EUROCONTROL

Approach and Departure Optimised **Wake Turbulence** Re-Categorisation and **Pair-Wise Separation** minima

RECAT-EU-PWS scheme

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TITLE			
"RECAT-EU-PWS" Solution **Optimised Wake Turbulence Categorisation and distance-based static Pair-Wise Separation (S-PWS) Minima on Approach and Departure**			
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Abstract

This document presents the European Optimised Wake Turbulence Categorisation and distance-based static Pair-Wise Separation (S-PWS) Minima for Approach and Departure, also named 'RECAT-EU-PWS' scheme.

The 'S-PWS' solution for Approach and Departure, developed under the SESAR2020 programme as PJ02.01.04 (S-PWS-A) and PJ02.01.06 (S-PWS-D), is a refinement from RECAT-EU, delivering further separation reduction of 0.5NM or 1NM for some frequent aircraft pairs, and supporting increased runway throughput.

The minima are derived on the basis of the same methodology as used in RECAT-EU (and endorsed by EASA), however aligning the wake turbulence encounter risk on a pair-wise basis. On this, EUROCONTROL has produced a generic Safety Case, submitted to EASA for review and recommendations, in support of regulatory acceptance of local deployments.

There are several ways to operate the RECAT-EU-PWS scheme: on a pair-wise basis (with ATC separation delivery tool support), on a categorical system basis (with/without ATC separation delivery tool support), or on a procedural basis for selected aircraft type pairs in view of upgrading the applied wake categorisation scheme and bringing quick wins.

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EXECUTIVE SUMMARY

This document, developed along the SESAR 2020 Wave 2 Very Large Demonstration VLD3-W2 "SORT" project, presents the Optimised Wake Turbulence Categorisation and Pair-Wise Separation (PWS) Minima for Approach and Departure, called RECAT-EU-PWS scheme.

The runway throughput in peak period is directly linked with the applicable minimum longitudinal separation between successive traffic on final approach or on departure.

Following **RECAT-EU as an initial step** of re-categorisation of ICAO legacy wake turbulence categories into a 6-category scheme, an additional optimisation step consists in the determination of static wake turbulence separation minima based on a "**Pair-Wise" regime, i.e. between pairs of aircraft types**.

The PWS minima are determined by similar principles as used for the RECAT-EU methodology and safety metrics, with refinements to provide adequate assurance for a pair-wise level of analysis and wake risk.

The PWS minima have been determined for **a list of 100+ aircraft types** (defined by an ICAO type designator), most frequent at major European airports and for which data are available to characterize the wake generation and wake encounter resistance with sufficient safety assurance. To further complete for all other less frequent types, a **RECAT-EU 20 CAT scheme** is established, by sub-division of the RECAT-EU categories, and where the aircraft are assigned to one of the 20 categories, based on their MTOM (Maximum Take Off Mass), span and wing aspect ratio.

There are three ways to operate the RECAT-EU PWS solutions:

- **Pair-Wise application**, which requires automation support with an ATC separation delivery tool, which could also enable time-based separation and optimum runway delivery (TBS-ORD);
- a **customized N-category scheme**, defined to be an optimum for a given airport traffic mix;
- a procedural wake minima enhancement for a **limited number of specific pairs** of aircraft types (or group of pairs)

In terms of benefits, the reduction of wake turbulence separation minima from ICAO legacy wake turbulence categories to the RECAT-EU-PWS minima can increase the runway throughput during peak periods by more than 10%, depending on local airport traffic mix of aircraft types.

Also, at equivalent throughput, the RECAT-EU-PWS separation reduction,

- ✓ supports a reduction of the overall flight time for an approach or departure sequence of traffic, which therefore benefits to the whole traffic sequence.
- ✓ offers more flexibility for the Air Traffic Controllers to manage the traffic.
- ✓ enables more rapid recovery from adverse conditions, helping to reduce the local airport delay and eventually the ATFM delay propagated at network level.

1. RECAT-EU-PWS minima

1.1 Background

As part of SESAR 2020 Industrial Research project PJ02, EUROCONTROL has led the development static pair-wise wake turbulence separation for Arrivals and Departures, identified as two SESAR solutions:

PJ02.01.04 Wake turbulence separation for Arrivals based on static aircraft characteristics ('S-PWS-A')

PJ02.01.06 Wake turbulence separation for Departure based on static aircraft characteristics (S-PWS-D')

Since resulting from optimisation from RECAT-EU, these solutions are also commonly named RECAT-EU-PWS scheme.

This development has been supported by UK NATS, providing an operational expertise review and London Heathrow operational data, in support of the analysis for separation design of some aircraft types.

The RECAT-EU-PWS scheme is also one of the solutions addressed in the scope of the SESAR 2020 Wave 2 PJ02 'AART' (Airport Airside & Runway Throughput) and Very Large Demonstration VLD3 'SORT' (Safely Optimised Runway Throughput) project, where a demonstration exercise application will take place in the London Heathrow airport environment, and following operational deployment expected by 2023.

1.2 RECAT-EU-PWS minima scheme

The RECAT-EU-PWS scheme, establishing optimised longitudinal wake turbulence separation minima on arrival and departure, is composed of the following:

For a list of 100+ aircraft type,

- **"RECAT-EU-PWS matrix"** where pair-wise separation minima are specified for a list of 100+ aircraft type (identified by the ICAO type designator), frequent in the traffic at major European airports and covering more than 95% of the traffic.

For all other aircraft types not in the 100+ / PWS list:

- **"RECAT-EU-20-CAT" separation matrix** specified between 20 Wake Turbulence Categories of aircraft types, consisting in a further optimisation / sub-division of RECAT-EU 6-CAT categories (but not to a pair-wise level).
- An **aircraft type assignment list** into the RECAT-EU-PWS and RECAT-EU 20-CAT matrix containing all ICAO type designators (2000+)

The PWS and 20-CAT separation matrices are detailed hereafter. The aircraft type assignment list is available separately (MS Excel file), and like for RECAT-EU, will be published on EUROCONTROL and EASA websites following the regulatory approval process.

1.2.1 RECAT-EU-PWS distance-based minima matrix (100+ aircraft type designators)

The RECAT-EU PWS minima matrix, presented in Figure 1, covers 103 frequent aircraft types. The list of aircraft types with PWS minima is provided in Appendix A.

*It must be noted that these **wake turbulence separation minima** have been specified down to 2NM minimum, this in view of possible reduction of minimum surveillance separation (MSS) as developed under SESAR2020 (reference solution: PJ.02-03 'Minimum-Pair Separations based on Required Surveillance Performance'.*

Some of these wake minima, as specified here (the darker colour, the larger separation), may become smaller than other local prevailing separation or spacing constraints, such as surveillance minima or runway occupancy time, which in this case prevail and remain applicable on top of the wake turbulence separation minima.

	A388	B748	B77L	B77W	A359	A35K	B744	A346	A345	B773	B772	A343	A332	A333	A342	B789	B788	MD11	B764	B762	B763	A306	A30B	A310	B752	B753
A388	2.5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
B748		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
B77L		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
B77W		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
A359		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
A35K		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
B744		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
A346		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
A345		2	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	3	3	3	3	2.5	2.5	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5
B773		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
B772		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
A343		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
A332		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
A333		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
A342		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
B789		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
B788		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3.5	3.5	3.5	3.5	3.5
MD11		2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2.5	3	3	3	3	3	3	3
B764		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	2.5
B762		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	2.5
B763		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	2.5
A306		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2.5
A30B		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2.5
A310		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2.5
B752		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
B753		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

	B38M	A21N	A20N	BCS3	BCS1	B739	B738	B737	B736	A321	A320	A318	A319	MD83	MD82	A148	B734	B733	B735	E195	E190	GL5T	GLEX	GLF5	B712	F100	F70	B463	RJ1H	RJ85	E170	CRJ7	CRJ9	GLF4
A388	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
B748	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
B77L	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
B77W	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
A359	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
A35K	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
B744	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
A346	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
A345	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
B773	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
B772	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
A343	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
A332	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
A333	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
A342	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
B789	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
B788	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	4	4	4	4	4	4.5	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4
MD11	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
B764	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	2.5	3	3	2.5	3	3	3	3	3	3	3	3	3	3	3	3.5	3.5	3
B762	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	2.5	3	3	2.5	3	3	3	3	3	3	3	3	3	3	3	3.5	3.5	3
B763	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	2.5	3	3	2.5	3	3	3	3	3	3	3	3	3	3	3	3.5	3.5	3
A306	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.5	3	3	3	3	3	3	3	3	3	3	3	3.5	3.5	3.5	3.5	3.5	3.5	3
A30B	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.5	3	3	3	3	3	3	3	3	3	3	3	3.5	3.5	3.5	3.5	3.5	3.5	3
A310	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.5	3	3	3	3	3	3	3	3	3	3	3	3.5	3.5	3.5	3.5	3.5	3.5	3
B752	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2	2	2	2	2	2.5	2	2	2	2	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5
B753	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2	2	2	2	2	2.5	2	2	2	2	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Safety case under review by EASA – For information only

	F27	F50	DH8D	AT75	AT72	FA7X	AT43	AT45	CRJ2	J328	E145	E135	CL30	F2TH	F900	FA50	CL60	GALX
A388	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
B748	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
B77L	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
B77W	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
A359	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
A35K	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
B744	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
A346	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
A345	4.5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
B773	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
B772	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
A343	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
A332	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
A333	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
A342	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
B789	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
B788	4.5	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5	5
MD11	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
B764	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	3.5	3.5	4	4	4	4	4	4
B762	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	3.5	3.5	4	4	4	4	4	4
B763	3	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	3.5	3.5	4	4	4	4	4	4
A306	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
A30B	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
A310	3.5	3.5	3.5	3.5	3.5	3.5	4	4	4	4	4	4	4	4	4	4	4	4
B752	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3	3	3	3	3	3	3	3	3	3.5
B753	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3	3	3	3	3	3	3	3	3	3.5

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	SF34	D328	E120	C680	C56X	H25C	C25C	LJ45	LJ40	H25B	C560	LJ60	BE40	LJ35	B350	C25B	PC12	C550	C25A	C501	C525	C510	P46T	PA34	C10T
A388	7	7	7	7	7	7	7	7	7	7	7	7	7	7	8	8	8	8	8	8	8	8	8	8	8
B748	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
B77L	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
B77W	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
A359	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
A35K	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
B744	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
A346	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
A345	5.5	6	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6	5.5	6.5	7	6.5	6.5	7	6.5	6.5	7	7	7	7
B773	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
B772	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
A343	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
A332	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
A333	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
A342	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
B789	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
B788	5.5	5.5	5.5	5.5	6	6	6	5.5	6	6	6	5.5	6.5	5.5	7	7	7	7	7	6.5	7	7	7	7	7
MD11	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6
B764	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4	4.5	4.5	5	5	5	5	5	5	5	5.5	5.5	5.5	5.5
B762	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4	4.5	4.5	5	5	5	5	5	5	5	5.5	5.5	5.5	5.5
B763	4	4	4	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4	4.5	4.5	5	5	5	5	5	5	5	5.5	5.5	5.5	5.5
A306	4.5	4.5	4.5	4.5	4.5	4.5	5	4.5	5	5	5	4.5	5	4.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	6	6	6	6
A30B	4.5	4.5	4.5	4.5	4.5	4.5	5	4.5	5	5	5	4.5	5	4.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	6	6	6	6
A310	4.5	4.5	4.5	4.5	4.5	4.5	5	4.5	5	5	5	4.5	5	4.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	6	6	6	6
B752	3	3	3	3	3.5	3.5	3.5	3.5	3.5	3.5	4	3.5	4	3.5	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
B753	3	3	3	3	3.5	3.5	3.5	3.5	3.5	3.5	4	3.5	4	3.5	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5

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	A148	B734	B733	B735	E195	E190	GL5T	GLEX	GLF5	B712	F100	F70	B463	RJ1H	RJ85	E170	CRJ7	CRJ9	GLF4	F27	F50	DH8D	AT75	AT72	FA7X	AT43	AT45	CRJ2	J328	E145	E135	CL30	F2TH	F900	FA50	CL60	GALX
B38M														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A21N														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A20N														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
BCS3														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
BCS1														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
B739														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
B738														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
B737														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
B736														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A321														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A320														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A318														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A319														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
MD83														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
MD82														2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

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	SF34	D328	E120	C680	C56X	H25C	C25C	LJ45	LJ40	H25B	C560	LJ60	BE40	LJ35	B350	C25B	PC12	C550	C25A	C501	C525	C510	P46T	PA34	C10T
B38M	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A21N	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A20N	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
BCS3	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
BCS1	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
B739	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
B738	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
B737	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
B736	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A321	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A320	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A318	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A319	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
MD83	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
MD82	3	3	3	3	3	3	3	3	3.5	3	3.5	3	3.5	3	4	4	4	4	4	4	4	4.5	4.5	4.5	4.5
A148							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
B734							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
B733							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
B735							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
E195							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
E190							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
GL5T							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
GLEX							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
GLF5							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
B712							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
F100							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
F70							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
B463							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
RJ1H							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
RJ85							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
E170							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
CRJ7							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
CRJ9							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
GLF4							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
F27							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
F50							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
DH8D							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
AT75							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
AT72							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
FA7X							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
AT43							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
AT45							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
CRJ2							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
J328							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
E145							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
E135							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
CL30							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
F2TH							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
F900							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
FA50							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
CL60							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
GALX							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3

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	SF34	D328	E120	C680	C56X	H25C	C25C	LJ45	LJ40	H25B	C560	LJ60	BE40	LJ35	B350	C25B	PC12	C550	C25A	C501	C525	C510	P46T	PA34	C10T
SF34							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
D328							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
E120							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
C680							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
C56X							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
H25C							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
C25C							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
LJ45							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
LJ40							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
H25B							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
C560							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
LJ60							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
BE40							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
LJ35							2.5		2.5	2.5	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3	3	3	3	3	3
B350							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C25B							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
PC12							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C550							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C25A							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C501							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C525							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C510							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P46T							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
PA34							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
C10T							2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Figure 1: RECAT-EU-PWS 103x103 matrix with distance-based Wake turbulence separation minima for approach and departures

The RECAT-EU-PWS matrix is provided as Appendix H to the EUROCONTROL RECAT-EU-PWS Safety Case, under the form of an MS Excel file.

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1.2.2 RECAT '20-CAT' scheme and distance-based minima

Based on the PWS matrix and list of aircraft types, a scheme with 20 wake turbulence categories is covering all other aircraft types not in the 'PWS' list.

A 14 categories scheme is built to assign aircraft types not in the PWS list on the basis of design similarities with aircraft types from the PWS list, defining **14-CAT scheme.**

This is further completed by the RECAT-EU 6 categories for the remaining most rare and specific aircraft types, leading to an **overall 20-CAT scheme**.

The table below shown as Table 1 contains a selection of aircraft types not in the PWS list, and assigned to the 14-CAT, for which separation minima are still further optimised compared to RECAT-EU.

14-Category designators	A1	B1	B2	C1	C2	C3	C4	D1	E1	E2	E3	F1	F2	F3
Selection of aircraft types assigned in 14-CAT (not currently assigned in PWS list)		B778 B779 . . .	A338 A339 B78X . . .	DC10 . . .	IL76 . . .	A3ST . . .	*(no other type than B757 being in the PWS list)*	A19N B37M B39M B3XM MD90 T154 . . .	AN72 CRJX E75S E75L FA8X GLF6 MRJ7 MRJ9 SU95 . . .	AN32 AT46 AT73 AT76 DH8C FA6X . . .	C750 CRJ1 E35L E45X G280 LJ85 . . .	C68A DHC4 . . .	B190 C650 FA20 JS41 LJ55 LJ75 PC24 . . .	*All types from ICAO Light WTC, except [C10T, C25A, C25B, C501, C510, C525, C550, P46T, PA34, PC12] which are in the PWS list*

Table 1 Example of assignment into the 14-Category scheme of the RECAT-EU 20CAT, with correspondence to aircraft types from the PWS list

This assignment is based on criteria comprising mass, wingspan and wake resistance factor, and can be resulting from a specific analysis, such as for the A330Neo (A338, A339) or Boeing 777X (B778, B779).

For aircraft types that do not fall into one of the 14 additional categories RECAT-EU 6-CAT category is maintained, enabling full coverage of the whole aircraft type fleet.

The assignment of all ICAO type designators into this 20-CAT is available in a dedicated list (Appendix G to the EUROCONTROL RECAT-EU-PWS Safety Case, under the form of an MS Excel file).

The distance-based separation minima for the 20-CAT wake scheme are provided in Figure 2

	A1	A	B1	B2	B	C1	C2	C3	C4	C	D1	D	E1	E2	E3	E	F1	F2	F3	F
A	3.0	3.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0	8.0
A1	2.5	3.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	7.0	7.0	8.0	8.0
B	2.5	2.5	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	7.0	7.0	7.0	7.0
B1		2.5	2.5	3.0	3.0	3.0	3.5	3.5	3.5	4.0	4.0	4.0	4.5	5.0	5.0	5.0	6.0	6.5	7.0	7.0
B2		2.0	2.0	2.5	2.5	2.5	3.0	3.5	3.5	3.5	3.5	4.0	4.5	5.0	5.0	5.0	5.5	6.5	7.0	7.0
C		2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.0	5.5	6.0	6.0	6.0
C1		2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.0	5.0	5.0	6.0	6.0
C3		2.0	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	3.0	3.5	4.0	4.0	4.0	4.5	5.0	6.0	6.0
C2		2.0	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	3.0	3.5	3.5	4.0	4.0	4.0	4.5	6.0	6.0
C4		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	2.5	3.0	3.5	3.5	3.5	4.0	6.0	6.0
D												2.5	2.5	2.5	2.5	2.5	3.5	4.0	5.0	5.0
D1												2.5	2.5	2.5	2.5	2.5	3.0	3.5	5.0	5.0
E												2.5	2.5	2.5	2.5	2.5	3.0	3.5	4.0	4.0
E1																		2.5	4.0	4.0
E2																		2.5	4.0	4.0
E3																		2.5	4.0	4.0
F																		2.5	3.0	3.0
F1																		2.5	3.0	3.0
F2																		2.5	3.0	3.0
F3																		2.5	2.5	2.5

Figure 2: 20-CAT Distance-based wake turbulence separation minima for arrival and departures

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1.2.3 RECAT-EU-PWS/20-CAT Aircraft assignment list

A list of aircraft type assignment with all ICAO type designators assigned into the RECAT-EU 20-CAT, and identifying the types of the PWS list, is developed and will be maintained for including new type designator identified in ICAO Doc 8643.

The RECAT-EU-PWS/20CAT aircraft assignment list is provided as Appendix G to the EUROCONTROL RECAT-EU-PWS Safety Case, under the form of an MS Excel file.

1.3 RECAT-EU-PWS Maintenance

- PWS matrix

As the traffic mix is evolving over time and some aircraft types will become frequent at major European airports, the PWS matrix will periodically evolve as well to incorporate additional frequent aircraft types based on their data-driven characterisation

- RECAT-EU-PWS aircraft assignment list

Since new aircraft type designators are periodically added over time, the RECAT-EU-PWS aircraft assignment list will periodically evolve as well to incorporate additional aircraft types.

The aircraft type assignment logic is illustrated in Appendix C.

1.4 Applicability of RECAT-EU-PWS distance minima

The distance-based separation minima are static, being applicable under ATS surveillance service and **conditions (same as for RECAT-EU) defined in regulation EU 2020/469 ATS.TR.220 and ICAO Document 4444 PANS-ATM** Section 8.7.3.4.1, when:

a) an aircraft is operating directly behind another aircraft at the same altitude or less than 300 m (1 000 ft) below; or

b) both aircraft are using the same runway, or parallel runways separated by less than 760 m (2 500 ft); or

c) an aircraft is crossing behind another aircraft, at the same altitude or less than 300 m (1 000 ft) below.

1.5 How RECAT-EU-PWS can be operated ?

There are three ways to operate the RECAT-EU PWS solutions.

1) **"Pair-Wise application"** for arrivals and/or departure:

   the PWS minima can be applied as such, completed by the 20-category separation matrix for other landplane aircraft ICAO types (or any other category-based separation scheme approved by local regulation authority).

It must be noted that the list of pairwise aircraft types is based on frequent types in the European traffic for which data (in particular approach speed profile) are available for PWS minima determination. Locally the pairwise aircraft types will not all be found at an airport.

For covering all local traffic types, a local PWS matrix must be established, from the combination of the PWS matrix, and from the category-based scheme for the remaining other (less frequent) aircraft types.

The pair-wise application requires an ATC separation delivery tool, which can be distance-based or could also enable time-based separation and optimum runway delivery (TBS-ORD), as illustrated in Figure 3.

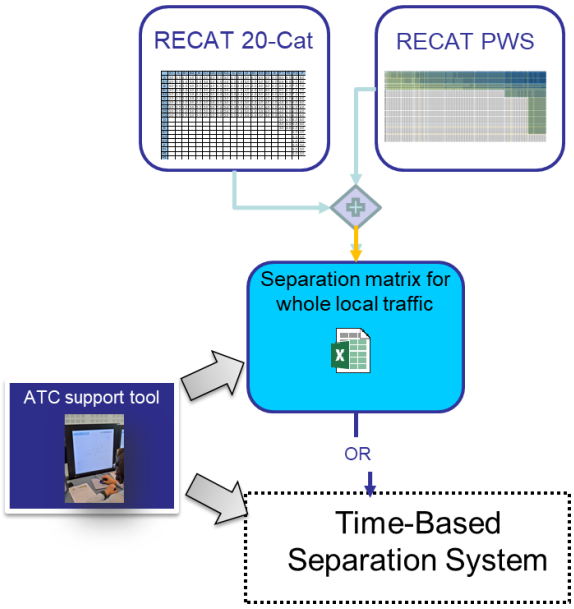

Figure 3: Operations of Pair-wise separation with support of ATC separation delivery tool

2) Customised N-category scheme

The RECAT-EU-PWS and RECAT-EU 20 CAT solutions can also be used to establish a **customized N-category scheme**, defined to be an optimum for a given traffic mix at an aerodrome, and built using a grouping of:

- categories of the 20-category scheme; or
- categories of the 20-category scheme complemented by another regulated standard (e.g. ICAO).

Such N-category scheme, applicable both on approach and departure, may need an ATC separation support tool, or not, depending on the number of categories and associated complexity of separation combination to be managed by ATC, as illustrated in Figure 4. The customized N-category separation scheme solution can correspond to RECAT-EU 6-CAT grouping (since RECAT-EU 20CAT minima are inclusive of it), but also allows further local optimization considering local traffic mix.

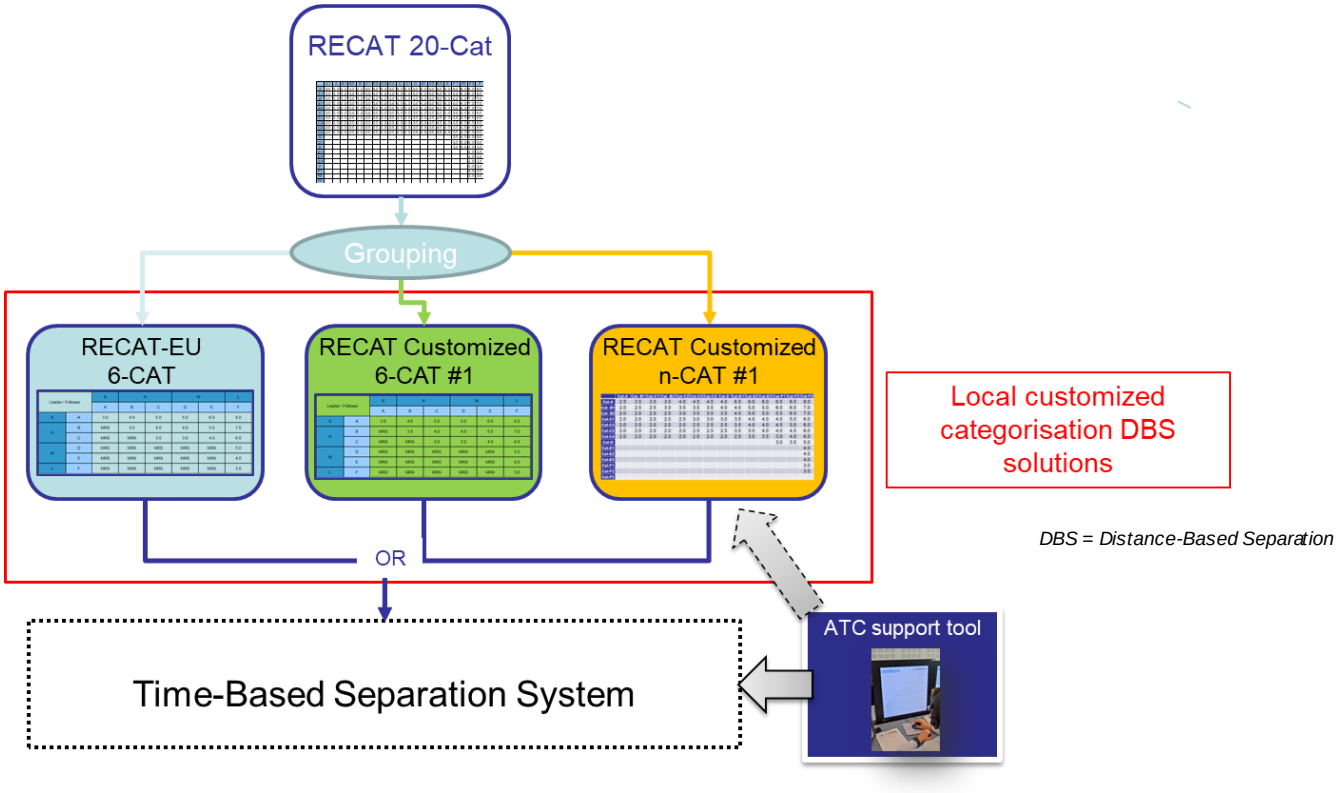

Figure 4: Operations of customised wake categories based on 20-CAT scheme with or without support of ATC separation delivery tool

Example of customised 7-CAT solution

The Figure 5 provides an example of customised 7-CAT wake turbulence separation scheme solution which can be of interest to some airports with high percentage of ICAO Medium wake category aircraft types.

	Cat-A1	Cat- B1	Cat-B2	Cat-C1	Cat-C2	Cat-C3	Cat-C4	Cat-D1	Cat-E1	Cat-E2	Cat-E3	Cat-F1	Cat-F2	Cat-F3
Cat-A1	2.5	4.0	4.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	7.0	7.0	8.0
Cat- B1	2.0	2.5	3.0	3.0	3.5	3.5	3.5	4.0	4.5	5.0	5.0	6.0	6.5	7.0
Cat- B2	2.0	2.0	2.5	2.5	3.0	3.5	3.5	3.5	4.5	5.0	5.0	5.5	6.5	7.0
Cat-C1	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	4.0	4.0	4.0	5.0	5.0	6.0
Cat-C3	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	3.5	4.0	4.0	4.5	5.0	6.0
Cat-C2	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	3.5	3.5	4.0	4.0	4.5	6.0
Cat-C4	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	3.0	3.5	3.5	4.0	6.0
Cat-D1												3.0	3.5	5.0
Cat-E1														4.0
Cat-E2														4.0
Cat-E3														4.0
Cat-F1														3.0
Cat-F2														3.0
Cat-F3														

	S	H	UM	MM Cat-E1	LM Cat-E2/3	SM / UL	LL
S		5.0	5.0	6.0	6.0	7.0	8.0
H		4.0	4.0	4.5	5.0	6.5	7.0
UM						3.5	5.0
MM Cat-E1							4.0
LM Cat-E2/-E3							4.0
SM / UL							3.0
LL							

Figure 5: Example of customised 7-CAT wake turbulence separation scheme derived from 20-CAT scheme

3) Hybrid ICAO-RECAT EU(-PWS)

For airports with specific traffic mix and frequent pairs involving heavy aircraft (e.g. A333-A320, B789-A320, or B789-B738), it is possible to keep operating ICAO legacy with a **wake minima enhancement between a limited number of specific pairs of aircraft types** (or group of pairs, e.g. A320 family following A330 family), for ATC procedural application or with limited system and HMI upgrade.

1.6 RECAT-EU-PWS safety case and key principles

The wake turbulence pair-wise separation (PWS) minima are directly determined from the **wake turbulence pair-wise risk assessment**, with detailed assurance provided in a Safety Case.

The minima are established by **direct comparison** between aircraft type pairs of wake turbulence encounter severity (determined in so-called reasonable worst-case conditions - RWC), and alignment onto levels defined by 'pivot' aircraft type pairs at ICAO separation minima as operated today, considered as acceptable.

Although the PWS design logic is to align most of the pairs to a higher Wake Turbulence (WT) severity exposure, some margins have been introduced by the selection of the reference pairs with corresponding WT severity level. Reference baseline pairs are selected to determine acceptable Roll Moment Coefficient (RMC) values for PWS design by alignment of other pairs to that WT severity level. The reference leader-follower pair could theoretically be a "worst-case" (most exposed) pair in ICAO scheme. However, the selected pairs should provide the assurance that

- the corresponding exposure level has been frequently experienced (aircraft type pair frequent in traffic mix in peak time at busiest European airports),
- that it does not lead to an increase of the risk of WT-induced accident and decreases this risk for the most exposed pairs, and
- it will provide an acceptable evolution in terms of overall risk.

The selected pivot pairs have, as leader, the AIRBUS A340-600 and cover three follower types, to accommodate different aircraft type configuration designs influencing Wake Vortex Encounter (WVE) impact, for acceptable severity alignment:

- the EMBRAER 145 (E145, 20m wingspan and 21 tons MTOM) for MEDIUM category jet types
- the ATR 42-500 (AT45, 24.6m and 19 tons) for MEDIUM category turbo-propeller types
- the Cessna 510 for LIGHT types
- the AIRBUS A310 (A310, 43.9m and 150 tons) for HEAVY types.

The PWS minima are then determined by aligning the calculated severity level (expressed in Roll Moment Coefficient – RMC) on that of reference pivot aircraft type pairs. Comparing PWS and ICAO minima, the WT risk in RWC is increased for the lowest severity levels, while the highest severity levels are reduced for smaller types, leading to a more aligned distribution.

Detailed safety assurance is presented in the EUROCONTROL Safety Case report on RECAT-EU-PWS minima for Arrival and Departure (ref: see Appendix B).

2. Delivering runway throughput benefits with RECAT-EU-PWS

As determined by the SESAR PJ02.01.04 solution validation results and performance assessment, RECAT-EU-PWS deployment will result in significant benefits in terms of runway capacity (increased arrival and departure throughput) and operational efficiency, further than RECAT-EU (based on 6 categories):

- Transitioning from legacy separation minima based on ICAO wake turbulence categories to the RECAT-EU-PWS separation minima can bring up to 10% increase in runway throughput during peak periods, depending on individual airport traffic mix.
  In addition, it should be noted that the use of a separation delivery tool (e.g. like for Time-Based Separation and Optimum Runway Delivery TBS-ORD) can bring another 5% increase thanks to enhanced separation consistency and predictability.

- At equivalent throughput, RECAT-EU-PWS also allows a reduction of the overall flight time for an arrival or departure sequence of traffic, and this is beneficial to the whole traffic sequence. This may offer more flexibility for the Controllers to manage the traffic.

- RECAT-EU-PWS will also enable more rapid recovery from adverse conditions, helping to reduce the overall delay and will also enable improvements in ATFM slot compliance through the flexibility afforded by reduced departure separations

Examples of PWS minima differences from standard ICAO Wake Turbulence Category or RECAT-EU 6-CAT are provided in Figure 6.

Lead/Follower aircraft type pairing	ICAO WTC minima	RECAT-EU minima	RECAT-EU PWS minima
A359/B77W – B763	4 NM (nautical miles)	4 NM	3.5 NM
A359/B77W – B764	4 NM	4 NM	3 NM
A333/B789 - B738 or B38M	5 NM	4 NM	3.5 NM
A333/B789 - A320 or A20N	5 NM	4 NM	3.5 NM
A333/B789 – BCS3 or BCS1	5 NM	4 NM	3.5 NM
A359/B77W/A333/B789 - E195/E190	5 NM	5 NM	4 NM
A359/B77W/A333/B789 - E175/E170	5 NM	5 NM	4.5 NM
B764/B763 - A320 or A20N	5 NM	3 NM	2.5 NM

Figure 6: Example of PWS minima differences from standard ICAO Wake Turbulence Category or RECAT-EU 6-CAT

3. RECAT-EU-PWS deployment considerations

As identified in the EUROCONTROL RECAT-EU-PWS safety case report, the following elements should be considered when deploying RECAT-EU-PWS minima:

- Ensuring traffic spacing **compatibility with runway occupancy time**
- Ensure **correct aircraft type data filed into flight plans**
- Ensuring Air Traffic Controllers appropriate training on ATC automation support and separation delivery tool for managing increased complexity
- Ensuring **Aircraft Operators and Flight Crews awareness** of
  - Locally applicable wake turbulence separation minima based on RECAT-EU-PWS (*).
  - Operations at or close to separation minima is associated to "High-Intensity Runway Operations" (e.g. minimizing runway occupancy time)
  - Possible overall increase in lower severity wake turbulence encounter frequency on approach / departure, and the recommendation for ensuring that cabin crews should be seated before final approach interception
- Ensuring safety monitoring in operations

(*) In case of Pair-wise separation application, the combination of possible separation minima is (too) complex to memorize unlike the reference conventional wake separation (e.g. 5NM for a Medium behind Heavy). However, what is of most interest for Flight Crews is the wake separation minima for the aircraft type he/she is flying on, and so the corresponding column from the separation matrix. Also the separation minima behind Heavy aircraft are grouped by clusters of Heavy aircraft type (in line with the Categories from the 20-CAT scheme), which significantly reduce the number of various minima cases. Examples for few aircraft types are provided in Figure 7

Leader Aircraft type	A320	E190	ATR72
A380	5 NM	6 NM	6 NM
A350/B77W/B744	4 NM	4 NM	5 NM
A330/B777	3.5 NM	4 NM	5 NM
MD11	3 NM	4 NM	4 NM
B767 / A300 / A310	2.5 NM	3 NM	3.5 NM
B757	2 NM	2.5 NM	2.5 NM

Figure 7: Examples of PWS minima for some aircraft types as followers behind various frequent large aircraft types as leader

Appendix A List of Aircraft Types with PWS minima

The list of aircraft types assigned to the pair-wise (PWS) wake turbulence scheme, with corresponding ICAO and RECAT-EU wake categories, are provided in Table 2:

Manufacturer	Model	ICAO Type Designator	ICAO Wake Turbulence Category	RECAT-EU
ANTONOV	An-148	**A148**	M	CAT-E
AIRBUS	A320NEO	**A20N**	M	CAT-D
AIRBUS	A321NEO	**A21N**	M	CAT-D
AIRBUS	A300B4-600	**A306**	H	CAT-C
AIRBUS	A300B2-1	**A30B**	H	CAT-C
AIRBUS	A310	**A310**	H	CAT-C
AIRBUS	A318	**A318**	M	CAT-D
AIRBUS	A319	**A319**	M	CAT-D
AIRBUS	A320	**A320**	M	CAT-D
AIRBUS	A321	**A321**	M	CAT-D
AIRBUS	A330-200	**A332**	H	CAT-B
AIRBUS	A330-300	**A333**	H	CAT-B
AIRBUS	A340-200	**A342**	H	CAT-B
AIRBUS	A340-300	**A343**	H	CAT-B
AIRBUS	A340-500	**A345**	H	CAT-B
AIRBUS	A340-600	**A346**	H	CAT-B
AIRBUS	A350-900 XWB	**A359**	H	CAT-B
AIRBUS	A350-1000 XWB	**A35K**	H	CAT-B
AIRBUS	A380-800	**A388**	J	CAT-A
ATR	ATR-42-300	**AT43**	M	CAT-E
ATR	ATR-42-500	**AT45**	M	CAT-E
ATR	ATR-72-201	**AT72**	M	CAT-E
ATR	ATR-72-500	**AT75**	M	CAT-E
RAYTHEON	300 (B300) Super King Air 350	**B350**	M	CAT-F
BOEING	737 MAX-8	**B38M**	M	CAT-D
BRITISH AEROSPACE	BAe-146-300	**B463**	M	CAT-E
BOEING	717-200	**B712**	M	CAT-E
BOEING	737-300	**B733**	M	CAT-E
BOEING	737-400	**B734**	M	CAT-E
BOEING	737-500	**B735**	M	CAT-E
BOEING	737-600	**B736**	M	CAT-D
BOEING	737-700	**B737**	M	CAT-D
BOEING	737-800B	**B738**	M	CAT-D

BOEING	737-900	**B739**	M	CAT-D
BOEING	747-400 (international, winglets)	**B744**	H	CAT-B
BOEING	747-8	**B748**	H	CAT-B
BOEING	757-200	**B752**	M	CAT-C
BOEING	757-300	**B753**	M	CAT-C
BOEING	767-200	**B762**	H	CAT-C
BOEING	767-300	**B763**	H	CAT-C
BOEING	767-400	**B764**	H	CAT-C
BOEING	777-200ER	**B772**	H	CAT-B
BOEING	777-300	**B773**	H	CAT-B
BOEING	777-200LR	**B77L**	H	CAT-B
BOEING	777-300ER	**B77W**	H	CAT-B
BOEING	787-8 Dreamliner	**B788**	H	CAT-B
BOEING	787-9 Dreamliner	**B789**	H	CAT-B
AIRBUS	A-220-100	**BCS1**	M	CAT-D
AIRBUS	A-220-300	**BCS3**	M	CAT-D
BEECH	400 Beechjet	**BE40**	M	CAT-F
CESSNA	P210 (turbine)	**C10T**	L	CAT-F
CESSNA	525A Citation CJ2	**C25A**	L	CAT-F
CESSNA	525B Citation CJ3	**C25B**	L	CAT-F
CESSNA	525C Citation CJ4	**C25C**	M	CAT-F
CESSNA	Citation 1SP	**C501**	L	CAT-F
CESSNA	510 Citation Mustang	**C510**	L	CAT-F
CESSNA	525 CitationJet	**C525**	L	CAT-F
CESSNA	Citation 2	**C550**	L	CAT-F
CESSNA	560 Citation 5	**C560**	M	CAT-F
CESSNA	560XL Citation Excel	**C56X**	M	CAT-F
CESSNA	680 Citation Sovereign	**C680**	M	CAT-F
BOMBARDIER	Challenger 300	**CL30**	M	CAT-E
CANADAIR	CL-600 Challenger 600	**CL60**	M	CAT-E
CANADAIR	Regional Jet CRJ-200	**CRJ2**	M	CAT-E
CANADAIR	Regional Jet CRJ-700	**CRJ7**	M	CAT-E
CANADAIR	Regional Jet CRJ-900	**CRJ9**	M	CAT-E
FAIRCHILD DORNIER	328	**D328**	M	CAT-F
DE HAVILLAND CANADA	DHC-8-400 Dash 8	**DH8D**	M	CAT-E
EMBRAER	EMB-120 Brasilia	**E120**	M	CAT-F
EMBRAER	EMB-135	**E135**	M	CAT-E
EMBRAER	EMB-145	**E145**	M	CAT-E
EMBRAER	EMB-170	**E170**	M	CAT-E
EMBRAER	EMB-190	**E190**	M	CAT-E
EMBRAER	EMB-195	**E195**	M	CAT-E
FOKKER	100	**F100**	M	CAT-E
FOKKER	F-27 Friendship	**F27**	M	CAT-E
DASSAULT	Falcon 2000	**F2TH**	M	CAT-E
FOKKER	Fokker 50	**F50**	M	CAT-E

FOKKER	70	**F70**	M	CAT-E
DASSAULT	Falcon 900	**F900**	M	CAT-E
DASSAULT	Falcon 50	**FA50**	M	CAT-E
DASSAULT	Falcon 7X	**FA7X**	M	CAT-E
IAI	Galaxy	**GALX**	M	CAT-E
BOMBARDIER	BD-700 Global 5000	**GL5T**	M	CAT-E
RAYTHEON	Sentinel	**GLEX**	M	CAT-E
GULFSTREAM AEROSPACE	Gulfstream G400/G450	**GLF4**	M	CAT-E
GULFSTREAM AEROSPACE	Gulfstream G500/G550	**GLF5**	M	CAT-E
RAYTHEON	Hawker 800	**H25B**	M	CAT-F
RAYTHEON	Hawker 1000	**H25C**	M	CAT-F
RUAG	Dornier 328 JET Envoy	**J328**	M	CAT-E
LEARJET	35	**LJ35**	M	CAT-F
LEARJET	40	**LJ40**	M	CAT-F
LEARJET	45	**LJ45**	M	CAT-F
LEARJET	60	**LJ60**	M	CAT-F
MCDONNELL DOUGLAS	MD-11	**MD11**	H	CAT-C
MCDONNELL DOUGLAS	MD-82	**MD82**	M	CAT-D
MCDONNELL DOUGLAS	MD-83	**MD83**	M	CAT-D
PIPER	PA-46-500TP Malibu Meridian	**P46T**	L	CAT-F
PIPER	PA-34 Seneca	**PA34**	L	CAT-F
PILATUS	Eagle	**PC12**	L	CAT-F
BRITISH AEROSPACE	RJ-100	**RJ1H**	M	CAT-E
BRITISH AEROSPACE	RJ-85	**RJ85**	M	CAT-E
SAAB-FAIRCHILD	SF-340	**SF34**	M	CAT-F

Table 2: List of aircraft types assigned to the pair-wise (PWS) wake turbulence scheme, with corresponding ICAO and RECAT-EU wake categories

Appendix B EUROCONTROL RECAT-EU-PWS Safety Case documentation

The RECAT-EU-PWS safety case documentation is essentially composed of the following:

1. EUROCONTROL RECAT-EU-PWS Safety case report

Appendix B – Wake turbulence severity metric (Restricted access under NDA[1])

Appendix C – Wake vortex data (Restricted access under NDA[1])

Appendix D – Aircraft types and arrival traffic Data (Restricted access under NDA[1])

Appendix E – Wake turbulence risk assessment additional results

Appendix F - RECAT-EU Appendix on Wake turbulence risk assessment for CAT-A / A380 (Restricted access under NDA[2])

Appendix G – RECAT-EU-PWS Aircraft assignment list (MS Excel file)

Appendix H – RECAT-EU-PWS Pair-wise minima matrix (MS Excel file)

Like with RECAT-EU, the RECAT-EU-PWS Aircraft assignment list will be maintained and published following the regulatory approval process.

[1] Covered by Non-Disclosure Agreement (NDA) with EUROCONTROL as containing Stakeholders proprietary data

[2] Covered by Non-Disclosure Agreement (NDA) with AIRBUS as containing proprietary data

Appendix C Aircraft type assignment logic into RECAT-EU-PWS scheme

The assignment logic of aircraft types into the RECAT-EU-PWS scheme is illustrated in Figure 8:

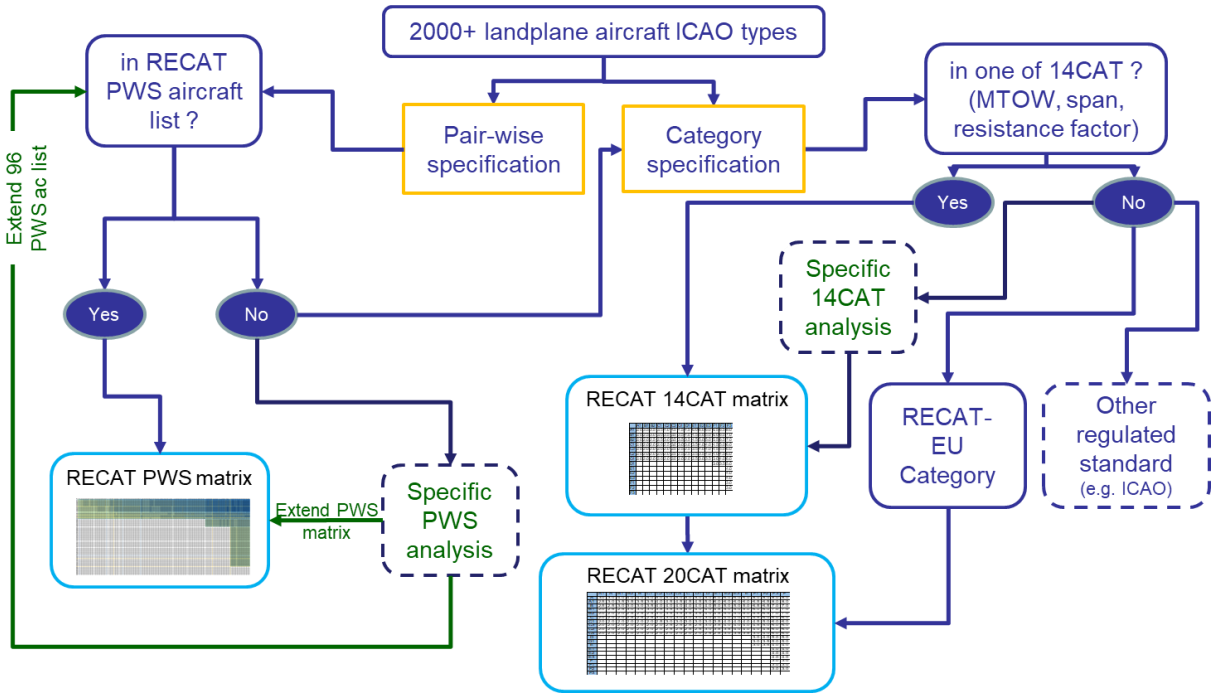

Figure 8: Aircraft type assignment logic into the RECAT-EU-PWS scheme

ABBREVIATIONS

ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Flow Management
ATS	Air Traffic Services
CAT	Category
EASA	European Aviation Safety Agency
EUROCONTROL	European Organisation for the Safety of Air Navigation
ICAO	International Civil Aviation Organisation
MRS	Minimum Radar Separation
MSS	Minimum Surveillance Separation
MTOM	Maximum certificated Take-Off Mass
MTOW	Maximum Take-Off Weight
NATS	UK National Air Traffic Services
NDA	Non-Disclosure Agreement
NM	Nautical Mile
NMD	EUROCONTROL Network Management Directorate
ORD	Optimum Runway Delivery
PWS	Pair-Wise Separation
R&D	Research and Development
RECAT	Re-categorisation
RMC	Roll Moment Coefficient
RWC	Reasonable Worst-case Conditions
S-PWS-A	Static Pair-Wise Separation for Approach
S-PWS-D	Static Pair-Wise Separation for Departures
TBS	Time-Based Separation
WT	Wake Turbulence

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