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Coordination Area “Concepts” Yearly Report 3

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THAv	Thales Aerospace
DLR	Deutsches Zentrum für Luft- und Raumfahrt
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
DFS	DFS Deutsche Flugsicherung GmbH
ONERA	Office National d’Etudes et Recherches Aéropatiales
NERL	NATS En-Route Plc.
UCL	Université catholique de Louvain
TUB	Technische Universität Berlin
ECA	European Cockpit Association
TU-BS	Technische Universität Braunschweig
A-D	Airbus Operations GmbH

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Executive Summary

The Coordination Action WakeNet3-Europe promotes multidisciplinary exchange between scientific and operational specialists in the field of wake turbulence. It enables the development of a shared view on how to address capacity-related issues caused by wake turbulence. It was established to continue the Thematic Networks WakeNet and WakeNet2-Europe.

This report provides details of the key activities of Coordination Area 3 within the third reporting period of the WakeNet3-Europe project (March – December 2011) including details of conference and workshop involvement.

Task Group "RECAT" organised an international Specific Workshop on "Re-Categorization" at Technische Universität Berlin (Technical University Berlin) on June 20th and 21st, 2011. Participants from industry, airports, air navigation service providers, authorities, pilot associations and research discussed how to define safe vortex separations.

The workshop objectives were:

- Networking between experts from regulators, ANSPs, stakeholders (airlines, airports, pilots and aircraft manufacturers) and research,
- Briefing on RECAT Phase I,
- Discussion on methodologies, models and severity metrics for RECAT II and III,
- Identify research needs for RECAT Phase II and III.

This report aims to give an overview of the final specific workshop in the Concepts Coordination Area. In addition, details are provided of the benefits assessments for Frankfurt airport and Cargo Airports in the USA. The report follows on from the second WakeNet3 Coordination Area 3 report which provided an overview of the other specific workshops and was delivered to the European Commission in August 2011.

1 Terms of Reference, activities and developments

1.1. Terms of Reference

The Terms of Reference outlined in the WakeNet3-Europe Description of Work for coordination of the 'Concepts' area are as follows:

- Coordination of activities in the 'Concepts' area which include the tasks:
 - Operational Concepts
 - Recategorisation
 - Capacity Analysis
- To provide information exchange between those working on wake vortex concepts, which are in the pre-implementation stage and operational stakeholders. This facilitates that appropriate scientific support is given to such concepts.
- To facilitate information exchange between partners within the area of 'Concepts', as well as between the other co-ordination areas.
- To ensure links between all WakeNet3-Europe partners interested in the 'Concepts' area with particular focus on EUROCONTROL and its links to SESAR with its role of implementation of projects.
- Suggesting, organising and be open to suggestions of workshops on topics which help to forward progress in the 'Concepts' area if required.
- Co-ordinating and reviewing reports and position papers within the Concepts area.
- Maintaining a list of contacts applicable to the Concepts area.
- Contributing to the WakeNet3-Europe internet site.
- Co-ordinating annual progress reports.
- Reporting to the commission.

1.2. Activities, achievements and developments

The coordination area includes the following Task Groups:

- Task Group 3.1 “Operational Concepts”
- Task Group 3.2 “Recategorisation”
- Task Group 3.3 “Capacity Analysis”

Coordination activities

- Authored and coordinated input to the second Concepts annual report (D-3.02).
- Coordination Area 3 contribution to the first WN3E Research Needs Report (DI-3.01).
- NERL provided updated information about the UK Wake Encounter Working Group activities for inclusion in the latest Links Annual Report.
- Attendance and contribution to the EC Review and the 5th WN3E Partner meeting hosted by NERL in Southampton, May 2011.
- Attendance at the 6th WN3E Partner Meeting hosted by Airbus via teleconference in October 2011.

Meeting/conference participation

- Attended the third WakeNet3-Europe annual workshop hosted by NERL in Southampton in May 2011. TU-BS presented on investigation of emerging concepts and technologies to support optimised wake vortex separations
- Attendance and contribution to the Concepts specific workshop hosted by TUB in Berlin in June 2011. TUB produced the minutes which were distributed and all partners contributed to the discussion and the definition of research needs in this area.
- TUB and TUBS participated in the specific workshop on Operational Wake Vortex Models held by UCL in November 2011, contributed to the discussion and the definition of research needs in this area.

2 Task Group 3.2 Recategorisation

2.1. Introduction

ICAO's definition of aircraft categories (HEAVY, MEDIUM, LIGHT) and corresponding separation distances was initiated by the advent of large jet airplanes (747, L1011, and DC10) in the late sixties. Since then, national modifications of the rules were enforced in the US after incidents behind 757 (MTOW of the 757 is at the end of the MEDIUM category) and local modifications and interpretation of rules were introduced at certain congested airports. Additionally, a new category SUPER with increased separation was established by ICAO for the Airbus A380 as a generator.

Definition of wake turbulence separation minima was based on measurements and the interpretation of measured data - supported by models of wake vortex physics. Such an empirical approach has limitations but physics-based methodology for the definition of safe separations is lacking.

Obviously, current separation distances are safe. However, it is commonly agreed

- that they are over-conservative under numerous conditions, and
- that risk is not evenly spread over all aircraft pairs, i.e. a 20 tonne and a 100 tonne aircraft have the same separation following another 100 tonne aircraft, but the reaction of the smaller aircraft is certainly more severe, if an encounter occurs.

The idea of re-categorization was first discussed at a workshop on Wake Vortex Encounter Criteria that was held at TU Berlin in 2006. A few months later, EUROCONTROL and FAA took the initiative to form the RECAT project. RECAT has the objective to review the existing ICAO wake turbulence categories and associated category-wise separation minima for both departure and arrival operations and to define harmonized safe and adequate minimum wake turbulence separation standards. The task is split into three phases, see Fig. 1:

- Phase I: Optimised Categories (2011),
- Phase II: Static pair-wise separation (to be delivered to ICAO in late 2013),
- Phase III: Dynamic pair-wise separation (2018).

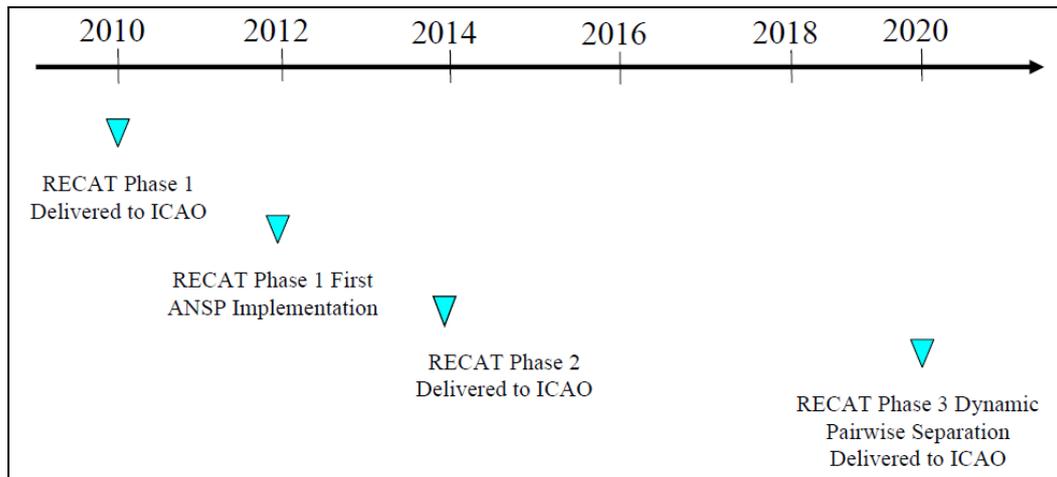


Fig. 1 Time schedule for RECAT (Source: FAA, Eurocontrol)

2.2. Specific Workshop on Recategorisation

Task Group “RECAT” organised an international Specific Workshop on "Recategorisation" at Technische Universität Berlin (Technical University Berlin) on June 20th and 21st, 2011. Participants from industry, airports, air navigation service providers, authorities, pilot associations and research discussed how to define safe vortex separations.

The workshop objectives were:

- Networking between experts from regulators, ANSPs, stakeholders (airlines, airports, pilots and aircraft manufacturers) and research,
- Briefing on RECAT Phase I,
- Discussion on methodologies, models and severity metrics for RECAT II and III,
- Identify research needs for RECAT Phase II and III.

This section is based on the presentations and discussions at the workshop, see [11], [12].

RECAT PHASE I: OPTIMISED CATEGORIES

The methodology, which RECAT Phase I proposes for definition of separation standards, uses wake strength (circulation) and rolling moment coefficient as the hazard metric. It takes into account wake decay models derived from joint FAA and EUROCONTROL measurements. The future RECAT Phases, especially Phase III, may require and could benefit from more sophisticated methodologies. Such a methodology must be transparent and validated.

It was emphasised that both the current ICAO and the RECAT categorization systems can coexist and that each ANSP can decide whether, when and how to implement the RECAT system depending on the individual benefits. RECAT provides a global solution to reduce wake turbulence separation minima, but local implementations may differ among airports.

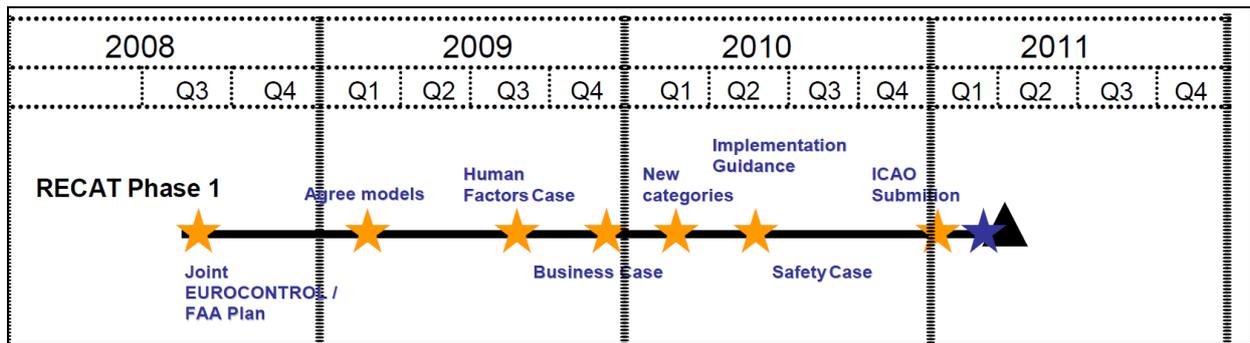


Fig. 2 Time Schedule RECAT Phase 1 (Source: FAA, Eurocontrol)

The methodology that has been developed for RECAT Phase I is described in [3]. It is applied to 61 aircraft that represent 85% of the traffic of the busiest EU and US airports. Wake strength (vortex circulation) is used as the primary severity metric and a linear decay line has been identified from wake vortex measurements at US and European airports. Additionally, the induced rolling moment coefficient is used as a severity metric to justify a separation reduction for follower aircraft that are at the top end of the ICAO HEAVY category. Assumptions are made on vortex decay function and approach speed profiles. Aircraft data are retrieved from public sources. RECAT Phase I proposes a 6 category system that is based on wing span as primary parameter and on maximum takeoff weight and additional aircraft characteristics as secondary parameters, see Fig. 3 and Fig. 4. The 6 x 6 separation matrix that is larger than the current 4 x 4 ICAO separation matrix seems no issue for air traffic controllers.

For the RECAT Phase I system an average capacity gain of 4% (Europe) and 7% (US) is estimated in comparison to the current ICAO system. However, this benefit analysis does not consider individual procedures (as used by ANSP at highly constrained airports) that differ from the ICAO system.

		Follower					
		A	B	C	D	E	F
Leader	A		5.0NM	6.0NM	7.0NM	7.0NM	8.0NM
	B		3.0NM	4.0NM	5.0NM	5.0NM	7.0NM
	C				3.5NM	3.5NM	6.0NM
	D						5.0NM
	E						4.0NM
	F						

Fig. 3 RECAT Phase 1 Separation Table (Source: FAA, Eurocontrol)

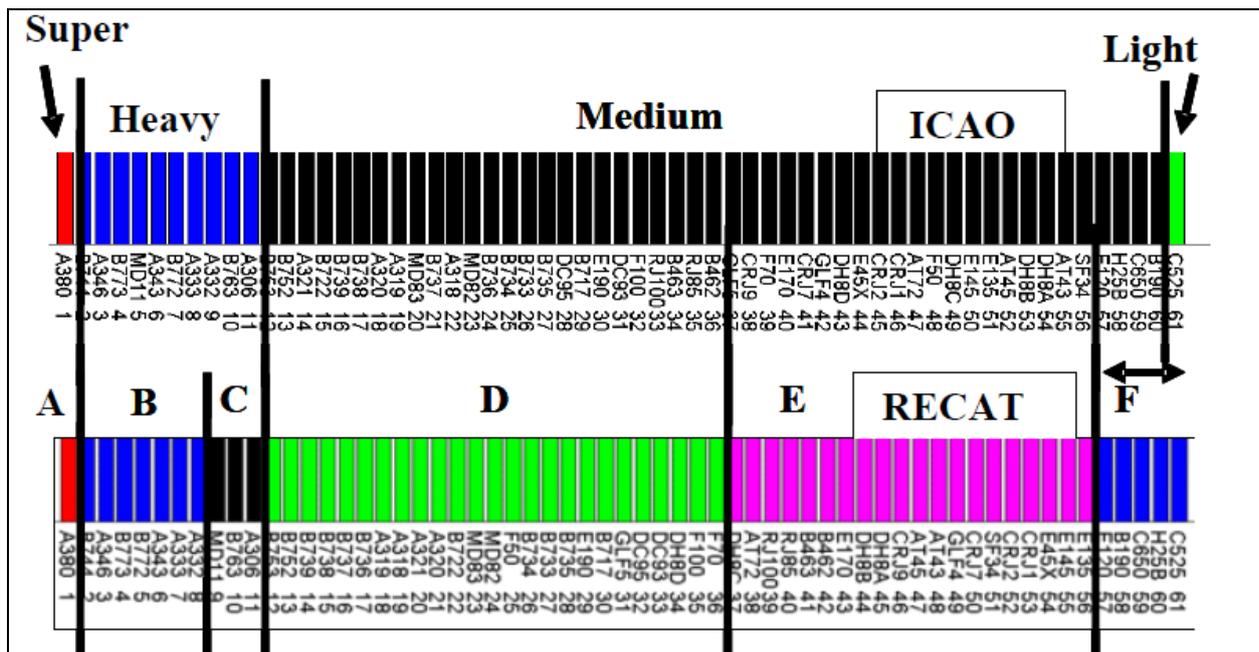


Fig. 4 Comparison of: RECAT and ICAO Categories (Source: FAA, Eurocontrol)

It is essential to note, that ICAO does not define the implementation of the systems if the proposal is accepted. For example, if an airport has more vortex encounters at glideslope/localizer intercept due to a local procedure (e.g. MEDIUM aircraft turning on lower behind a HEAVY aircraft) then the local ANSP has to determine whether the procedure is acceptable or whether it should be changed.

The methods developed under RECAT Phase I (as for the other phases) need to be open as well as guidance on its application needs to be available so that an ANSP can use the methods to assess the operational performance and the effect of local procedures and new concepts.

In 2011, Eurocontrol and FAA published the following (non-public) documents for RECAT Phase I:

- RECAT Preliminary Safety Case [1];
- RECAT Safety Assessment report [2];
- RECAT Methodology report [3];
- RECAT report extending RECAT to all ICAO aircraft types [4]; and
- RECAT report on Wake Turbulence incidents [5].

They have been reviewed by stakeholders in the ICAO Wake Turbulence Study Group. The original objective of presenting the results to the ICAO Air Navigation Commission for acceptance has been postponed.

For the US, FAA intends to introduce all solutions that are developed in RECAT into NextGen. Other ANSPs have shown interest to apply RECAT Phase I as well. Eurocontrol is studying an amendment, called "RECAT B" that addresses Category D aircraft. The study shows a higher potential capacity benefit for European airports Paris, London and Frankfurt (approximately 3% more slots compared to 1.5%), see [15].

RECAT PHASE II: LEADER/FOLLOWER STATIC PAIR-WISE SEPARATION

The tentative schedule for RECAT Phase II includes delivery of the recommendations to ICAO by late 2014 and first implementations in 2015, see Fig. 2. FAA and Eurocontrol intend to use the same methodology for RECAT Phase II as for Phase I. The goal is to implement static pair-wise separation minima that are independent of fleet mix. In contrast to the 6 category system of RECAT Phase I, the RECAT Phase II system can be optimized specifically to any individual airport in order to achieve further capacity gains. The methodology for Phase II shall use metrics and methods from Phase I, possibly refined and enhanced to include manufacturer provided aircraft performance data and recommendations from stakeholder. Separations for all potential aircraft pairs (not only 61) will be defined. Assuming approximately 1200 x 1200 potential aircraft pairings, 25 aircraft types may represent 99% of an airport's traffic mix. So a 25 x 25 matrix would be sufficient in that case.

The goal of RECAT Phase II is to provide available data for the ANSPs to decide about implementation of the system (as it is for RECAT Phase I), but not to give specifics on the implementation e.g. for adjacent airports. Each ANSP is free when and how to implement a RECAT Phase II system as both RECAT systems and the current ICAO rules can co-exist.

RECAT PHASE III: DYNAMIC PAIR-WISE SEPARATION

The overall objective of RECAT Phase III is dynamic pair-wise separation. A detailed project schedule or methodology does not exist yet. However, some elements of RECAT Phase III are already underway, such as CREDOS, Heathrow TBS, WTMA-S. At later stages RECAT Phase III will include wind dependent and vortex decay driven solutions for which ground-based and airborne weather sensors and wake monitoring systems are needed. There are also plans to apply RECAT Phase III to en-route operations.

ENROUTE WAKE VORTEX SEPARATIONS

The ICAO wake vortex study group is currently reviewing whether there is a need to consider wake vortex separations for en-route operation. So, there could be a solution for the en-route phase that is independent from RECAT.

SESAR JOINT UNDERTAKING P6.8.1

The SESAR JU project 6.8.1 intends to develop solutions for a flexible use of wake turbulence separations. The project consists of three steps:

1. Time-based separations, TBS (2013),
2. Weather dependent separations accounting for transport of vortices (2015),
3. Dynamic pair wise separations (2017).

Implementation of concepts is not part of SESAR since it is a R&D project. Steps 1 and 2 shall ideally be verified within the timeframe of the project. Step 3 of the project is closely linked to RECAT Phase III but verification for step 3 will not be achieved within the duration of SESAR.

HELICOPTER WAKE TURBULENCE SEPARATION AND OPERATIONS AS FOLLOWER

Regarding the application of wake turbulence separation (WTS) minima with respect to helicopter operations, attention was brought towards the ambiguity of the rules given in ICAO Annex 14 and ICAO P-ATM. The practices described there are inconclusive. The issue is the separation that a Final Approach and Takeoff Area (FATO) should have to a runway to allow independent operations of helicopters, e.g. can it be less than 760m? For runways and FATO with less than 760m separation, there could be an agreement at ICAO level to include crosswind in the operational practice. In the absence of the refined separation minima, helicopters departing from helipads spaced less than 760m from the RWY(s), where fixed-wing aircraft are operating, are forced to 3 (4) minutes separation following the departure of the heavier fixed-wing aircraft. Such a situation at the regulatory level, leads to heavily hampering the helicopter operators efficiency and adding significantly to the ATCO workload.

It was also emphasised that scientific studies about wake turbulence effects on helicopters are needed.

DISCUSSION ON MODELS, METHODS AND METRICS FOR RECAT

The models that are used for RECAT Phase I are relatively simple, transparent and easy to understand. However, they only partially address the complete process chain.

Over the last years the available knowledge in wake vortex physics has improved 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.

State-of-the-art is that the complete physical process (see [Fig. 5](#)) can be modelled from wake creation to encounter severity and encounter frequency. Before such a model and its sub-models can be used for vortex encounter risk assessment, a validation is necessary and general acceptance of models and methodology has to be achieved. Validation must be based on measured data. As the complete wake encounter process model is highly complex and the acquisition of data is expensive and time-consuming, the proof of validity is a challenge. However, similar challenges have been mastered in other certification tasks (e.g. certification of automatic landing systems) and the procedures used there may be adaptable.

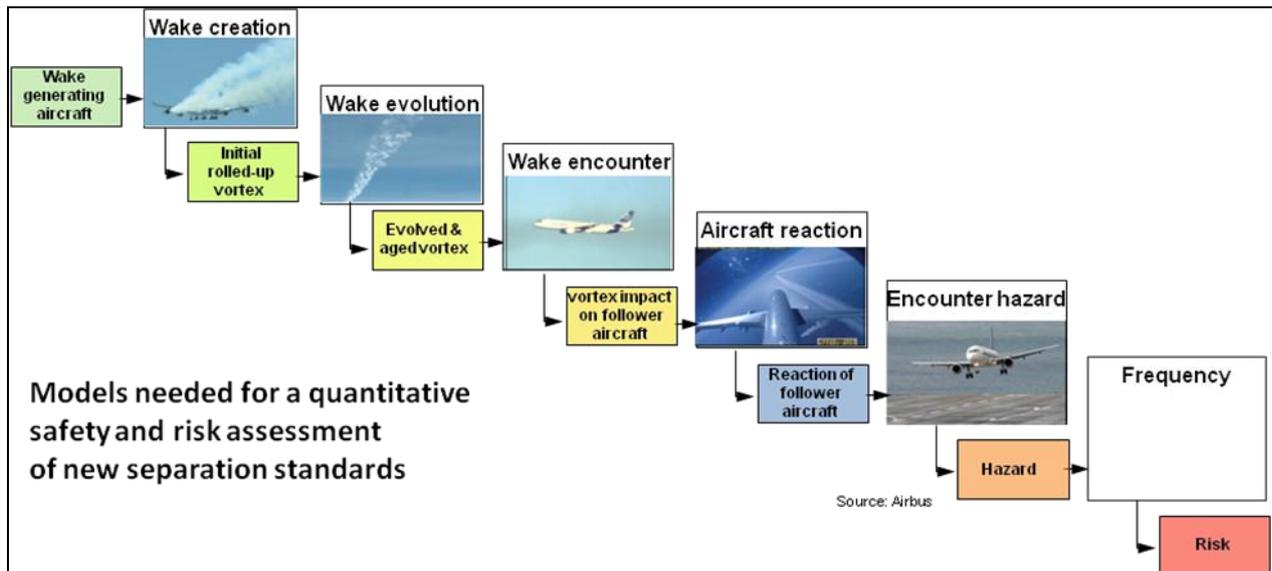


Fig. 5 Process chain from wake generation to encounter risk (Source Airbus, TU Berlin)

Important requirements for safety assessment models are that they are “adequate for the task” and that they represent the “simplest possible model that satisfies the requirement”. In addition, they have to be documented, reviewed and then accepted by authorities. Everything has to be transparent and understandable for all stakeholders, especially regulators as they can only certify if they have trust that the whole process is absolutely correct.

A list of parameters that affect the vortex encounter assessment was proposed for consideration in RECAT phase II and III methodologies. The effects of these parameters were discussed and potential metrics for RECAT Phase II were proposed.

Sensitivity studies on the impact of core radius r_c (or r_c/b ratio) and wing span ratio (b_f/b_f) on vortex-induced roll acceleration showed a significant impact. This raises the question whether such effects should be considered for the RECAT Phase II and III methodology.

NLR is proposing equivalent roll rate (ERR) as a suitable vortex encounter severity metric as it does not require aircraft characteristics other than wing geometry (assuming lift distribution and an approximation of lift gradient). ERR is the roll rate in the equilibrium situation where WV induced rolling moment and aircraft roll rate induced rolling moment are in balance. The advantage is that no roll inertia data is required, as it is necessary to compute the roll acceleration and no rolling moment derivative for aileron or roll spoiler deflections as required for the commonly used roll control ratio (RCR).

But not only roll dynamics parameters describe wake vortex hazards. Simulator studies showed that also the sink rate is important for large aircraft in an encounter.

NATS recommends focusing on “hot spots” for improvements of models and methods for wake separation reduction. In case of Heathrow hot spots are at the threshold and the localizer intercept. Validated models to assess the impact of wake encounter (taking the actual intercept path into account)

are required and RECAT encounter upsets do not reflect those documented in current wake encounter reports.

2.3. Research needs for a wake vortex dynamic separation system

This section summarizes the discussion on research needs for a wake vortex dynamic separation system (RECAT Phase III). It is based on inputs of the workshop participants. More details can be found in [11].

Progress in rule making for wake vortex separation standards offers capacity benefits. This progress can significantly be supported by continuing the international cooperation between industry, airports, air navigation service providers, authorities, pilot associations and research. The international network of experts from regulators, ANSPs, stakeholders (airlines, airports, pilots and aircraft manufacturers) and research that is sponsored by WakeNet3 Europe, WakeNet US and WakeNet Global has an important role in distributing the required knowledge.

1. Definition for an operational concept for a dynamic wake vortex separation system

The system shall provide information to avoid significant wake encounters in a fashion that changes depending on weather and operational factors. This requires research, development and standardisation activities that must be addressed by system developers, users, and regulators in the following areas:

- Operational concepts
- System concepts (sensors, airborne and ground components etc.)
- Ground-based systems (wake vortex and meteorological sensors etc)
- Airborne systems (wake vortex sensor, crew interface)

A key component of future concepts is the acquisition of meteorological data. Improved standardisation of the capabilities of meteorological sensors (methodology, quantities, resolution, accuracy etc.) is needed.

2. Validation of large and complex encounter models for risk assessment

The methodology of RECAT Phase I (and probably of Phase II) uses simple models for the definition of separation standards. That is due to the requirement that those models have to be accepted as state-of-the-art, they have to be public, understandable and available. As the state-of-the-art has improved significantly over the last years, the advantage should be investigated i) of using more sophisticated models with higher fidelity and ii) of including models for manual or automatic control of the airplane as well as models for severity assessment, which are not included yet. Enhanced models offer higher accuracy and allow reducing safety margins, whereas simple models need to deliver

conservative results because of inherent model uncertainties. Those margins limit potential capacity gains.

The RECAT Phase I methodology models a limited part of the complete physical process from vortex generation to encounter hazard, thus it is not complete. Among others, a model of the effect of manual or automatic aircraft control is missing as well as an assessment of the encounter severity.

RECAT Phase III (dynamic pair-wise separation) requires more models and methods. Such models and the necessary expertise are available and offer higher prediction accuracy. Methodologies like WakeScene, VESA, WAVIR, ASAT that use large and complex models for safety and risk assessments of regulations on wake vortex separations are in development.

However, the models need to be validated against RECAT Phase III requirements, which are not defined yet. Requirements could be for example: they have to address the world's fleet of 9000 aircraft, they need to be conservative, they must be suited for fast-time simulations, they have to be transparent and understandable, and so on. RECAT Phase III requires the models in 2017. To be ready in time, development and validation of such models has to start now. This implies that funding has to be provided now.

3. Metrics and Criteria for severity assessment

Criteria for wake encounter severity assessment have to be derived with involvement of relevant stakeholders (authorities, operational, etc). It has to be assured that they are commonly accepted by stakeholders. This includes analyzing the data and results available worldwide so far and conducting additional human-in-the-loop tests under conditions and with parameters that have been agreed upon beforehand.

4. Wake vortex encounters in cruise are rare, however their occurrence is expected to rise with increasing traffic and their severity is expected to increase as aircraft weight differences are becoming larger (VLJs and HEAVIES above 500 to MTOW). Currently, there are no wake vortex separations defined for cruise flight. It has to be investigated whether this is still adequate. To do so, measurements of wake vortex characteristics and evolution (decay and transport) at high altitudes should be performed for model validation. Wake vortex encounters in cruise should be investigated in flight tests and in flight simulators taking the impact of simulator limitations into account. Wake vortex transport and decay models would require knowledge of meteorological conditions (stratification level, turbulence).
5. Wake vortex encounters (WVEs) in flight simulators: To develop models for pilot severity assessments, a significant number of vortex encounters have to be recorded and rated by pilots. Analysis of in-flight WVEs during routine airline operations is extremely costly. WVEs in flight tests have the disadvantage that the pilots are prepared for an encounter. The only alternatives are certified full-flight simulators with WVE capabilities, in which unexpected encounters during routine

pilot training should be performed. Simulated aircraft reactions should be validated against flight test results and the impact of flight simulator limitations on pilot ratings should be investigated.

6. Wake vortex awareness and avoidance techniques:

The improved understanding of encounter physics and operational implications should be used to enhance regular airline pilot (and air traffic controller) training to address wake vortex awareness and avoidance techniques.

7. Helicopter wake vortices

- Safety issues with helicopter wake turbulence, with helicopters as vortex generators should be addressed. Helicopter wake vortex has caused 6 accidents in the past 5 years in UK and Europe – currently there is limited guidance on wake vortex avoidance distances especially for light aircraft following helicopters.
- There is an urgent operational need to quantify the distances and/or time values that prescribe the minima allowing helicopter operations (IFR landings and all take-offs) to be conducted independently and/or simultaneously with heavier fixed wing aircraft operations on the same and/or proximate runways. A 3 to 4 minutes separation is required for helicopter that is departing from a helipad spaced less than 760m from a RWYs after a heavier fixed-wing aircraft depending on the airport layout.
- Experience, so far, indicates that helicopters are more "resistant" to wake vortex encounters than fixed wing aircraft. This is nowhere quantified in a manner that would enable development and/or refinement of the existing ICAO wake turbulence separation minima in regard to helicopters as followers. RECAT effort should be extended to cover this missing facet of the ATM procedures related to wake turbulence.

8. Wind turbine wake turbulence

- Guidance for wind turbine wake turbulence is missing as it is a relatively new topic and its effects on aviation should be determined, particularly when sited in the vicinity of runways.

ATM programmes like SESAR (EC) and NextGen (FAA) should provide the required resources. A harmonized concept and roadmap that links RECAT and SESAR is needed to achieve a standard safety methodology.

Requirements on models, methodologies and data for RECAT Phase II and III need to be formulated in order to guarantee that models and methodologies, which are fit for purpose, are available when needed. As the time that is needed for research can be three years or more, it is essential to start that process early enough.

3 Task Group 3.3 Capacity Analysis

3.1. Airport capacity effects of RECAT

The capacity effect of reduced separations provided by RECAT Phase I has been assessed by FAA and Eurocontrol studies separately for major US and European airports. This has been done using analytical estimations as well as fast-time simulations and the average capacity increase value of 4% (Europe) to 7% (USA) has been estimated. However, it is important to assess realistic benefit estimation for individual implementation cases taking into account local procedures, dependencies and constraints. This has been done in the scope of a study for Frankfurt airport (FRA) considering the detailed procedures and the new 4-runway layout [12]. Another study carried out by MITRE CAASD at FAA request estimated potential RECAT Phase I benefits for cargo airports with a high proportion of heavy operations [13]. The results of these studies will be presented in the following.

3.1.1. RECAT Capacity Analysis for Frankfurt International Airport

Since October 2011, the 4th runway of Frankfurt airport (runway north-west, 25R/07L) is operational and allows independent parallel approach operations for 25R/25L and the opposite direction; the centre runway (25C/07C) is mainly used for departures as shown in Fig. 6. Consequently the use of the new runway leads to a major capacity increase that is sufficient to cover the current demand (especially for arrivals (ARR)). However, there is still need to increase departure (DEP) capacity as there are ARR/DEP dependencies resulting in the request for arrival gaps which has an influence on the overall capacity.

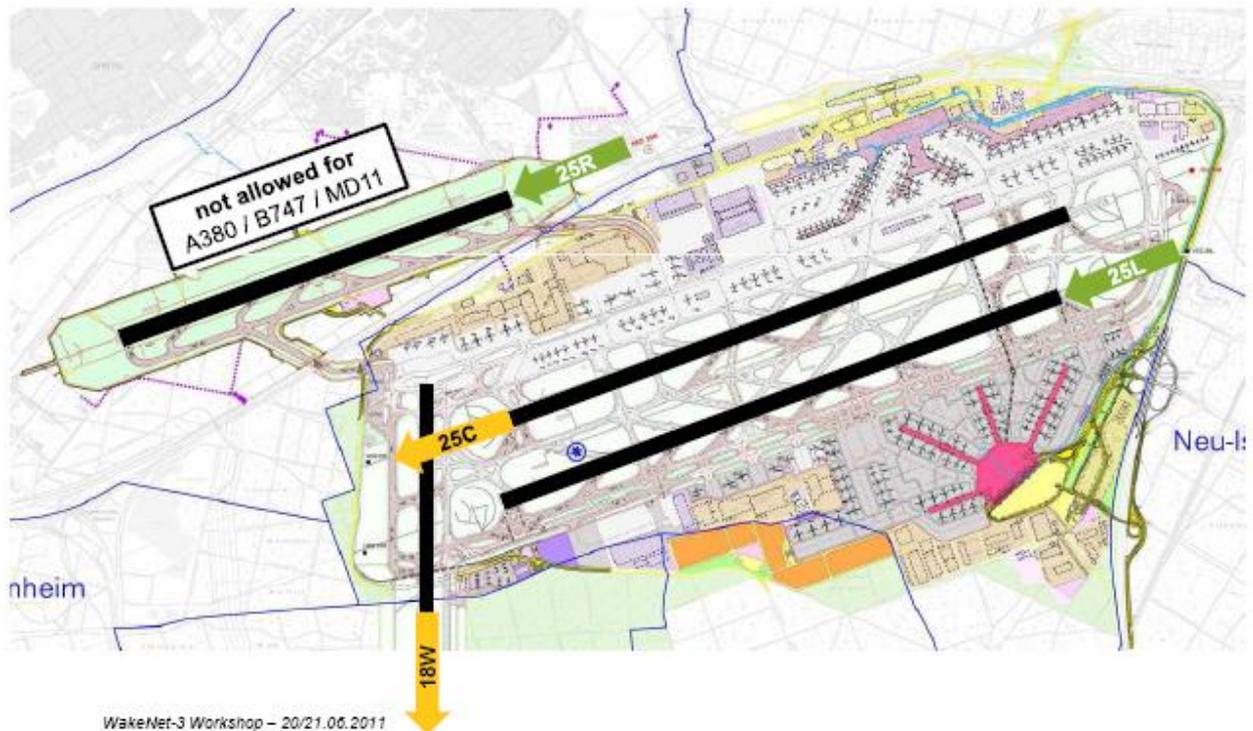


Fig. 6 Current runway structure in FRA [12]

In general, there are three major points that need to be taken into account as local parameters when estimating capacity impact of the separation reduction provided by RECAT:

- the local traffic mix
- arrival/departure procedures and dependencies
- influence of the airport-specific runway occupancy time (ROT)

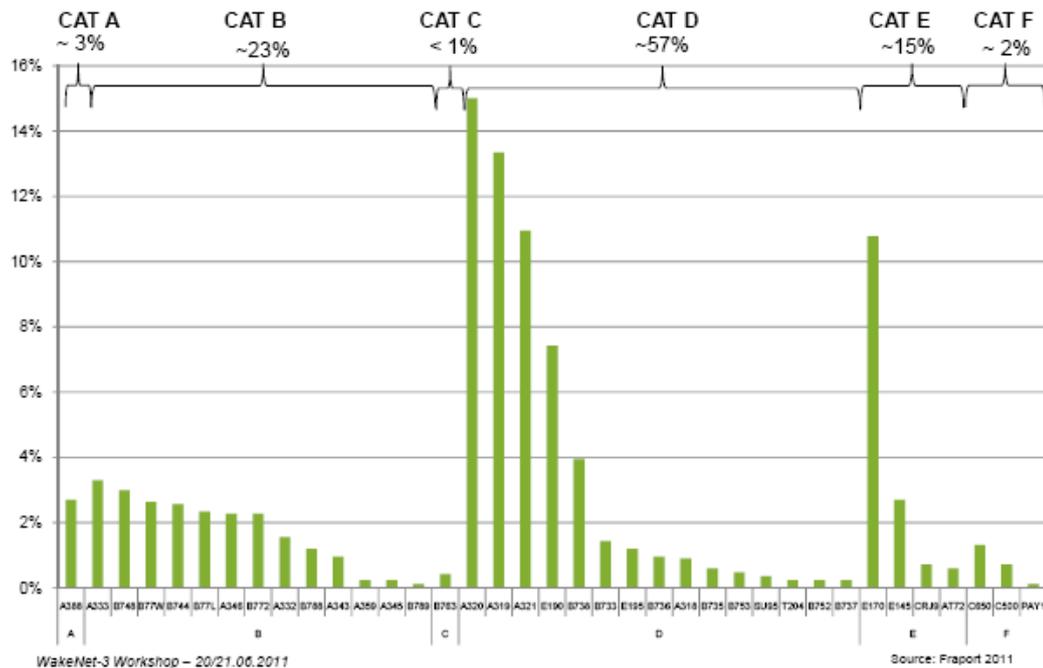


Fig. 7 Predicted aircraft distribution 2015 at FRA [12]

The study for Frankfurt airport addresses these issues as follows:

The traffic mix dependency is calculated analytically based on the actual and forecasted (2015, see Fig. 7) traffic mix related to RECAT Phase I categories. The analytical probability of separation reduction is estimated to be ~9% for current traffic mix and ~7% in the future. This would result in a slight reduction of the average separation and therefore only in a minor capacity increase.

Dependencies between arrivals and departures are accounted for by adding an interarrival buffer of 1 NM to the average separation within the analytical calculations.

Simulations of different baseline and RECAT implementation scenarios indicate benefits for the RECAT scenario with the 2015 traffic mix mainly for arrival capacity that could be explained by a higher arrival capacity and in consequence a higher level of efficiency of RECAT as well as a rising amount of CAT B aircraft. The impact of runway occupancy time (ROT) as well as the ATC controller acceptance for RECAT cannot be estimated by simple analytical models. However, ROT can be set as a limiting factor when estimating capacity effects by fast time simulations. Analysis of 85000 data sets for arrivals focusing on the calculation of ROT in FRA has indicated that the actual ROT is longer than required for maintaining RECAT separation minima in a significant number of cases (see as example Fig. 8). For CAT B aircraft, 75 seconds would be required between two consecutive aircraft, for CAT C it would be 60 seconds; these values are exceeded by 11% and 25% respectively. As a consequence, the real ROT will have to serve as the limitation factor of minimum separation, meaning that the RECAT Phase I minimum separation would not be fully applicable to avoid a significant increase of go-around rates (which would also have an adverse effect on capacity).

Due to the following reasons, Fraport, DFS as German ATC and DLH as main airline stakeholder in Frankfurt concluded not to implement RECAT Phase I at FRA at the moment:

- the available ARR capacity at FRA (with opening 4th runway),
- the low estimated capacity gain of RECAT for FRA,
- the necessary effort for ATC-controllers
- and the necessary ROT for CAT B/C aircraft.

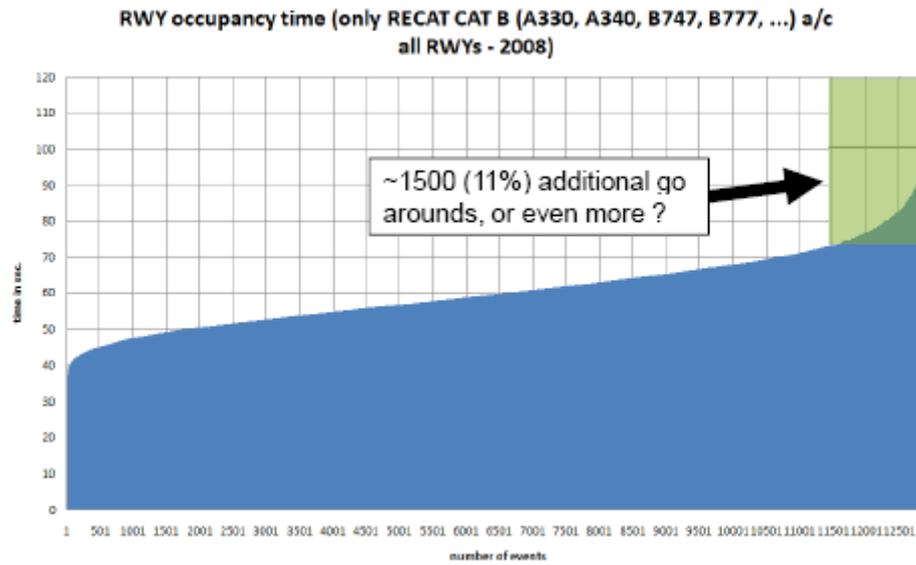


Fig. 8 ROT data analysis, sample for RECAT CAT B aircraft [12]

3.1.2. RECAT Phase I Benefit Analysis for Cargo Airports in the US

As traffic mix is one of the major impact factors on the capacity benefit it is expected that airports with a high proportion of heavy and Boeing 757 operations will see high benefit from the separation reductions provided by RECAT Phase I for these aircraft categories. Cargo airports usually operate in these conditions during off-peak and night hours so a capacity benefit analysis has been carried out for the following five US airports to examine this assumption:

- Memphis International Airport MEM (FedEx SuperHub)
- Ted Stevens Anchorage International Airport ANC
- Louisville International Airport SDF (UPS Worldport)
- Miami International Airport MIA
- Indianapolis International Airport IND

The method used in this study was fast-time simulation using the *runwaySimulator* developed by MITRE [14]. Different operational scenarios were assumed taking into account three priority options:

- Arrival Priority AP
- No Priority NP

- Departure Priority DP

The capacity benefits have been assessed for three nominal visual conditions: Instrument, Marginal and Visual Meteorological Conditions (IMC, MMC, VMC).

Three different weightings have been applied to link the benefits to impact on:

- Peak Hour Operations
- Cargo Tonnage
- Peak Time Constrained

Capacity improvements assigned to weather, priority mode and weighting are presented in Fig. 9, showing an average for all five assessed airports. Benefits are identified for all priorities in IMC and for departure priorities in all-weather which means that even in MMC and VMC wake delays behind departures will be reduced under RECAT compared to today's operations. When looking at individual airports, benefit values vary but are consistent with the average benefit.

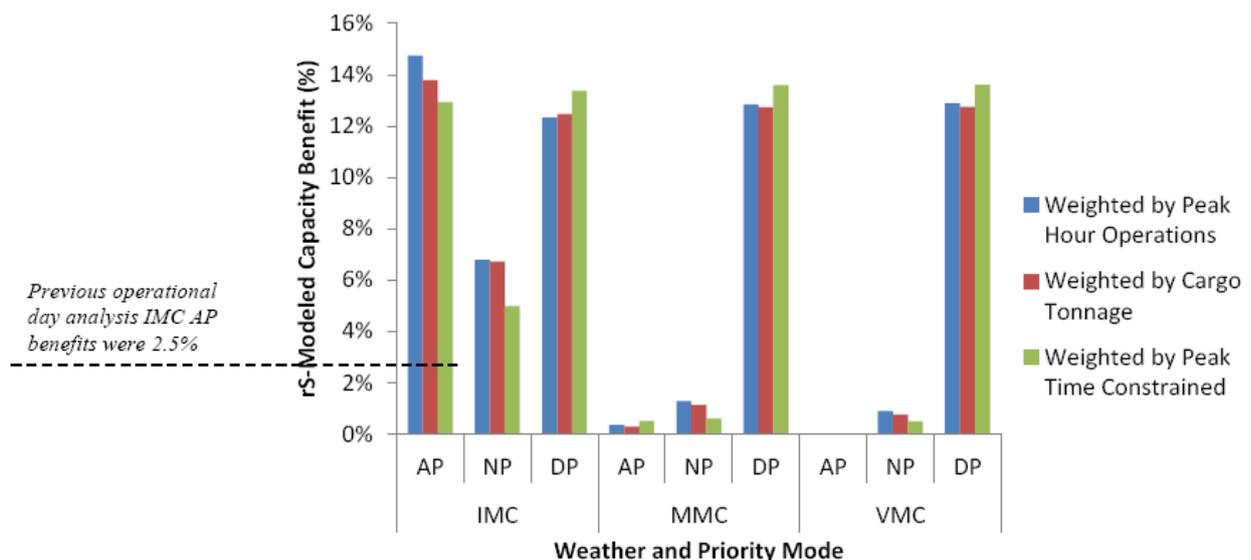


Fig. 9 Average capacity improvements by weather and priority mode [13]

Highest capacity increases were identified at MEM and SDF which is highly connected to the traffic mix at these airports. The trend of higher benefits driven by fleet mixes dominated by heavy and B757 aircraft is confirmed by further analysis results shown in Fig. 10. Cargo airports with traffic mixes comparable to those of MEM and SDF would profit significantly from separation reductions and should be taken into consideration for a staged implementation of RECAT.

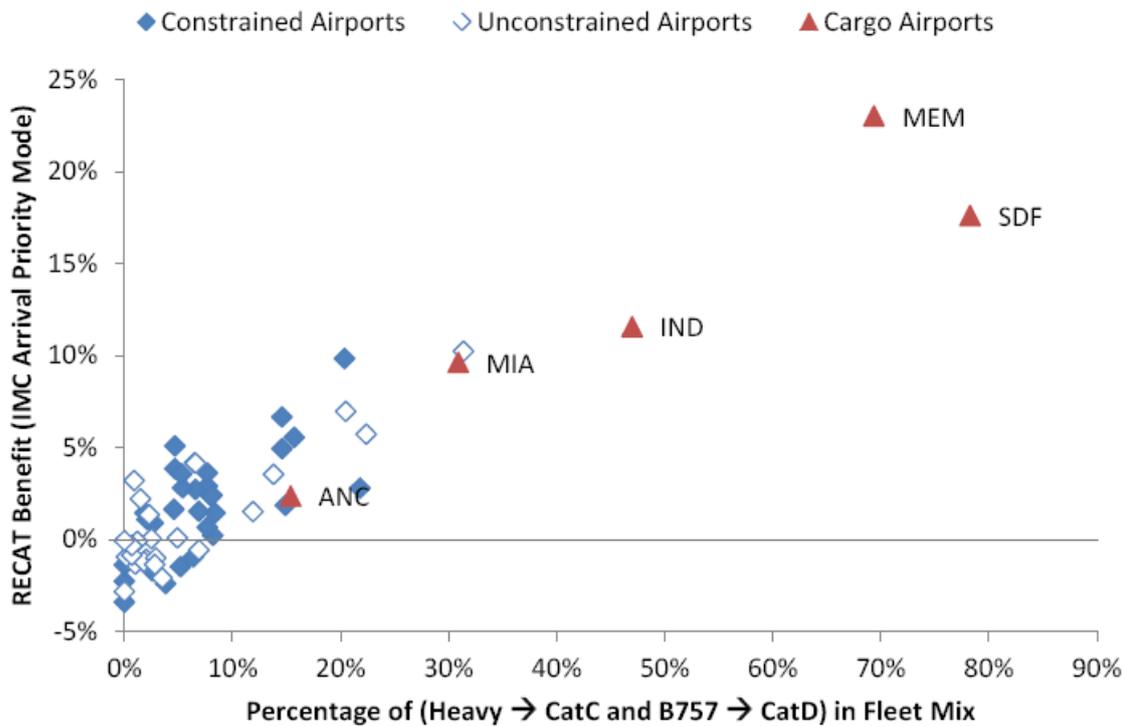


Fig. 10 RECAT benefits over lower heavy/B757 operations [13]

3.2. Research needs for capacity analysis of RECAT

From the study of capacity effects of RECAT for a local application at Frankfurt airport following conclusions can be drawn for the further capacity assessments:

- The influence of arrival and departure capacity has to be carefully accounted for. This recommendation is particularly valid for airports with complex runway and procedure designs and dependent runways.
- The impact and limitation posed by the ROT has to be included in future analyses. For further assessments of RECAT gains ROT should be regarded as the lower boundary.
- For realistic benefits estimation for specific airports the baseline should be real data and local circumstances which can lead to complex dependencies but also to more realistic results.

4 References

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