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Coordination Area “Concepts” Yearly Report 2

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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 Aéronautiques
 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 over the last 18 months including details of conference and workshop involvement.

The first WakeNet3-Europe Concepts Workshop was held at Heathrow in February 2011. This two day event incorporated the specific workshops for the Task Groups “Operational Concepts” and “Capacity Analysis”.

The objective of the workshop was to review the current state of a number of operational concepts which are on-going in the wake turbulence community. The workshop acted as a forum for each of the concepts to be discussed with operational stakeholders from across Europe. The emphasis of the discussion was placed on the future research needs to allow for successful implementation of the concept into the operational environment.

This report aims to give an overview of the concepts and capacity analysis methodologies discussed at the workshop including latest project developments and research needs for the future. The report follows on from the first WakeNet3 Coordination Area 3 report which was delivered to the European Commission in May 2010.

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

- Coordinated input to first Concepts annual report (D-3.01).
- First and second versions of the Concepts Bulletin distributed to wider operational community.
- Attendance at the 4th WN3E Partner Meeting hosted by Airbus in Toulouse, October 2010.
- Coordination Area 3 contribution to the first WN3E Research Needs Report (DI-3.01).

- 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.
- Input to the second Safety annual report (D2.02).

Meeting/conference participation

- NERL presented on the WakeNet3-Europe project and Wake Vortex Reporting and Category Harmonisation in the UK at WakeNet-USA (March 2010).
- Attended the second WakeNet3-Europe annual workshop hosted by Airbus in Toulouse in June 2010.
- NERL attendance and presentation on “Wake Vortex Incident Analysis in the UK” at the Safety specific workshop hosted by NLR in Amsterdam in November 2010.
- NERL gave a presentation on the WakeNet3-Europe project, key deliverables and upcoming events at the UK Wake Encounter Working Group in November 2010.
- NERL hosted the Operational Concepts specific workshop (DI-3.04) on the 8th February 2011 at Heathrow. The workshop was attended by 24 delegates with the emphasis of the discussion on the research needs to ensure the implementation of concepts into the operational environment.
- TU-BS hosted the Capacity Analysis specific workshop (DI-3.06) on the 9th February 2011 at Heathrow. The workshop was attended by 22 delegates and focused on the presentation of capacity assessment methods and results as well as the discussion of associated research needs and required capacity benefits to ensure successful concept implementation.
- Attended the second Wakenet3-Europe annual workshop hosted by Airbus in Toulouse in June 2010. NERL presented on “Wake Vortex Reporting and Category Harmonisation”.
- 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.

2 Task Group 3.1 Operational Concepts

2.1. Terms of Reference

The Terms of Reference outlined in the Description of Work for Task Group 3.1 focussed on 'Operational Concepts' are as follows:

- 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 keep abreast of developments within the area of operational concepts.
- Contributing to the Terms of Reference of the Coordination Area.
- Promoting communication between the partners and interest groups.
- Organising a specific workshop.
- Contributing to Wakenet3-Europe reports.
- Contributing to the WakeNet3-Europe internet site.
- Reporting to the commission.

2.2. Specific Workshop – Operational Concepts

A specific workshop for the Task Group “Operational Concepts” was held on 8th February 2011 at NATS Heathrow House, London as part of the WakeNet-3 Europe Concepts Workshop.

The objective of the workshop was to review the current state of a number of operational concepts which are on-going in the wake turbulence community. After each concept was presented, the workshop acted as a forum for the concept to be discussed with operational stakeholders from across Europe. The emphasis of the discussion was placed on the future research needs to allow for successful implementation of the concept into the operational environment. The contents of these discussions will be incorporated into the Research Needs report, a key WakeNet3 project deliverable for the EC.

The following sections give a high level overview of the concepts presented at the workshop together with project updates and possible future research needs. The concepts discussed in this document are as follows:

- Procedural Time-Based Separation
- CROPS
- SESAR WP6.8.1
- Green-Wake
- SESAR WP9.11 & WP9.30

- SESAR WP12.2.2

2.2.1 Procedural Time-Based Separation

The NATS Procedural Time-Based Separation project aims to improve the landing rate resilience on approach in strong headwind conditions. The objective of the project is to reduce wake separation by 0.5Nm dependent on meteorological conditions likely to be in the region of a 10-15kts headwind. A crosswind component is also being considered as part of the concept. The meteorological measurement options for the project in the short term are as follows:

- Runway Anemometer.
- Wind Profiling LIDAR.
- Mode S derived wind data (used to develop a statistical forecast / monitor).

The initial benefit analysis at London Heathrow shows up to 12% overall annual delay recovery and a landing rate improvement of approximately 3 per hour compared to the current Distance Based Separation (DBS) operational baseline.

The key wake encounter safety analysis activities focus on wake behaviour at low altitude (IGE/NGE) and established on the glide path (OGE). A LIDAR measurement campaign has been ongoing at London Heathrow to measure the vortex behaviour IGE/NGE and OGE. IGE/NGE has been analysed in terms of circulation strength over time and the probability of wake persistence at separation minima. Figure 1 shows the persistence probability in a >10kt surface headwind is always significantly below <5kt headwind under current day DBS rules. It suggests that, as indicated in the initial LIDAR analysis, vortices do appear to decay at a faster rate in stronger headwind conditions.

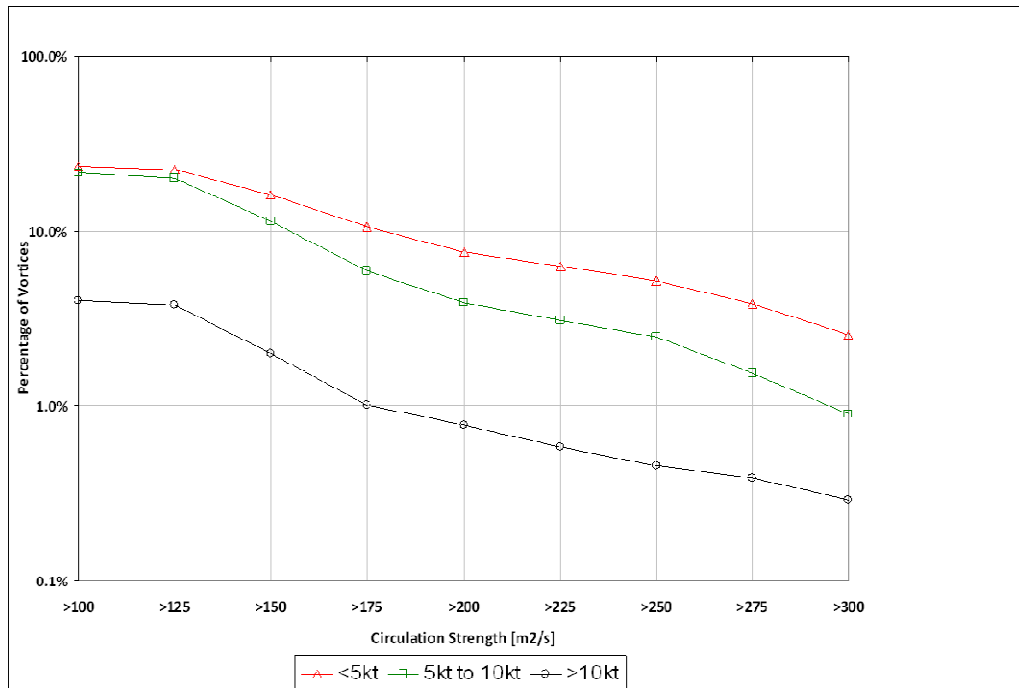


Figure 1: DBS in different surface headwinds, Heavy leader – Heavy follower

Project Status in February 2011: The Feasibility and Options stage of the project will be completed by March 2011 and the current activities include:

- Concept Definition
- Evaluation of the meteorological capability
- Initial assessment of wake risk against safety arguments
- Business benefit

Research Needs

- Data sharing across different research organisations.
- Improved understanding of wake encounter risk in relation to operational practices and procedures.
- Target level of safety.
- Improved airport instrumentation (MET) and aircraft data collection.
- Validated wake models sufficient for regulator review.
- Continued wake vortex data collection.

2.2.2 CROPS

CROPS is a EUROCONTROL implementation project focused on runway use optimisation by conditional reduction of separations for departures and/or arrivals in crosswind conditions. The concept was developed mainly based on the CREDOS concept, but also with some elements of the ATC-WAKE concept of operations (for arrivals) and it involves a procedural change only with limited system support.

The main objectives of the project are to facilitate a local implementation of the CROPS concept; provide immediate local benefits in terms of increased runway throughput or reduction of delays. For arrivals, a separation reduction of 0.5Nm has been determined with required surface crosswind component of 6kts plus buffer (size of the buffer depends on accuracy of local wind information).

The proposed safety criteria for the project involves taking a relative risk assessment. The aim is that the risk of an accident due to wake turbulence when reduced (DBS) minima are applied to an aircraft on final approach in crosswind conditions proposed by CROPS shall not be greater than the risk of an accident in low wind conditions (<5kts).

Wake vortex risk curves, i.e. cumulative distribution of the frequency of each circulation value have been generated for Heavy-Heavy and Heavy-Medium pairs. The total wind and headwind has been derived from runway anemometers and the crosswind and wake vortex tracks from LIDAR using a lateral corridor of +/- 75m. An example from the initial safety assessment results can be seen in Figure 2.

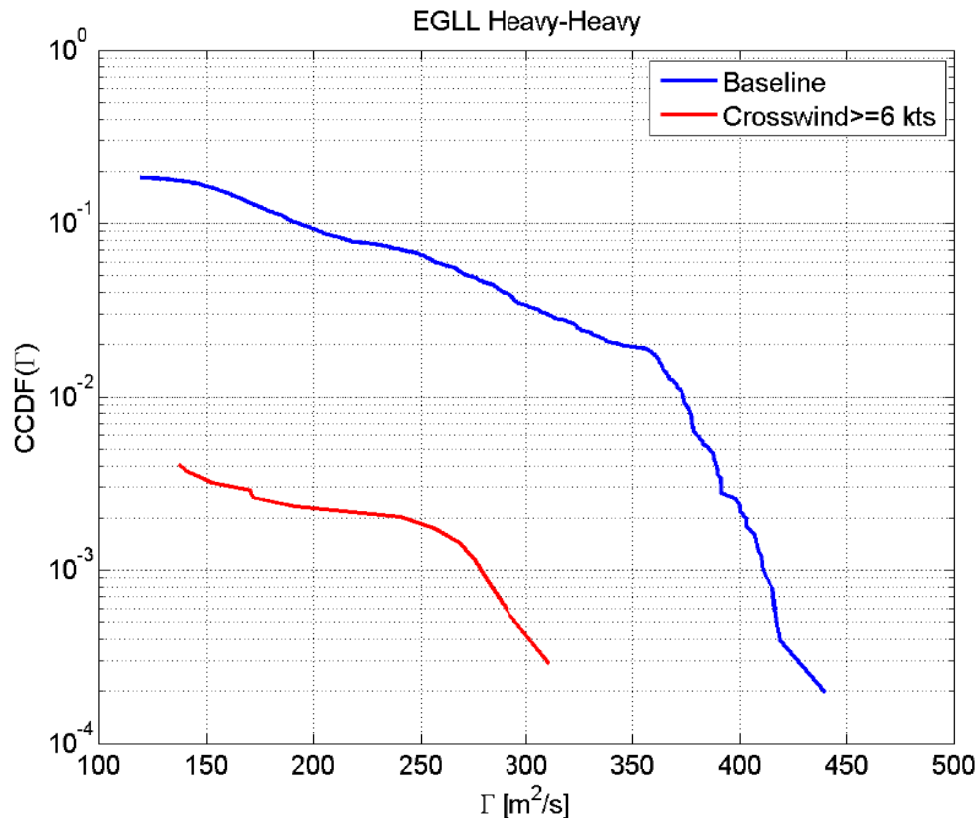


Figure 2: Initial Safety Results, H-H Pairs, 0.5Nm reduction, Crosswind ≥ 6 kts

The initial wind thresholds for application of CROPS and p-TBS have been identified with the minimum surface crosswind component defined as 6kts plus a buffer and a headwind component of 10kts plus a buffer (dependent on the accuracy of the local wind information).

Research Needs

- Merging of the p-TBS and CROPS concepts into a combined wind concept.
- How to deal with wind forecasting in operational terms in today's environment.
- Acceptability of the safety argument.

2.2.3 SESAR WP6.8.1 – Flexible and Dynamic Use of Airspace

Existing departure and arrival wake turbulence separations are considered at times to be over-conservative in that they are fixed regardless of the prevailing meteorological condition impact on the transport and decay of wake turbulence. SESAR WP6.8.1 will develop a wake turbulence related operational concept and specify user and high level system requirements in order to, conditionally or permanently reduce landing and departure wake turbulence separations and, consequently, to increase

the runway throughput in such a way that it safely absorbs arrival demand peaks and/or reduces departure delays.

The objective of SESAR WP6.8.1 is to develop solutions to:

- Permanently provide arrival capacity resilience to challenging wind conditions to redress the current impact of such conditions on the achieved capacity (TBS).
- Conditionally provide arrival and departure throughput increases in favourable prevailing meteorological conditions to more efficiently handle peaks and queues in arrival and departure demand (WDS).
- Permanently provide arrival and departure capacity increases across all conditions for both more contingency provision for non-nominal conditions and more provision for capacity declaration across all conditions (PWS).

The project is currently in Phase 1 (TBS) and the tasks involving the high level Operational Concepts Document (OCD) and Operational Service & Environment Description (OSD) preparation have been completed. The detailed TBS OSD definition involves converting the minimum time separation based on the preceding aircraft's position into a distance and also incorporating an expected catch-up time and translating this into distance.

Tasks which are currently on-going include the research into wake vortex encounter severity metrics. The approach used will derive models for roll axis disturbance for any aircraft type and will be sufficiently accurate to include relevant characteristics of the generating and following aircraft. The collection of LIDAR data (21 months of correlated LIDAR data at London Heathrow) will also be continued.

Research Needs

- Usability of the proposed HMI logic, Human Factors considerations.
- Availability of wind information broadcasted by aircraft.
- Investigation of whether it is possible to go below today's Minimum Radar Separation.
- How to deal with the lack of awareness for the pilot in PWS conditions.
- Acceptability of new severity metrics.
- More wake measurement campaigns to continually improve understanding of wake behaviour.

2.2.4 Green-Wake

Green-Wake is a European Commission (EC) funded project which is part of the 7th framework research programme.

The objective of the project is to demonstrate an instrument which can:

- Detect wake vortices and wind shear in a timely manner.
- Anticipate and mitigate the effect of wake vortices and wind shear on the aircraft and occupants.
- Investigate mitigation via flight controls.
- Develop, demonstrate and validate innovative technologies: UV LIDAR based.
- Provide air traffic system wide benefits.

The project aims to not only improve crew and passenger safety but increase airport recovery via reduced separation minima and increase environmental hazard awareness. A demonstration of the Green-Wake wake vortex detection system is shown in Figure 3.

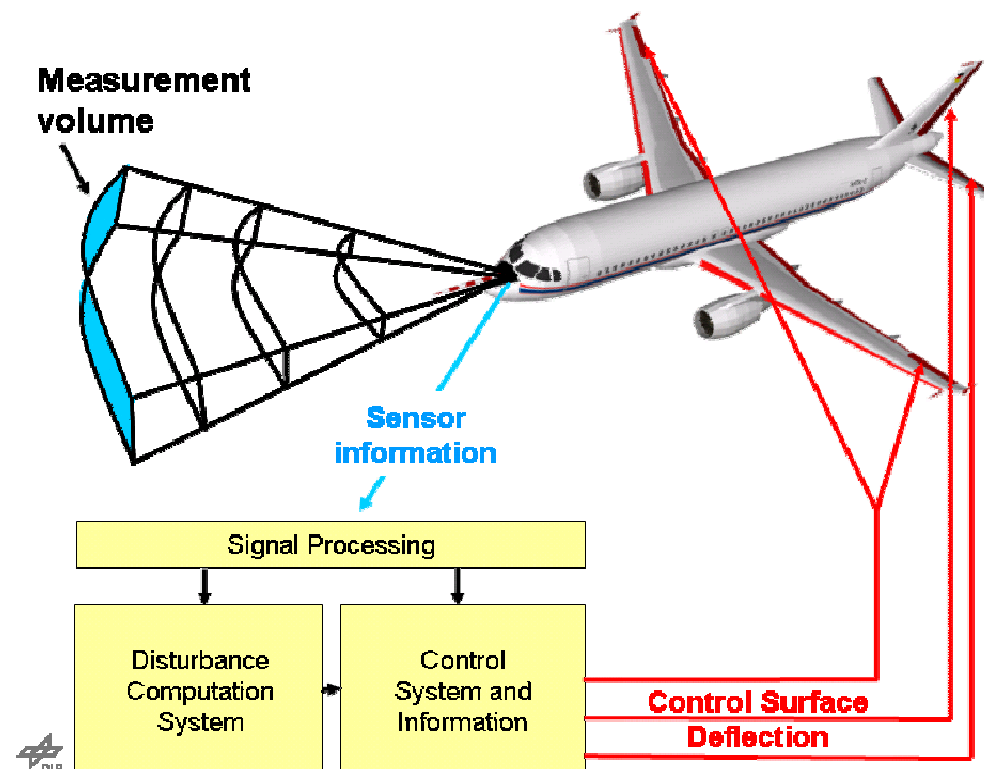


Figure 3: The GreenWake Concept, airborne detection, control and warning

The GreenWake project aims to model and simulate wake vortex and wind shear detection by an imaging LIDAR system. This simulator is the first of three major outputs of the project. It will help with the main deliverable which is to develop and test an Imaging Doppler LIDAR system that is capable of detecting and measuring wake vortices and wind shear phenomena of the order of 50-100m in front of an aircraft. This will allow action to be taken to reduce or avoid the hazard. Other key deliverables from the project

include the integration and demonstration of the performance of the system and the creation of a 3D hazard map which will be used to visualise the movement of air and therefore enhance the presentation of hazard information.

Trials at the Hovemere premises are planned (March 2011) to test the basic operation using existing LIDAR. Additionally, a wind tunnel trial of the GreenWake system without scanning mechanism will be conducted in Prague (July 2011) in order to test the detection of wake vortices, wind shear and gusts. Airfield trials are also planned for 2012 to test the full GreenWake system and will be validated with DLR coherent LIDAR. This will be a ground based trial with the GreenWake prototype positioned at a suitable range behind landing aircraft to demonstrate that wake vortices can be detected. The instrument used for these trials will be fundamentally the same as that used for the wind tunnel trial.

Research Needs

- Novel detector configurations.
- Lighter, faster scanning mechanisms.
- Integration into flight control system.
- Human Factors Integration.

2.2.5 SESAR WP9.11 – Aircraft Systems for Wake Encounter Alleviation SESAR WP9.30 – Weather Hazards & Wake Vortex Sensors

Within the SESAR development programme the two projects 9.11 and 9.30 are directly related to investigations of airborne wake vortex systems. These are called Wake Encounter Prevention Systems (WEPS) in the context of these projects.

There are two interacting and complementary system solutions:

(1) On-board wake encounter prediction, alerting & avoidance system – WEPS-P

- Identification of potential wake encounters based on air-to-air data link and model-based wake prediction.
- Determination of small-scale, short-term avoidance manoeuvres.

(2) On-board wake encounter alleviation system enabled by detection – WEPS-C

- Alleviation of wake encounter upsets through dedicated flight control function.
- More robust, less vulnerable aircraft.
- Based on current and new air data sensors, including forward-looking LIDAR.

The WEPS systems are designed so that there is no change against the current method of managing aircraft separations and to decrease aircraft vulnerability to wake encounters. In case of predicted severe wake turbulence, WEPS-equipped aircraft will perform a short-term, small scale avoidance manoeuvre.

The project will deliver benefits in two main areas:

- **Safety** - By providing the means to predict an imminent wake encounter and determining an avoidance manoeuvre, the solution directly contributes to safety by reducing the number of wake encounter incidents. The system will be independent from new ATC separation schemes.
- **Capacity** - When integrated into an appropriate new separation scheme, the solution allows reduced wake-related separations for equipped aircraft, thus directly contributing to runway capacity increases. A new separation scheme like pair-wise separations would be required.

The WEPS-P system will predict the evolution of wakes from surrounding aircraft by utilising probabilistic wake prediction models and the broadcast of traffic and meteorological data to WEPS equipped aircraft via ADS-B or similar. The system will detect potential conflicts between the intended flight path and the predicted zone of wake location. The decision for alerting/avoidance will be determined by using encounter severity metrics developed and validated in the SESAR WP6.8.1 project. Conflict resolution will either be vertical or lateral avoidance manoeuvres, adjustment of speed or potentially going around if on final approach. As part of the project a HMI will be developed to present the information to the pilots and the interaction with existing surveillance systems and other airborne systems will be considered. An overview of the WEPS-P system is shown in Figure 4.

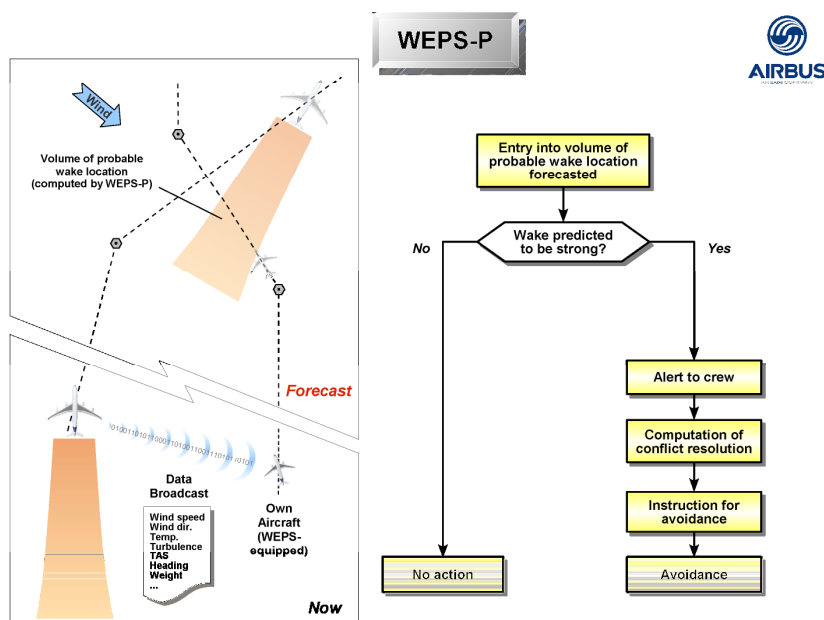


Figure 4: WEPS-P Operational Principle

As part of SESAR WP9.30, the WEPS-C system will be developed. The function of the WEPS-C system involves the alleviation of flight control. Today's Fly-by-Wire flight control already reduces the effect of a

wake encounter; however further improvement of alleviation of wake encounter effects are deemed possible. Different, new and dedicated control strategies are enabled if the type of disturbance is known (through WEPS-P) or the measurement of disturbance can be improved (e.g. through new sensors). As part of this project a new, forward-looking sensor will be developed. This will be a short-range LIDAR sensor capable of measuring line-of-sight velocity at several points in front of the aircraft. An overview of the WEPS-C system is shown in Figure 5.

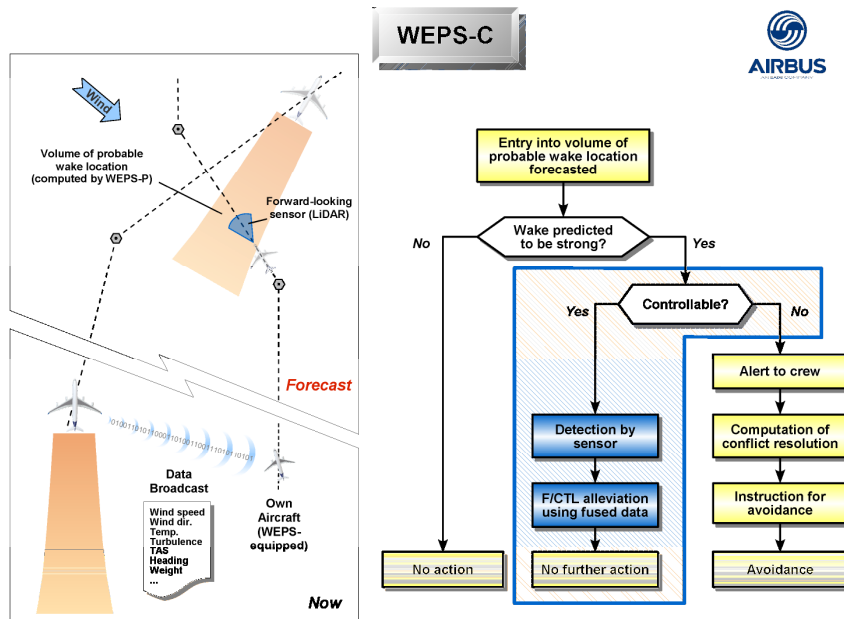


Figure 5: WEPS-C Operational Principle

Research Needs

- Interaction with ATC in case of avoidance.
 - Would ATC require any information?
 - Should this information be downlinked to other systems?
- Avoidance manoeuvre definition in case of manual vectoring.
- Pilot interface – Is it helpful to display probable wake locations to the pilot?
- Harmonised and integrated wake vortex operational concepts.
 - Assure harmonization between airborne and ground-based wake vortex advisory systems and their contributions and roles in the context of new wake vortex separation rules.
 - Use of airborne wake vortex system and benefits in the context of future air traffic operational concepts.
- Safety assessment
 - Additional activities are needed to identify how the capabilities of airborne wake vortex systems can / have to be taken into account in wake vortex safety assessments.

2.2.6 SESAR WP12.2.2 – Runway Wake Vortex Detection, Prediction and Decision Support Tools

Wake turbulence separation minima between aircraft are fixed, expressed in time for departures and in distance for arrivals. These fixed separation minima are considered as being sometimes over-conservative. In particular, the impact of meteorological conditions on wake vortex decay and transport is not taken into account due to the lack of information about the actual position and strength of wake vortices and details of local weather. Additionally, the existing aircraft categories regarding wake turbulence separation could be improved with a better knowledge of the actual generated wake vortices of the leading aircraft and the sensitivity to wake vortices of the trailing aircraft for each aircraft type pair.

The objective of the project is to define, analyse, develop and verify a Wake Vortex Decision Support System (WVDSS) according to the operational concepts defined in the SESAR WP6.8.1 project. The development of the WVDSS will be iterative and will therefore need to be validated for:

- **TBS** – Acquisition and processing of information about position, strength and behaviour of wake turbulence in significant headwind.
- **WDS** – Real time assessment of wake turbulence dependent on all weather conditions.
- **PWS** – Demonstration of the system capability to dynamically deliver separation for each aircraft pair. This will require an aircraft characteristics database and customisation at different airports for different runway configurations.

The concept development will be validated by the use of the WVDSS simulation platform calibrated with the XP0 Trial in 2011 and with the use of the full scale WVDSS platform on two major airports in ‘shadow mode’ with controllers in the loop:

- XP3 Trial at Paris CDG in 2014
- XP4 Trial at Frankfurt in 2016

The WVDSS will be able to optimise runway throughput and reduce delays for different airports and runway configurations in all weather conditions. Figure 6 gives an overview of the sensor deployment during the XP0 trial at Paris CDG airport.

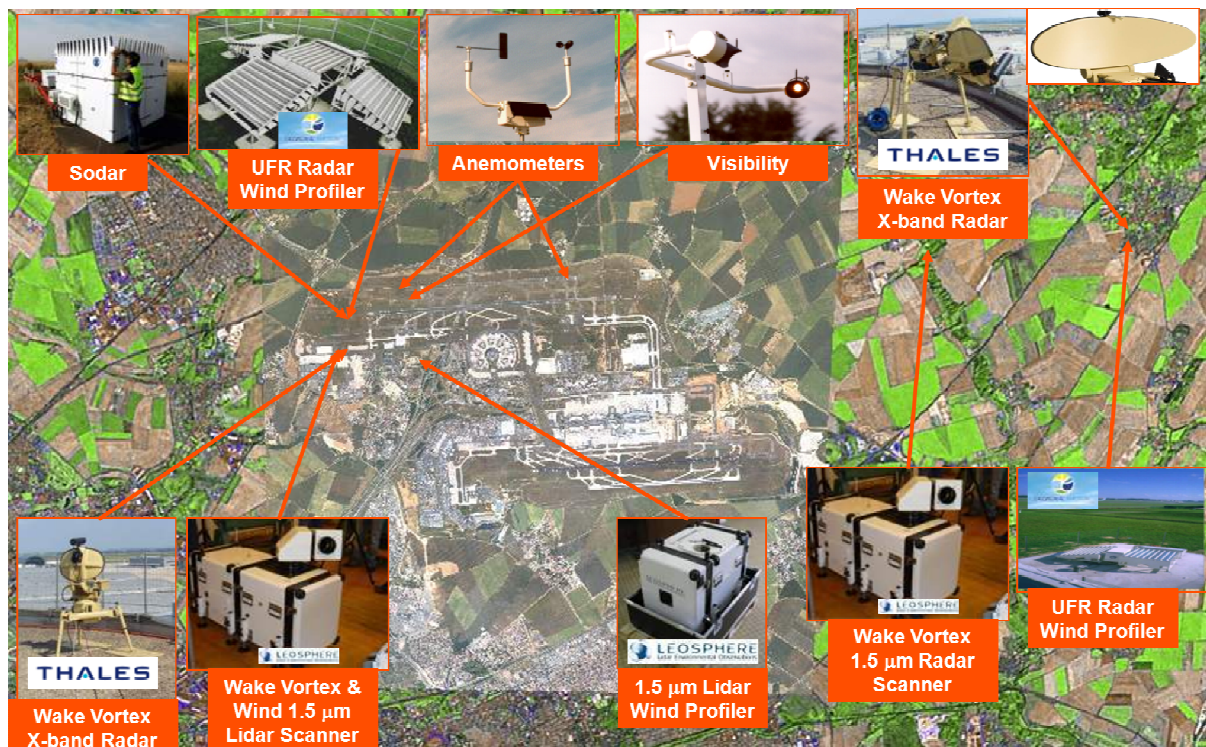


Figure 6: XP0 Paris CDG Trials – WV and Wind Sensor Deployment

The preliminary system requirements have been defined covering the three phases and have been split into five sections including the HMI and interfaces with other systems. The requirements will be refined during each successive phase of the project taking into account input from the SESAR WP6.8.1 project and results from previous phases.

The preliminary system architecture will be compliant with Enterprise Architecture as defined by WPB4.3 and involves the definition of each interface, the allocation of each system requirement to sub-systems and the creation of a local weather data cube. Similarly to the system requirements this will be refined as the project continues through the relevant phases.

Operational concept requirements and the WVDSS system requirements will be constrained by operational weather capabilities such as local weather forecast models, operational weather sensor capabilities and operational wake vortex sensor capabilities.

3 Task Group 3.3 Capacity Analysis

3.1 Terms of Reference

The Terms of Reference outlined in the Description of Work for Task Group 3.3 focussed on 'Capacity Analysis' are as follows:

- Contributing to the Terms of Reference of the area.
- Keeping track of the developments in the various projects and studies.
- Promoting communication between the partners and interest groups.
- Organising a workshop on Capacity Analysis.
- Elaboration of respective reports.
- Contributing to the Wakenet3-Europe website.
- Reporting to the commission.

3.2 Specific Workshop – Capacity Analysis

A specific workshop for the Task Group “Capacity Analysis” was held on 9th February 2011 at NATS Heathrow House, London as part of the WakeNet-3 Europe Concepts Workshop.

Three main issues were addressed and discussed at the workshop:

1. Methods of capacity analysis
2. Results of benefit assessments for selected operational concepts
3. Discussion of the topic and research needs for capacity assessments

A summary of these issues are presented in the following sections and will form the basis of further investigation of developments in the Task Group “Capacity Analysis”. The contents of the discussion will be incorporated into the Research Needs report.

3.2.1 Methods of Capacity Analysis

General definitions of relevant terms connected to capacity were given and the methods to analyse the capacity impact of an operational concept were discussed.

Capacity:

The term **capacity** in the context of an airport or airspace describes the capability of the facility to provide service within some period when there is continuous demand, e.g. the number of aircraft landings and/or departures per hour. A distinction has to be made between the **maximum theoretical** capacity of an airport and its **practical** capacity which is always smaller. Scheduled airport capacity is associated with the practical capacity due to the trade-off between maximum throughput and the acceptable level of delay.

Another aspect of capacity investigation is the division into **strategic** and **tactical** capacity gains. Strategic capacity is equal to the scheduled capacity of an airport and it is assumed that it is available for nearly 100% of operational time. Tactical capacity is available only when specific operating conditions are met (e.g. when crosswind conditions are favourable) and can be used to reduce delays or accommodate additional unscheduled flights.

It should be considered that capacity is characterised by the number of arrivals and departures on a runway. This should be kept in mind during the design of a concept and during the capacity assessment process.

Analysis methods:

In order to assess the capacity impact of a new operational concept, different methods can be applied that imply modelling the system under investigation, running simulations and designing metrics to

evaluate the impact. These models, simulations and metrics vary in the level of detail and complexity. The following methods are usually used to perform capacity analyses, with increasing level of detail:

- Analytical models which can be applied to different airports and are used for high level analyses.
- Process or event driven simulations that make use of synthetic traffic scenarios and emulate basic functions.
- Fast-time simulations that take into account realistic traffic scenarios, ATC procedures and the airport and airspace layout.
- Real-time simulations that take place in the complete operational context including realistic aircraft behaviour and the entire ATM system with its interactions; human factors are also assessed via human-in-the-loop simulations involving air traffic controllers and (pseudo) pilots.

3.2.1.1 Benefit assessments for selected operational concepts – current status

The results of the benefit assessments for selected operational concepts and systems were presented at the workshop to show the application of capacity analysis methods and to show the benefit results of these concepts. Also research needs identified for these concepts were addressed by the presenters.

The capacity analyses and impact of the following three selected concepts will be discussed in this document:

- The Wake Vortex Prediction and Monitoring System (WSVBS).
- Wake Turbulence Mitigation for Departures (WTMD).
- RECAT Phase 1.

3.2.1.2 The Wake Vortex Prediction and Monitoring System (WSVBS)

The wake vortex prediction and monitoring system WSVBS (WirbelSchleppen Vorhersage- und Beobachtungssystem) has been developed by DLR. It aims at **tactically** increasing airport capacity for approach and landing on closely-spaced parallel runways by dynamically adjusting aircraft separations (using ConOps developed by DFS) depending on current weather conditions by assuring the current level of safety. The system contains wake vortex transport and behaviour prediction based on meteorological measurement, short term weather prediction and LIDAR monitoring acting as a safety net [2].

Methodology of capacity analysis and results

Real-time simulations were performed involving air traffic controllers and pseudo pilots demonstrating the integration of the system in the Air Traffic Control environment at Frankfurt Airport. Additionally, a performance test has been carried out for 66 days. These trials indicated that the reduced separations could have been used for 75% of the time.

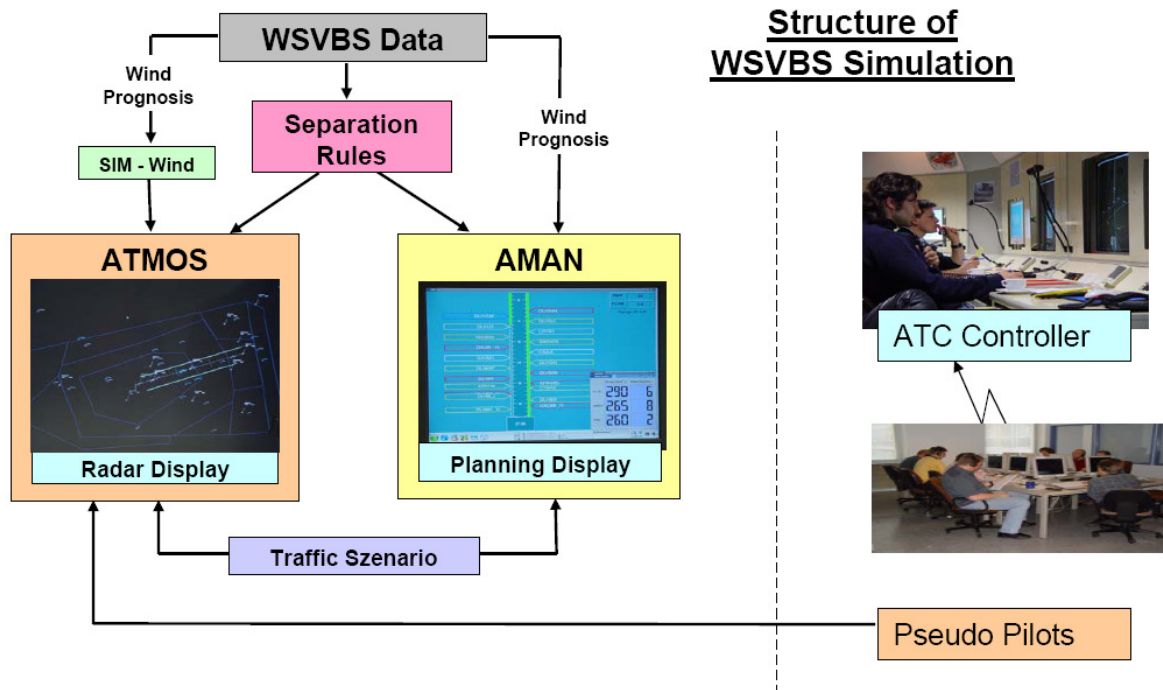


Figure 7: Structure of WSVBS simulation [3].

Fast-time simulations were undertaken using the SimmodPLUS software taking into account the airport and route structure, separation schemes as well as traffic scenarios and weather data. Simulation results for Frankfurt indicate a potential capacity gain of 3-4% which could be used to increase traffic flow or decrease delay.

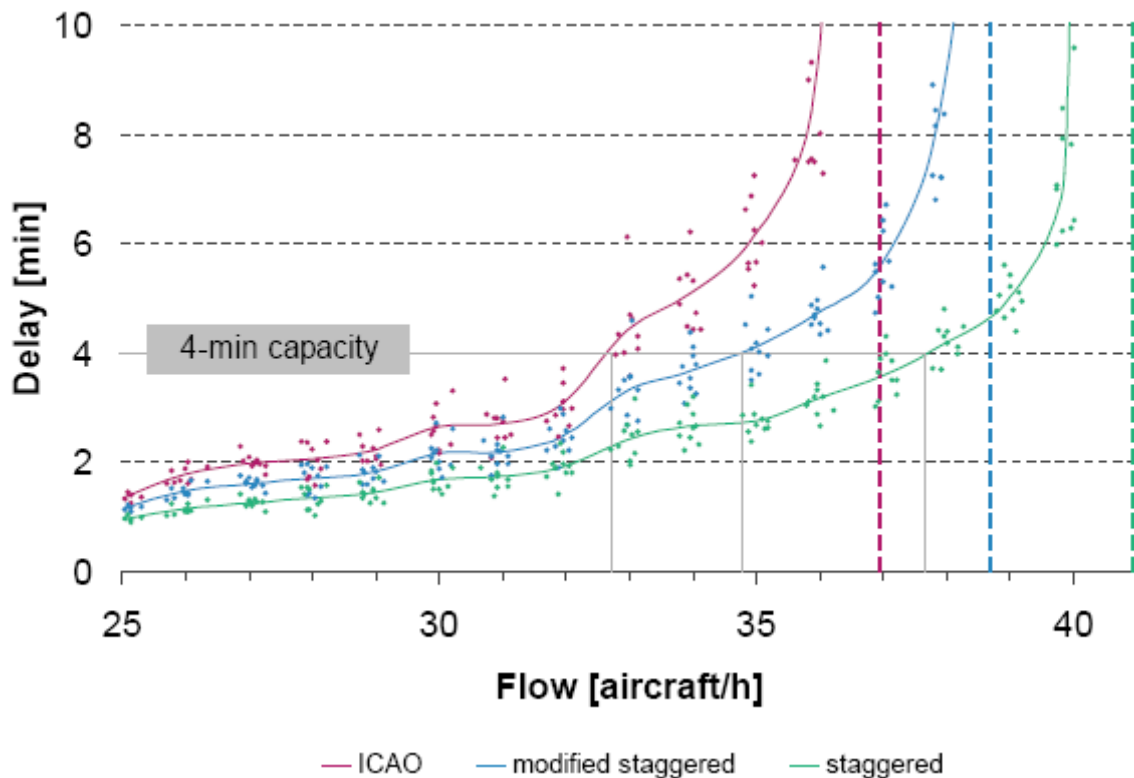


Figure 8: Average delay versus traffic flow (for a typical traffic mix of H/M/L aircraft) for the concepts of operation ICAO (red), MSL/R (blue), and STG (green) from fast-time simulations; the “4-min delay” capacity is indicated by grey vertical lines [2].

Research Needs

- A connection between the concept and business case as well as the safety case is required for realistic benefit assessment.
- What amount of capacity benefit is needed to justify effort for development of a new system?
- It has to be ensured that meteorological systems (as the one developed in SESAR WP11.2) will provide the required parameters for wake vortex prediction.
- Comprehensive risk analyses as well as consistent safety levels are needed.
- A wake vortex warning system is required to prevent encounters.

3.2.1.3 Wake Turbulence Mitigation for Departures (WTMD)

The WTMD concept aims at reducing capacity limitations imposed by wake turbulence separation standards on closely spaced parallel runways (CSPRs). Airports with CSPR complexities and significant numbers of B757 and “Heavy” aircraft departures are in the scope of this concept and will benefit from the changed procedures. The concept takes advantage of the fact that wake generated on the downwind

runway will be transported away from the upwind runway by crosswinds with sufficient velocity. Therefore, wake separation of upwind runway departure traffic from traffic on the downwind runway is not required.

Methodology of capacity analysis and results

Two different estimation methods used for the WTMD benefit assessment were presented: airport capacity simulation using a MITRE developed method called runwaySimulator (see Figure 9) and a Day in the Life Analysis. Whereas the runwaySimulator method estimates future capacity with increased demand, Day in the Life provides capacity increase with current day demand. Estimated results shown in Figure 10 indicate that the WTMD concept could bring potential benefits for several US airports considered for this analysis.

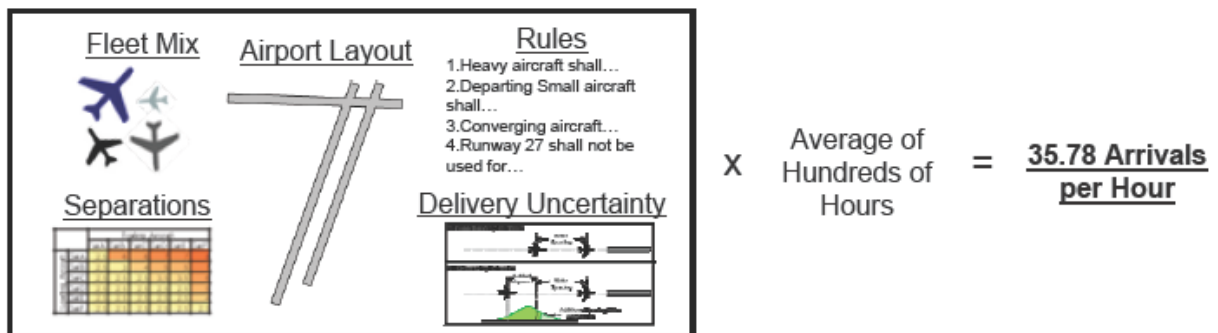


Figure 9: Runway capacity simulator scheme and considered factors [4].

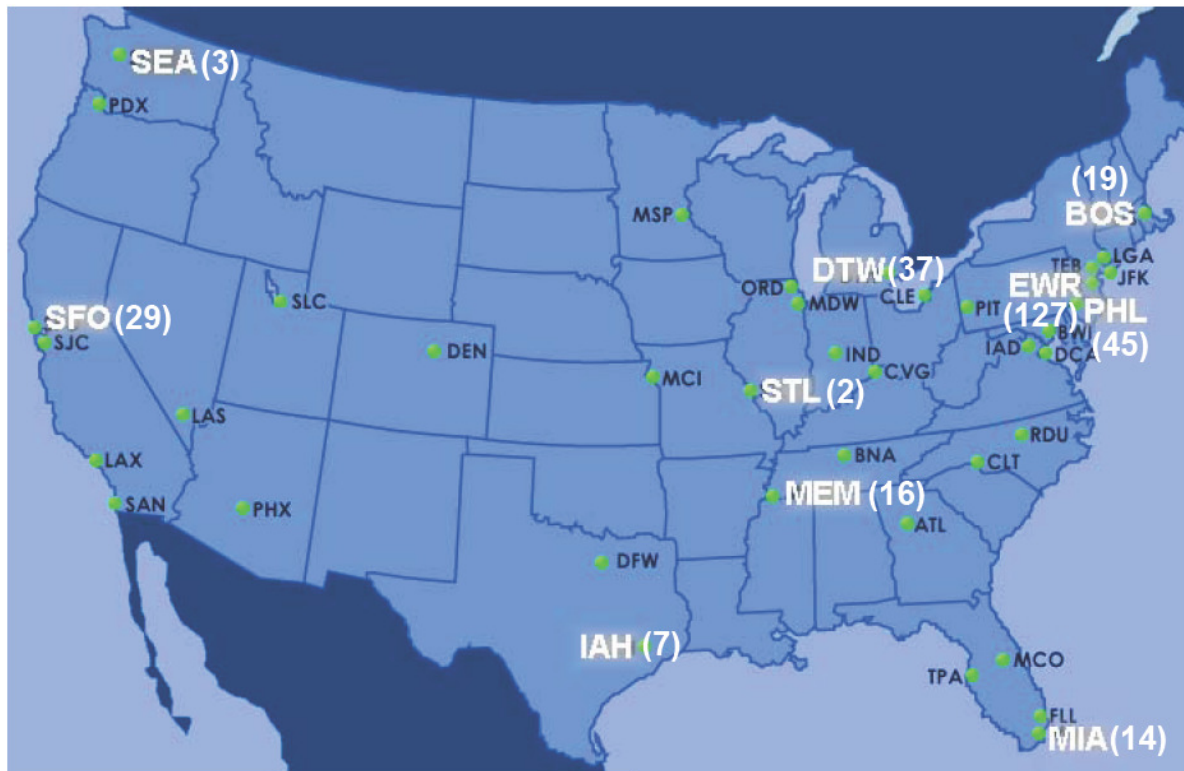


Figure 10: WTMD candidate airports – estimated departures per day no longer incurring wake delay [4].

Research Needs

- Not only increased capacity is a concept benefit, but also flexibility, reduced controller workload, procedure workload, that are hard to model but should not be omitted.
- Many concepts show benefits, but the results must be accurate and easy to explain to the stakeholders.
- How do different concepts fit together (e.g. different local concepts in NAS)?

3.2.1.4 RECAT Phase 1

The Recategorisation effort aims to increase the capacity of an airport by redefining the current ICAO wake vortex categories and the associated minimum separations assuring the same or improved level of safety. The initiative is divided into three phases. Phase 1 focuses on the static six category separation matrix. In this stage, 61 aircraft types representing 85% of the worldwide fleet have been grouped into six categories as the result of the project. Categories (see Figure 11) have been optimised to current fleet mixes and evaluated for potential future fleet mixes in order to provide optimal capacity benefit. Traffic figures were taken from five U.S. and four European representative airports. This assumption was confirmed by analysing traffic mixes at capacity congested airports across the world.

		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						

Figure 11: RECAT separation table [5].

Methodology of capacity analysis and results

Different methods were used to analyse capacity; the two main methods were **analytical estimations** and **fast-time simulations**.

An example for the analytical estimation is the Average Minimum Separation AvgMinSep that models the impact on capacity based on the assumption that aircraft follow each other in-trail at the exact separation minima. Results of these estimations are shown in Figure 12.

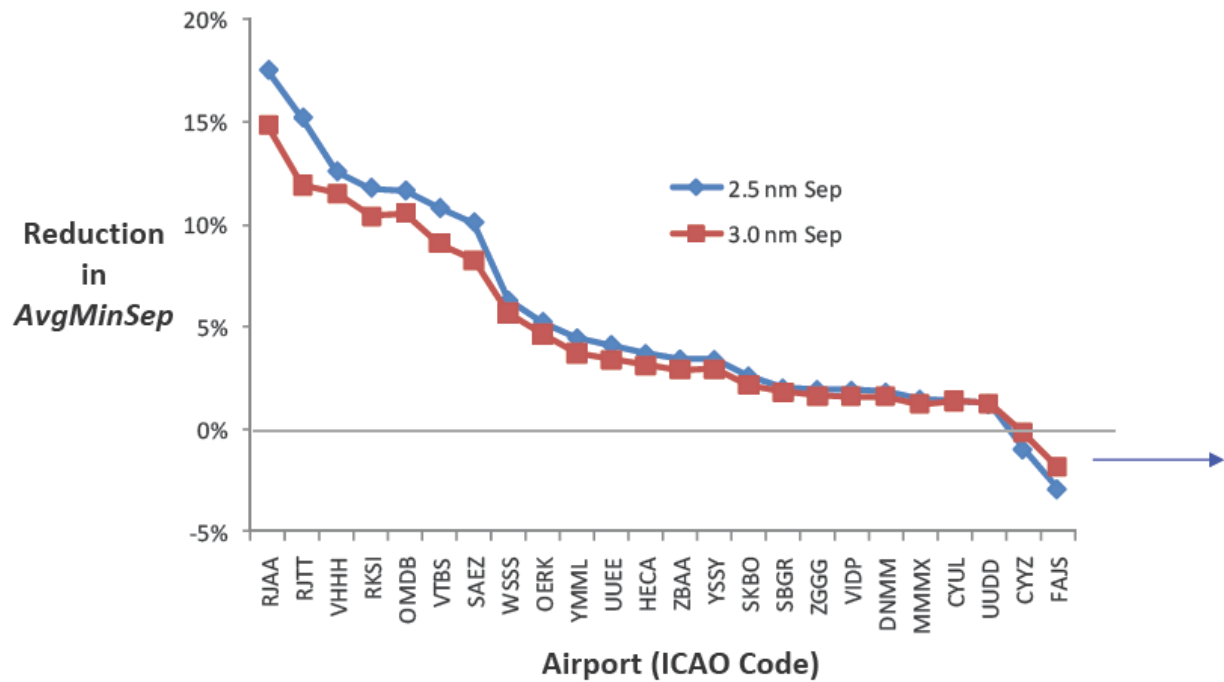


Figure 12: RECAT benefits for different airports worldwide using AvgMinSep [4].

Fast-time simulations provide a more detailed analysis and have been conducted for various traffic-mixes that are representative of main European and US airports. Results for the U.S. airports obtained using runwaySimulator method (an airport simulation package developed by MITRE) are shown in Figure 13.

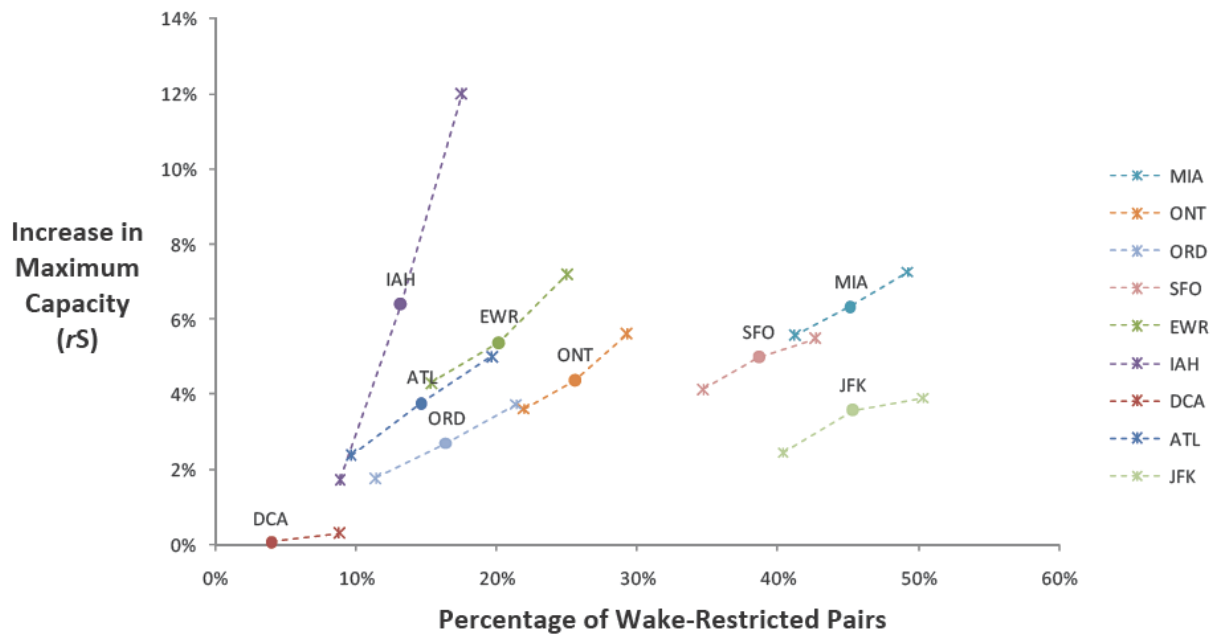


Figure 13: RECAT benefits for U.S. airports worldwide using runwaySimulator [4].

The capacity assessment in the U.S. and Europe has shown that the traffic mix and local procedures influence the benefit to a considerable extent. As a result, different strategic capacity gains were estimated for European congested airports (~4% increase) and U.S. congested airports (~7% increase).

Research Needs

- What capacity increase is needed to adopt the RECAT scheme globally, regionally and locally?
- How can capacity be evaluated (different requirements are available locally – airport unique procedures)?
- How will dynamic separations impact ATCO and pilot? Will airport unique separations be accepted by the crew?

3.3 Summary of workshop discussion and open questions for the area “Capacity Analysis”

The following points were discussed during the specific workshop and provided the basis for identifying research needs in the area of “Capacity Analysis”.

- Factors influencing results of capacity analyses are manifold and should be taken into account when assessing a concept and creating benchmarks. Among those factors are:
 - Influence of uncertainty (e.g. in weather prediction for wind/weather based concepts)
 - Stability of forecast and the persistence of operational modes
 - Airport design and procedures
 - Traffic mix
 - Impact on safety and the risk assessment
 - Selected metrics to quantify capacity (e.g. influence of metrics related to payload/passengers)
- There has to be a trade-off or a sound balance between capacity increase (referring to scheduled capacity) and the tolerated increase of delay occurring when the conditions of a concept can not be satisfied. It should be considered to transfer some of the capacity gain into delay reduction.
- The right capacity metric is still under discussion – aspects of this discussion are:
 - Relation of capacity metric to the aircraft type (payload/passenger)
 - Weighting between arrivals and departures
- The importance of realistic capacity benefit estimation for the successful implementation of a concept and for communication with the stakeholders is obvious. Yet it is still a challenge to provide such realistic estimations using the methods available today.
- For most of the concepts developed today, one of the central questions remains: What capacity increase is needed to adopt the concept/to justify the implementation of the concept by the stakeholders? Therefore, the communication between developers, authorities and operational stakeholders is one of the important challenges for the next years to find a common answer.

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