdf*

Comments, Questions & Answers:

Q: You have results of Lidar trials and statistics of wake transport, taking into account extreme wind conditions. How about extreme wind conditions in bad weather where Lidar measurements are not good?
A: We measured the wake transport based on crosswinds. We need to have high crosswinds, while in low visibility crosswinds are usually too low to support wake vortex reduced separations.

Q: RNAV is for CSPR?
A: The graph indicates that RNAV can support the wake encounter avoidance in combination with other measures already in place.

Q: Can you explain how a wake encounter probability of e.g. 10-5 was computed from Lidar data, if the Lidar datasets in total are much smaller than 105 cases?
A: What is shown is a relative analysis using the Lidar measured on single runway […]

Q: Have you thought about if you can safely maintain 1.5 NM between a series of aircraft, not only one pair (e.g. medium-medium-medium)?
A: No. We are still considering this case but not within this NRC: it was setup for Small or Large aircraft in the lead.

Wake turbulence safety assessment of the arrival and departure segregated operation in Paris CDG
Vincent TRÈVE / EUROCONTROL

Reference: *none*[1]

Comments, Questions & Answers:

Q: Who was the initiator of this?
A: Eurocontrol, specifically Jean-Pierre Nicolaon, jointly with the French authorities, but it was in fact launched by Jean-Pierre. It was facilitated by the existing network.

Q: Who financed the initiative?
A: The Lidar is an investment from Eurocontrol, the funding for the man power is shared by Eurocontrol and DSNA.

[1] The presentation given by V. Trève, Eurocontrol, has not been received the WN3E coordinator by March 20th, 2009.

Q: It is interesting that a wake encounter would be acceptable before the lift-off point. Are there any special effects from the wake vortex injection that could lead to rejection (e.g. engine compressor stall)? Is the acceptance under any conditions or only special ones?
A: It was discussed extensively with stakeholders, but all encounters on the ground were judged acceptable (on the ground means there is no lift: the weight is on the wheels).

Developing Local Wake Turbulence Separation Standards
Isa ALKALAY / Skyguide

Reference: *WN3E_WS1_Topic3_7_Alkalay.pdf*

Comments, Questions & Answers:

Q: You mentioned omni-directional winds, did you use the ICAO-defined 10m-wind or an actual wind profile?
A: Cannot answer on the topic as it goes deep into the level of details of the modelling.

Q: The assumption of 1 out of 100 wake encounters is catastrophic is rather high.
A: 1/100 catastrophic encounter is a rather conservative number (an encounter being defined as having a duration [exposure] over 1s). The graph reads that if you accept the given vorticity, then you might end up in the 1/100 catastrophic events. Typically, the encounter will hit you first before the mid-air collision.

Q: It looked like the risk of Near Mid Air Collision was higher then for WVE? Would be worried about that.
A: That is because of the much lower Cutoff Point Distance assumed, at the usual 14 NM it would be much lower.

Topic 4 – Wake Advisory and Warning Systems

Wake sensors and model-based predictions allow for dedicated wake advisory and warning systems on the ground (especially at capacity-constrained airports) as well as in the air. Onboard and ground-based systems may operate independently or in collaboration. They may use sensors and/or models to assure safety. They may replace existing separation rules or act as additional safety nets.

- Which general concepts are feasible? What are their individual strengths and constraints?
- What could be the roles attributed to ground and airborne systems? How should they interact?
- How do advisory and warning systems relate to general recategorisation?

The fourth session was chaired by Peter ERIKSEN, EUROCONTROL.

ATC-Wake: Integrated ATC Wake Vortex Safety and Capacity System
Lennaert SPEIJKER / NLR

Reference: *WN3E_WS1_Topic4_1_Speijker.pdf*

Comments, Questions & Answers:

Q: During the introduction the statement was made about the measurement of capacity benefits not being sure, while this was achieved at Frankfurt. DFS has already completed its Wake Vortex Advisory System in Frankfurt, just did not get permission to use it operationally.
A: It is acknowledged.

Wake Vortex Advisory System
Jean-François MONEUSE / Thales Air Systems

Reference: *WN3E_WS1_Topic4_2_Moneuse.pdf*

Comments, Questions & Answers:

Q: What kind of tool is the "wake predictor"? A model?
A: It is an available model from UCL.

Q: What are the functionalities of the DART tool?
A: The DART is a suite developed as part of the safety: it is parameterized, configures and can do fast time simulation to adjust the parameters. It can be used to adjust the wake turbulence encounter function for example (the wake vortex data used in the WTE can be replayed).

Q: Are you intending to protect from WV separation minima infringement (where STCA already exist) or are you going to warn about possible WVE? How to build the trust in the system?
A: The WVTE advisory is a means to warn the controller that one aircraft is predicted to enter the wake vortex in the short term (~ 30s).

Q: Where is the pilot involved?
A: In the plane.

Q: Are you planning to develop a new asterix category for WV info, are you considering developing also format standard for datalink exchanges for air-ground?
A: At the moment there is no standard for the sensors, so having a standardisation at the asterix level is a good start and will be pushed at Eurocontrol. Solutions will appear in the cockpit so air-ground datalink exchanges data format standard will be done.

Technologies and procedures for wake vortex flight safety in the Russian next-generation air navigation system
Eduard FALKOV / GOSNII AS

Reference: *WN3E_WS1_Topic4_3_Falkov.pdf*

Comments, Questions & Answers:

Q: Sort of favouritism for VDL-4 goes in collision with priority set in Link2000+ and other Eurocontrol initiatives. The priorities have been decided at European level, this is why you are facing some difficulties pushing this trough. Wake vortex is not the prime killer… did you contemplate on this?
A: VDL-4 is not only Swedish, it is adopted by SESAR. Indeed we tried to use both: it did not work in 1090ES but it did using VDL-4. You will soon realise that the only way out is VDL-4, at least for small aircraft. Other capabilities can be investigated but you will see that in the end VDL-4 is the only solution. We analysed the situation from the reality point of view.

Q: Airbus is still evaluating these systems, the possibility to add VDL-4 is there but someone will have to pay for it and today we cannot say that the system can provide the required benefits and safety. It is interesting to see that the ConOps is there in Russia and we will be happy to discuss it. But what do you think is the benefit to the customer?
A: Airbus announced that from 2009 on all Airbus aircraft will be produced with 1090ES with Change3. However, Change3 is about to be changed in that everlasting process and will not work for many years still. If a client, for example Aeroflot, requests VDL-4, then this need should be considered. Russia is going to implement VDL-4 throughout the country in the coming years, in Sweden it is already deployed.

Topic 5 – Towards Recategorisation of Wake Turbulence Separations

General recategorisation of wake turbulence separation is evaluated by ICAO, Eurocontrol and FAA. Concepts range from "simple" subdivision of existing weight categories to dynamic separations. The goal is to provide initial capacity gains in the short term and allow for more complex methods providing larger gains in the future.

- What are the current plans, options and constraints?
- What exactly could constitute dynamic separation?
- How shall the new separations be introduced? How would the corresponding safety cases be established? Would it require an absolute or relative safety assessment?
- How can it be assured that new separation schemes are fair?
- Which technical enablers are required?

The fifth session was chaired by Prof. Robert LUCKNER, Technical University of Berlin. Robert LUCKNER is engaged in wake vortex related research since 1998 (at that time for Airbus) and currently leading the WakeNet3-Europe Task Group on Recategorisation.

Model-based recategorisation – options and challenges

Andreas REINKE / Airbus

Reference: *WN3E_WS1_Topic5_1_Reinke.pdf*

Comments, Questions & Answers:

Q: The goal seems to be only an increase of capacity; this might be too narrow, the actual safety should probably be considered too.
A: Safety is definitely considered in the approach. But in the mathematical optimisation capacity acts as single optimisation goal with a predefined target level of safety as fixed constraint.

Q: Have you considered using the Maximum Landing Weight as a criterion as well? Which new weight boundaries do you propose?
A: We do not propose any new weight boundaries here on purpose. The results shown are primarily intended to describe a possible recategorisation method.

RECAT Phase1: Towards the Identification of new Static Wake Turbulence Categories along with their Associated Wake Turbulence Separation minima

Elsa FREVILLE / EUROCONTROL, Catalin LEPADATU / EUROCONTROL, Steven LANG / FAA

Reference: *WN3E_WS1_Topic5_2_Tittsworth_Lepadatu_Freville.pdf*

Comments, Questions & Answers:

C: In my opinion Recat is only used to increase capacity, but at many airports we are already down to 2-3 NM separation. With an even more reduced separation you will never get the same or even a higher level of safety.

Q: You said you limited the analysis to a set of 61 aircraft. Which 61 aircraft are used exactly? Would you make it available?
A: The aircraft list can be provided.

C: You could improve capacity even more with a higher number of categories.

Q: The airspace is at a limit already. How will new (big) aircraft fit into that at all with only static separations?
A: The second phase of Recat will have dynamic spacings as well.

Workshop Wrap-up
Bram ELSENAAR / NLR retired

Bram ELSENAAR - former coordinator of WakeNet2-Europe - was invited by the WakeNet3-Europe Coordination Board to participate to the workshop and to share his thoughts on today's status of wake vortex research and implementation. The following text is based on notes taken during his speech:

"The Meeting was very pleasant, it was the old atmosphere of the network. The interaction between the audience and the speaker is very well. The social event was nice and well organised: people should work together the way the cavalier and the horse were: respectful and elegant.

The program was a little too tight maybe, maybe allow a little less papers next time.

We see now a second generation of wake vortex people: the universities breed these experts and they are very important to foster new ideas.

Some observations:

At the first meetings, the message from the pilots was always "avoid". Since then we have discussed all the items and it continued at this workshop. The classification of the A380 wake separation was always in the background of WakeNet and today we have seen how it was done and what are the recommendations, the validation methods. This has also brought together the US and the European side, in the A380 exercise, RECAT and in the exchange in networks.

Two years ago, we had no rule change that was accepted, except the Frankfurt situation. Today we see at least for 4 different cases: rule changes are accepted. We see the efforts have paid off.

We witness the development of Lidar equipment and X-Band radar, this is a continuing story but it remains an essential element.

Modelling of the WV behaviour has increased in maturity, IGE [in ground effect] has been added - to a large extent in FAR-Wake. We are now at a point where two models are available and can be used for safety cases. It is left for the next WakeNet to find which further validation is required.

Wake vortex is now really embedded in the larger context of SESAR. The integrated look at the whole problem is important and the solution can only come from an integrated approach. SESAR opens new possibilities.

RECAT is a very essential step for the future. However one wonders why it did not start earlier as all the elements existed already a few years ago, but we were focused on the A380.

A few things not so clear:
- *Perspective to use airborne Lidar: it is not not clear that any progress has been made or have we come to the conclusion that it is not possible? Pilots nevertheless request an onboard system.*
- *Modifying the wake at the source remains difficult. FAR-Wake did not give a clear idea how to further proceed with that. Much more fundamental work should be done, and WakeNet should keep that in mind as well. It is difficult, but not impossible. Universities are a key player for this.*
- *The representation of airlines and airports at the workshop. This is an old issue since the benefits for them are not so clear yet. It is the work of the network to bring out these numbers and to communicate them to the airlines.*
- *Standardisation is a very important issue and WakeNet should do something about it; equally for the severity criteria. WakeNet should make an effort to make progress in this area."*

5. Workshop Conclusions

Concluding thoughts on topic 1 by the session chair
Jean-Luc MARCHAND / Eurocontrol

Will SESAR and NextGen produce different ATM systems? This genuine and legitimate question largely dissolves when considering that these initiatives will serve the same users, they will follow similar timescales, they aim to solve universal problems and they are in similar structural environments.

So, do they contemplate one Wake Vortex concept? No is the answer which comes from a systemic approach. Both SESAR & NextGen follow the same evolution to reach a performance based concept from a time based concept via an intermediate step with 4D trajectories. They both build on the quite numerous existing results on Wake Vortex (past and present projects) and aim at integrating these results in different places of unified Work Programmes. They will put the Wake Vortex issues in a vision whose content is yet to be defined but which first priority is to help defining an agreed level of acceptability for wake vortex encounters.

In the short term, both initiatives expect to implement quick wins using those Wake Vortex results which can be implemented while more recent ones could be put forward to ICAO processes.

Do we progress on the standardisation front? Certainly yes for enablers which post significant progresses. But an important issue remains on how to feed these progresses at the appropriate level to SESAR and NextGen which appears as fortresses to the non-members…

Being similar - and not yet at a competitive stage - SESAR and NextGen call de facto for a strong co-operation on R&D Wake Vortex Safety issues. Even more, the cooperation arena must be enlarged to include Russia and China at least.

The good news is that the workshop showed strong, positive signs on cooperation!

Concluding thoughts on topic 2 by the session chair
Sebastian KAUERTZ / Airbus

In this session we were diving right into the technical aspects of current and recent wake vortex research. Many of the emerging technical concepts that are envisaged to help mitigate wake vortex aspects in the future air transport system require operationally usable (which usually means fast) wake vortex behaviour models, and/or a reliable detection of wakes within a certain space, either from the ground or directly from the aircraft. Therefore the session contributions focused largely on these two aspects.

Presentations by UCL and DLR have shown impressively how their models could be developed in the last few years, also largely using wake vortex measurements that took place at different airports during several projects. The general conclusion seems to be that those models now have reached a good point of maturity that allows them to be applied in operational concepts. Nevertheless, those models are still subject to uncertainties, either due to the inputs feeding them having limited accuracy, or due to limitations in the physical modelling itself (three-dimensional effects, vortex ring stadium etc.). This makes it almost mandatory to pursue a probabilistic approach, and it could be shown that both models presented match well with measured data.

However there is also considerable research going into the deeper understanding of wake vortex physics and evolution and possible ways to influence and attenuate the vortices, shown by reports from Boeing and from the recently completed FAR-Wake project. While these might not be directly used in an operational sense, they are valuable research if one wants to find ways to mitigate the actual vortices, or investigate the impact of a vortex wake on an encountering aircraft, which largely depends on the wake characteristics in the far field.

Presentations by Thales and ONERA have shown the progress in detection and measurement techniques for wake vortices, using different technologies such as LiDAR or Radar. Especially LiDAR measurements have been extensively used in the last few years not only to provide valuable validation data for models, but they are now also beginning to be used to support Safety Cases for different wake vortex related concepts (see WIDAO for Paris-CDG airport or projects like CREDOS in Europe or WTMD in the US).

Last not least the session also showed that different further approaches are pursued as well, apart from the pure prediction or detection of vortices. One example is the identification of wake encounters from Flight Data Recorder data, developed by NLR. This method can not only help in classifying incidents as a wake encounter, but used in large scale on FDR data it could also provide clearer views on the actual frequency of wake encounters in daily operation. Another example was the fusion of measurements and prediction models to utilize advantages of both approaches in the best way. While admittedly in an early stage, it shows that there are still new ideas to be developed that may eventually add to the toolbox needed to tackle the wake vortex problem in a quickly growing air transport system.

Concluding thoughts on topic 3 by the session chair
Tim FOWLER / Det Norske Veritas

Tim Fowler's personal opinions on the WakeNet3-Europe Workshop, 8 to 9 January 2009:

As a risk analyst, my perspective on all the presented talks is, "How could this help to demonstrate acceptable levels of wake vortex safety?". This question prompts another question which is shorter and possibly even more complex, "What is safety?".

First, a system or operation is safe when it is consistent with safety criteria defined by the industry or the industry's regulator (absolute safety assessment). The values of such criteria are essentially determined by political choices. In Europe, the main safety criterion is the frequency of Air Traffic Management-induced fatal accidents per flight hour defined by ESARR 4. In order to compare wake vortex risk to this criterion it will be necessary to estimate the probability of a fatal accident given a specified type of wake vortex encounter. To estimate and agree such a set of probabilities would be a significant technical and political challenge and this meeting did not indicate any real progress towards this goal, in my view.

Second, a system or operation could be shown to be at least as safe as operations today (relative safety argument). This approach has now been used in a number of safety assessments, as presented during the meeting. The approach is not without its own challenges, but it is practical and robust, though it prompts a subsidiary question, "Are all wake turbulence standards set today safe?". My view is that some current standards may appear safe because in practice the scenarios they represent occur at very low frequencies in normal operations (Light 6NM behind Heavy on approach may be an example).

Concluding thoughts on topic 5 by the session chair
Robert Luckner / Technische Universität Berlin

ICAO definition of aircraft categories (HEAVY, MEDIUM, LIGHT) and corresponding separation distances was initiated by the advent of large jet airplanes (B747, L1011, and DC10) in the late sixties. Since then, national modifications of the rules were enforced in the US after incidents behind the B757 (MTOW of the 757 is at the upper end of the MEDIUM category) and local modifications and interpretation of rules were introduced at certain congested airports. Additionally, a new category SUPER with additional separation was established for A380 by ICAO.

Obviously, current separation distances are safe. But risk is not evenly spread over all aircraft pairs, i.e. a 20-tons and a 100-tons aircraft require the same separation following another 100-tons aircraft, but the reaction of the smaller aircraft is certainly more severe, if an encounter occurs.

Up to now, all regulations for wake turbulence separations are based on measurements, the interpretation of measured data - supported by models of wake vortex physics. However a methodology on how to define safe separation distances is lacking. Andreas Reinke (Airbus) presented a promising approach. It uses Monte Carlo Simulations and allows assessing and comparing wake vortex encounter risk for individual aircraft pairs for certain safety levels and includes a prediction of the impact of rule changes on capacity. Airbus would support its application in RECAT.

Eurocontrol (Elsa Freville, Catalin Lepadatu) and FAA (Steven Lang, Jeff Tittsworth) presented the RECAT initiative that has the objective to review the existing ICAO wake turbulence categories and associated pair-wise separation minima for both departure and arrival operations. The task will be addressed in three phases. A transparent and validated methodology is needed to support that approach. The required knowledge has improved in the last years significantly, a huge amount of data has been recorded in a significant number of campaigns and especially the Airbus wake vortex and encounter data base can be essential for model validation. It is planned and certainly important to include this activity in the European Single European Sky ATM Research (SESAR).

There is interest in other nations to become involved in this initiative as it was expressed by Eduard Falkov, GosNII AS, Russia. This request was explicitly welcome by the RECAT initiative that is looking for participation and finally for acceptance by all stakeholders.

Concluding, I believe that the RECAT initiative has an excellent chance to redefine separation distances while achieving the same or even higher safety levels in combination with improvements in traffic flow. The Airbus proposal is a well suited methodology for that project. However, other contributors should be encouraged to contribute to this program as well.

6. Workshop Evaluation

Technical evaluation of the 1st WakeNet3-Europe Workshop

Bram ELSENAAR / NLR retired

Introduction

This workshop was the first that was organised by the European Thematic Network WakeNet3-Europe (see http://www.wn3e.eu).

The very first Wakenet Workshop was held 1-2 December 1998 in Chatillon, France whereas the last Workshop at the end of Wakenet2-Europe took place on November 29-30, 2005 at EUROCONTROL Experimental Centre in Bretigny. After an interim period coordinated by Eurocontrol, Wakenet3-Europe started on April 1st 2008 and is planned to run for a period of three years.

This present Workshop, with more than 100 participants, fitted very well in the tradition of the WakeNet Workshops with participation from Air Traffic Service Providers, Aircraft and Equipment Industry, Research Institutes and Universities. The larger part of the participants came from Europe (85), but there were also representatives from the US (13) , Russia (4), China (4) and Australia/Canada (3). The workshop was truly multidisciplinary with lively discussions between researchers, pilots, air traffic controllers and rule makers.

The workshop was very well organised at the premises of Thales Université. At the social evening at the end of the first day, the participants watched an equestrian show in the Versailles Castle, a bit cold but very fascinating. After that the 'performers' could be visited in the Royal Staples followed by an enjoyable evening with drinks and French cuisine. The program was a bit too tight and it is advised to limit the number of contributions for the next workshop. The report below will focus on the most important developments since the last Workshop, including some recommendations. Reference will be made to the contributions with [session no/presentation no].

Safe separation distances for the A-380

Airbus [3/4] reported on the tests that were used to derive safe separation distances for the A380. The A380 wake vortex flight test campaign represents an unprecedented effort with more than 300 flight tests hours, more than 600 Lidar runs and close to 1050 wake encounters. The LIDAR tests indicated higher vortex strength relative to the B747. The ICAO state letter has been based on these tests as well as on the encounters made at cruise. From the encounter tests for approach conditions it was concluded by Airbus that there should be no penalty for Heavies and Mediums. The work in the international working group will be continued. It still remains to be clarified why stronger vortices result in comparable encounter characteristics. AIRBUS also stated that encounter tests are still essential to prove safety for new or adapted rule making. Results will be made available to the community as soon as the International Working Group has concluded its activities.

Other safety cases

At the Brétigny Workshop safety cases have been discussed but none of these cases was at that time accepted by the authorities. Today, and in addition to the A380 wake vortex assessment, three wake vortex related safety cases have been accepted by the authorities: a rule change for a limited number of airports with CSPR in the US [3/5], a rule change for CDG in Paris, also related to CSPR [3/6] and a change for Kloten near Zürich related to interference with missed approaches [3/7]. In one other case [3/1] the safety arguments for adequate vertical separation in the Rotterdam/Schiphol area were documented. For the CREDOS project [3/3] the present status of the safety case was presented. These examples indicate an important step forward. In most of these cases actual measurements (LIDAR or encounter statistics) have been used for the safety case. Could they have been replaced by

models like those used for vortex characterization (see below) and encounters (like VESA)? It is recommended that, wherever possible, validation of these models will continue against the data used for the safety cases. As part of these efforts it is also essential that agreement is reached on a standard to measure the severity of wake encounters. Who will take the lead here?

Equipment

Presentations have been given on two new techniques to measure the vortices. The 1.5 μm Pulsed Fiber Lidar (ONERA et al; [2/4]) allows better onboard wake detection whereas the X-band RADAR system (Thales; [2/5]) provides an all-weather capability for ground measurements. Both developments are promising. However, there was no new information on the prospects of airborne vortex detection, a long lasting pilot's wish. THALES also presented the architecture of a Wake Vortex Advisory System as part of A-SMGCS (Advanced-Surface Movement Guidance and Control Systems) in use at airports. The presented architecture is very similar to what was developed by the European ATC-wake consortium [4/2] developed in the past as a European Informatics Project. This is another example how industry makes use of the research facilitated by the European Commission. In view of the larger involvement of industry, it is not unexpected that THALES stressed the need for standardization of Wake Vortex DataLink Services [1/4]. At the meeting the Russian representatives [4/3] stressed that FAA, Boeing, Eurocontrol and Airbus all promote 1090 ES radar replacement instead of full ADS-B (situational awareness not provided). If full ADS-B with VDL-4 is not accepted in airspace it will be much more difficult to implement onboard wake vortex safety systems (fusing ground and onboard information).

Modelling of wakes

Two models are in use in Europe to model the wake vortex characteristics from weather data and aircraft characteristics: the UCL VDM/PDM [2/1] and the DLR P2P [2/2] methods. Due to the efforts in the European Far-WAKE program, modelling the ground effects has been improved significantly. In the presentations the quality of each of these methods has been showed and one can argue that the point has been reached where the agreement with experimental data depends also on a (often unknown) quality of the experimental data. It is essential that the experimental accuracies are carefully assessed by those that generate the data: not only the value itself but also its accuracy is essential for further use of the data. Another source of uncertainty is the specification of (aircraft dependent) starting conditions for the wake [2/3]. This is also important to better understand differences in wake behaviour for almost identical (in terms of weight and span) aircrafts.

There are differences between the two methods and they should be clearly listed. Also, since both methods are (partly) based on experimental data, it is essential to describe precisely which data have been used to 'turn the knobs' of the models. These same data can not be used to measure the success of the models in predicting the wake characteristics. Before these models can be accepted in safety cases, further independent validation involving rule makers and safety experts is required. It is important to note here that the presently available models (P2P or PDM for wake characterisation, VESA for encounter severity) describe in principle the whole chain from wake generation till encounter for almost all weather conditions. Hence theoretically a wide variety of wake encounter conditions can be simulated in Monte-Carlo assessments, including very specific conditions in the 'tails' of the probability distributions.

Fundamental studies: university involvement

In 2008 the European FARWAKE program ended. In this program studies have been made on fundamental phenomena related to the stability of wake vortices. It was reported [2/8] that none of these has lead to an early destruction of wake vortices but some mechanisms have been discovered (notably perturbations at the symmetry plane) that might be successful. Research should continue.

The study of wakes in ground effect was another very important result of this program as mentioned above.

DLR continued its work on wake vortex advisory, risk analysis and encounter safety [3/2] and presented the maturity level of wake vortex observation and prediction tools [2/2]. The Technical University Braunschweig is working on means to enhance prediction quality by fusion of measured and modeled data [2/6].

Over the years wake vortex studies have become more and more applied, and there is a danger that Universities become less interested in wake vortex research. It is important to keep them 'in the loop' and the WakeNet consortium might think of means to achieve this e.g. by defining specific problems that require more fundamental studies. From this a possible new program can be defined. This doesn't have to be confined to flow physics (for wake modelling) and flight dynamics (for encounters). Other area's like the use of probabilistic theories in safety assessments, informatics (for handling the data streams from various sources) and man/machine interactions (pilots and ATC workload) are equally important.

SESAR

The SESAR program started its Development Phase for the period 2008 - 2013 under management of the SESAR JU (Joint Undertaking; see www.sesarju.eu). The fact that wake vortices are now embedded in the larger SESAR structure is very important [1/1;1/2]. SESAR is performance driven with 'Stakeholder Buy-in' and with the integration of the various systems as a key element. In the comparable US program NextGen a similar approach is followed [1/3]. The important thing to note here is the structured approach to the air transportation system (for Trajectory Based, Time Based or Performance Based Operations). This might result in an infrastructure that increases the chances to integrate in a cost effective way 'dynamic wake vortex separation' schemes.

One specific project is concerned with Recategorisation, a joint undertaking of Europe and the US [5/2]. Some preliminary and very promising results of step 1 (simple adaptation of ICAO rules based on a new MTOW-based classifications (more categories, new boundaries)) were presented by Airbus [5/1]. Are specific flight encounter tests essential to prove the validity of a rule change (as Airbus [3/4] suggested)? This will be costly. However, with the systematic collection of data from FDR's [2/7] one gets the flight tests 'for free'. This approach should be followed with more vigour in an integrated context (better quality FDR data, better aircraft data for the aerodynamic derivatives).

Final remarks

Since the last WakeNet workshop, now just over 3 years ago, important changes are to be noted. Wake vortex related studies have been more and more applied leading to the approval of some concepts by the authorities based on specified safety cases. Industry, notably THALES in Europe, is getting more involved on the system side. The integrated approach that SESAR provides opens new opportunities and Wakenet3-Europe can play an important role here to stimulate and facilitate the so needed multi-disciplinary approach. However, at the end, the final success can only be judged from the capacity improvements that are realised, while maintaining or even improving safety. Only then improved and advanced wake vortex separation schemes will be accepted by the air transportation community.

7. Workshop Participants

Group photo

Group photo, taken on January 8th, 2009

List of registered participants

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