SUPPORTING EUROPEAN AVIATION

Runway Throughput Enhancement Solutions

Ways to increase airport capacity

Valerio Cappellazzo
EUROCONTROL NM Airport Operations

Supporting Optimisation of Airport Operations

Aerodrome Capacity studies (incl. HF)

Multi-disciplinary support

- ✈ Airport Data analytics
- ✈ Airside Operations
- ✈ Landside Process
- ✈ Human Factors

Airport Operational Optimization

Continuous Capacity Performance Monitoring
'CCPM' application / service

Runway Performance (focused) studies
Solutions Deployment support / guidance

Runway Throughput Enhancement Solutions

ICAO

Arrival and Departure Throughput depends on time separation

- Runway capacity / throughput is directly linked to the **applied separation / spacing**
- Every **constraint** counts, and **every time saving matters..**

100s average separation means 36 landings per hour
90s average separation means 40 landings per hour

Optimising separation standards

Optimising separation delivery

Solutions for Increasing ARR & DEP Throughput

Optimising

- ✈ Wake Turbulence Separation on ARR (final APP) and DEP
  - ☑ RECAT-EU & PWS solution
- ✈ Runway Occupancy Time spacing on ARR (final APP)
  - ☑ ROCAT solution
- ✈ Delivery to separation minima on ARR (final APP)
  - ☑ TBS-ORD solution
- ✈ Delivery to separation minima on DEP
  - ☑ OSD solution

Wake ICAO WTG / RECAT-EU / -PWS

Optimising separation standards

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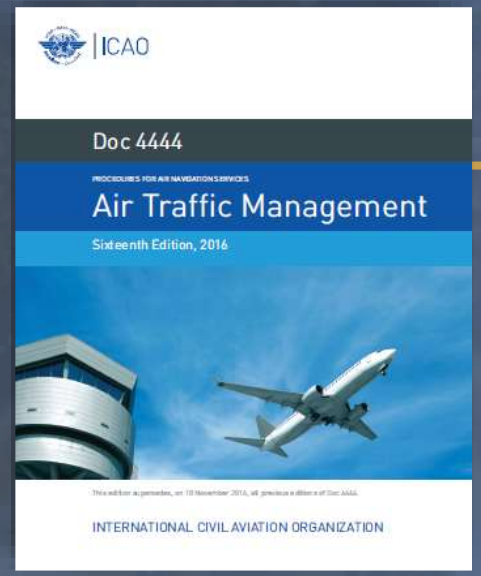
ICAO Wake Turbulence Groups (WTG)

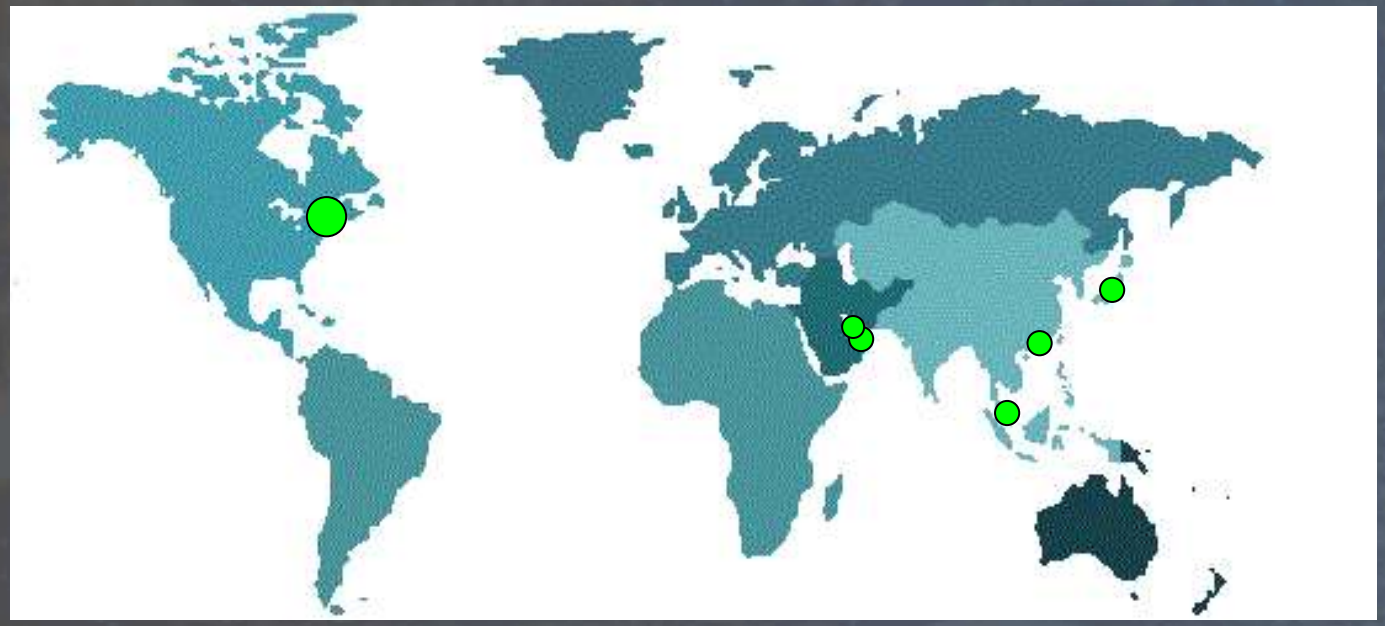
SUPER	HEAVY		MEDIUM			LIGHT
A	B	C	D	E	F	G
A388	A124	A306	A318	B732	AT43	FA20
		A30B	A319	B733	AT45	D328
	A332	A310	A320	B734	AT72	E120
	A333		A321	B735		BE40
	A343	B762			B462	BE45
	A345	B763	B736	DH8D		CL30
	A346	B764	B737		CRJ1	H25B
	A359		B738	E190	CRJ2	
		C135	B739		CRJ7	JS32
	AN22			F50	CRJ9	JS41
		DC10	B752	F70		
	B744		B753	F100	E135	LJ35
	B748	IL76			E145	LJ60
	B772		BCS1	SU95	E170	
	B773	L101	BCS3			P180
	B77L				GLF4	
	B77W	MD11	MD82			C650
	B788		MD83		RJ1H	C525
	B789	TU22	MD87			C180
		TU95	MD88		SF34	C152
	IL96		MD90			



Legacy	SUPER	HEAVY		MEDIUM			LIGHT
RECAT	CAT-A	CAT-B	CAT-C	CAT-D	CAT-E	CAT-F	CAT-G
Baseline Criteria	M ≥ 136 t 80 m ≥ b > 74,7m	M ≥ 136 t 74,7m ≥ b > 53,34m	M ≥ 136 t 53,34m ≥ b > 38,1m	136t > M ≥ 18,6t 38,1m > b > 32 m	100 t > M ≥ 18,6 t 32m ≥ b > 27,43m	100 t > M ≥ 18,6 t b < 27,43m	18,6 t > M
Aircraft type examples	A380	A124 / A330 / B777	MD11 / B767	B757 / A320 / B737NG / BCS1	E190 / DH8D	E170 / ATR72 / CRJ1	CL30 / LIGHT
A380		4	5	5	6	6	8
A124 / A330 / B777		3	4	4	5	5	7
MD11 / B767				3	3.5	3.5	6
B757 A320 / B737NG							4
E190 / DH8D							4
E170 / ATR72 / CRJ1							
CL30 / LIGHT							

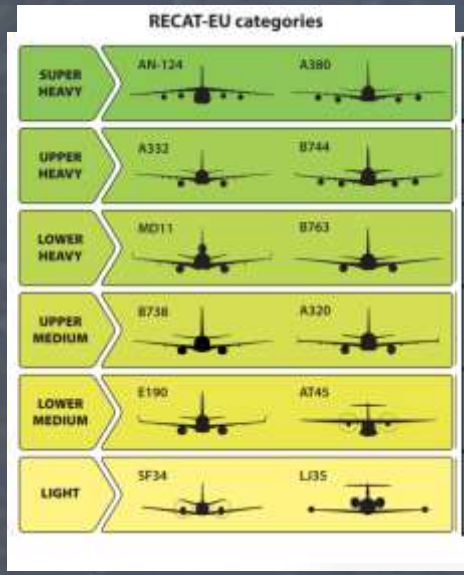
Examples of common aircraft types

WTG deployment overview



- ✓ Doha
- ✓ Dubai
- ✓ Hong Kong
- ✓ Singapore
- ✓ Tokyo Haneda & Narita
- ✓ Toronto

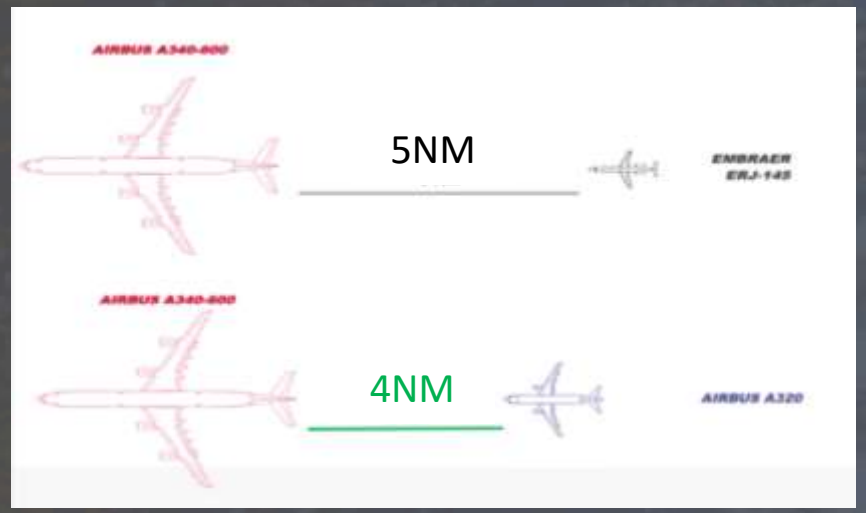
RECAT-EU - Optimised wake separation scheme

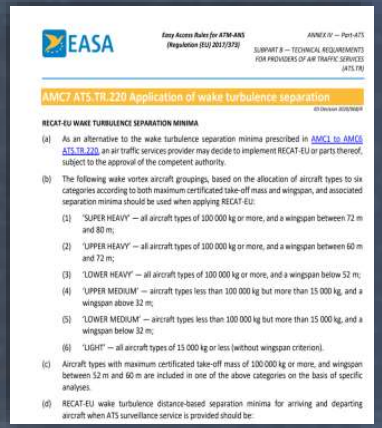


SUPER HEAVY	UPPER HEAVY	LOWER HEAVY	UPPER MEDIUM	LOWER MEDIUM	LIGHT
3.0	4.0	5.0	5.0	6.0	8.0
	3.0	4.0	4.0	5.0	7.0
	MRS*	3.0	3.0	4.0	6.0
					5.0
					4.0
					3.0

Reduced

Increased





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RECAT-EU in Operations

Full scheme

- **LFPG & LFPB – De Gaulle Approach**
  DBS minima
- **LEBL – Barcelona Approach)**
  DBS minima

- **EGLL – London Approach**
  DBS for ARR (in conjunction with TBS)
  Time minima for DEP
- **EHAM – Amsterdam Approach** DBS for ARR (in conjunction with TBS)

Hybrid

- **LOWW – Vienna Approach**
  DBS minima

Partial scheme

- **EPWA Warsaw: Upper Heavy (A330/A350/B777/B787) and Upper Medium (A220/A320/B737NG-MAX/ E2)**

- **EDDP Leipzig/Halle & EDDK Cologne/Bonn**
  procedure only for B757, B767, A300

- **LFBO – Toulouse for AIRBUS flight (all types) as followers**

Static Pair-Wise Separation (S-PWS)

SESAR solution PJ02.01.04

Leader / Follower		Super Heavy	Upper Heavy	Lower Heavy	Upper Medium	Lower Medium	Light
		A	B	C	D	E	F
Super Heavy	A	3 NM	4 NM	5 NM	5 NM	6 NM	8 NM
Upper Heavy	B		3 NM	4 NM	4 NM	5 NM	7 NM
Lower Heavy	C		(*)	3 NM	3 NM	4 NM	6 NM
Upper Medium	D						5 NM
Lower Medium	E						4 NM
Light	F						3 NM

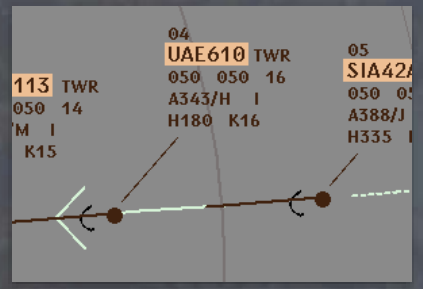
- **103x103 pair-wise separation matrix**
- **Covering most frequent aircraft types (97 % of top 25 ECAC traffic)**

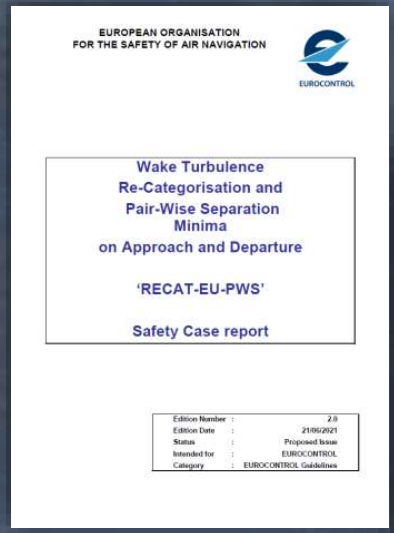
PWS (103x103)

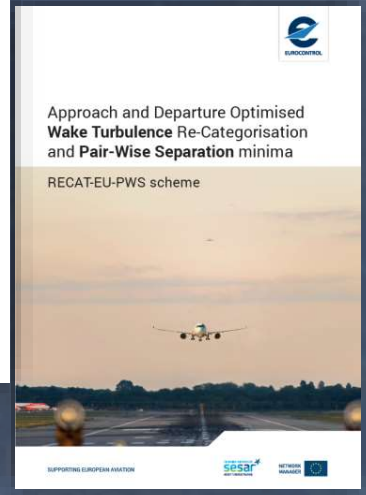
Leader Aircraft type	A320	E190	ATR72
A380	5 NM	6 NM	6 NM
A350/B77W/B744	4 NM	4 NM	5 NM
A330/B777	3.5 NM	4 NM	5 NM
MD11	3 NM	4 NM	4 NM
B767 / A300 / A310	2.5 NM	3 NM	3.5 NM
B757	2 NM	2.5 NM	2.5 NM

20-CAT

	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







https://www.eurocontrol.int/publication/recat-eu-pws-scheme

RECAT-EU-PWS in Operations

Full scheme

- **EGLL – London Approach** - since Dec 2024 !
  for ARR (in conjunction with TBS)

iROT / ROCAT spacing

Optimising separation standards

Reduced Surveillance Separation Minima (RSSM) and ROT

8.7.3 Separation minima based on ATS surveillance systems (PANS-ATM)

A reduced separation minimum of 4.6 km (**2.5 NM**) may be applied, provided:

i. the average runway occupancy time of landing aircraft is proven, by means such as data collection and statistical analysis and methods based on a theoretical model, not to exceed 50 seconds;

ii. Good braking action

iii. an ATS surveillance system with appropriate azimuth and range resolution and an update rate of 5 seconds or less is used in combination with suitable displays;

…

- The ROT criteria needs to be satisfied by **all traffic**, impairing benefits from MRS reduction if only some aircraft does not meet the criteria on average

EUROCONTROL

Reduced Surveillance Separation Minima (RSSM) and ROT

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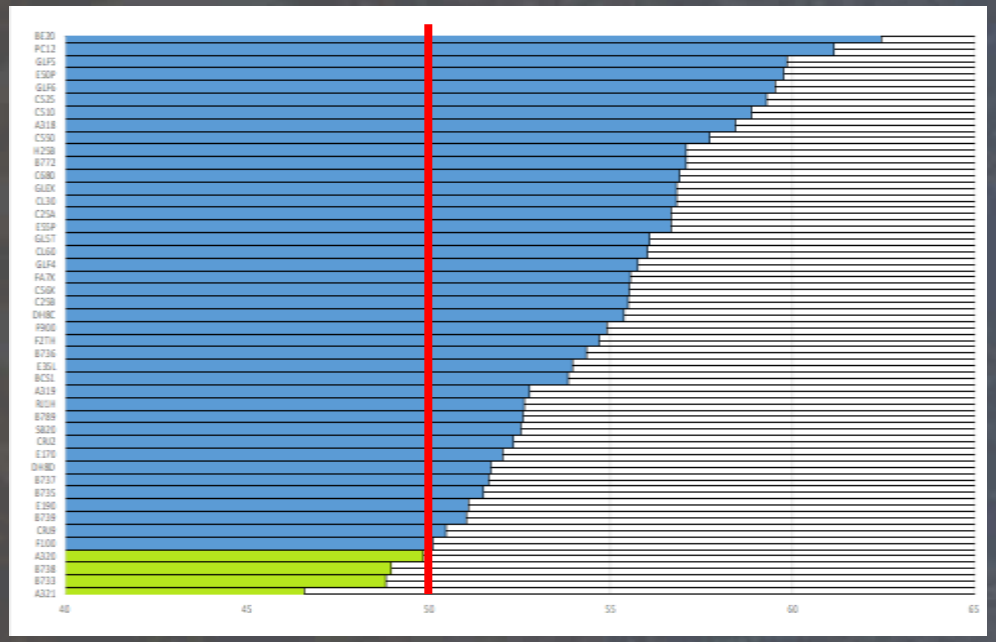
Optimised ROT spacing based on Local Runway Occupancy Time Characterisation

ROCAT (iROT) Solution (SESAR ref. PJ02.08.03)

Up to 5 -10+ %* ARR THP

* Depending on traffic mix



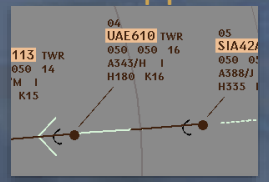
based on local ROT characterisation (per runway, aircraft type)

iROT (Notional)

	Heavy	A320	A319	B738	BCS3	E190	DH8D	...	Light
Heavy	4.0	5.0	5.0	5.0	5.0	5.0	5.0	...	6.0
A321	2.6	2.6	2.6	2.6	2.6	2.6	2.6	...	5.0
B738	2.7	2.7	2.7	2.7	2.7	2.7	2.7	...	5.0
A319	2.5	2.5	2.5	2.5	2.5	2.5	2.5	...	5.0
BCS3	2.6	2.6	2.6	2.6	2.6	2.6	2.6	...	5.0
GLF5	2.9	2.9	2.9	2.9	2.9	2.9	2.9	...	5.0
...	...	...	...	...	...	...	...	...	...
Light	3.0	3.0	3.0	3.0	3.0	3.0	3.0	...	3.0

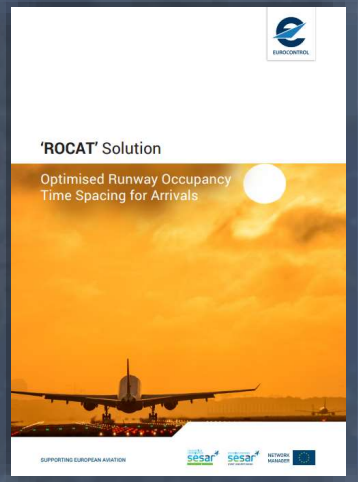
Wake | MRS | ROT

HMI support



ROCAT

Follower / Leader	Heavy	Medium (low ROT)	Medium (high ROT)	Light
Heavy	4 NM	5 NM	5 NM	6 NM
Medium (low ROT)	2.5 NM	2.5 NM	2.5 NM	5 NM
Medium (high ROT)	3 NM	3 NM	3 NM	5 NM
Light	3 NM	3 NM	3 NM	3 NM



https://www.eurocontrol.int/publication/optimised-runway-occupancy-time-spacings-arrivals

ROCAT in ICAO

- In contact with ICAO SASP to develop a draft PFA and guidelines on ROCAT to PANS ATM 4444

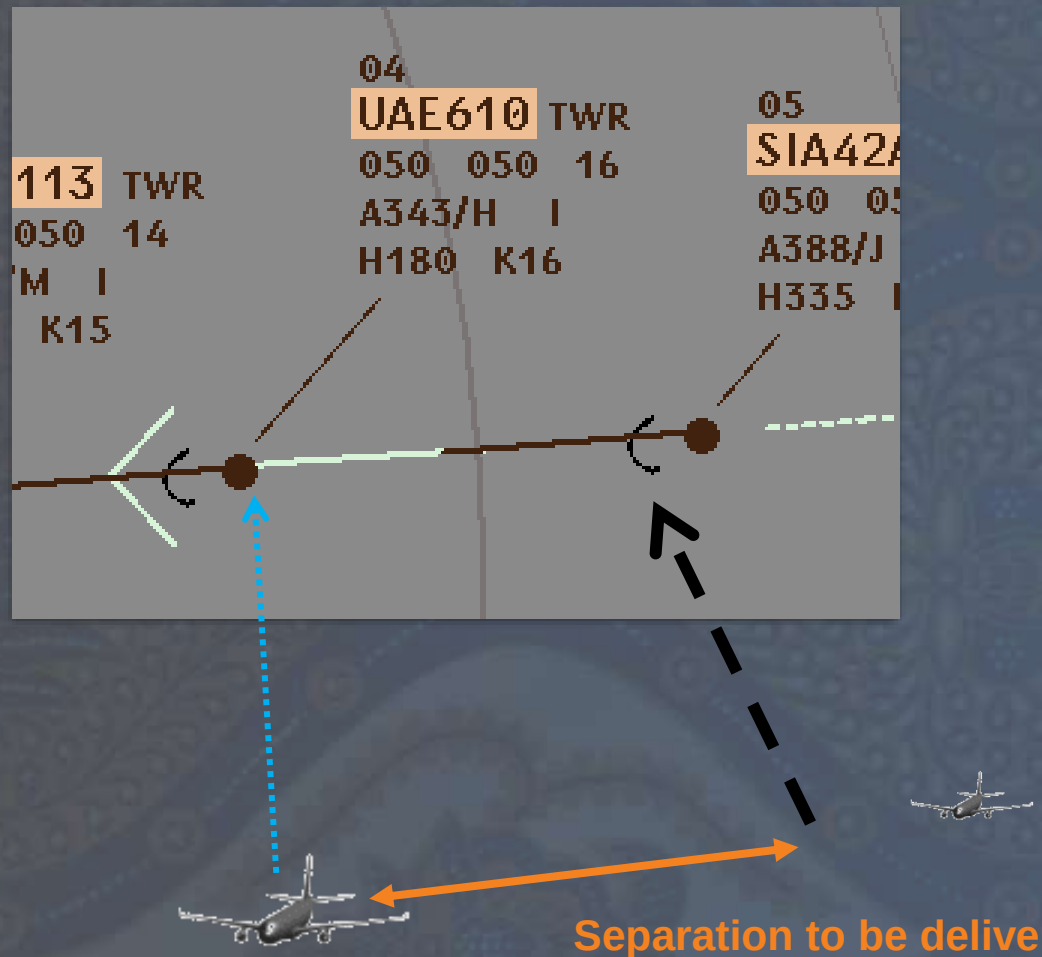
Separation Delivery Tool

FTDI - Final Approach Separation Indicator

Supporting / Optimising separation delivery

ICAO

Final Target Distance (FTD) indicator (between arrival traffic pairs)

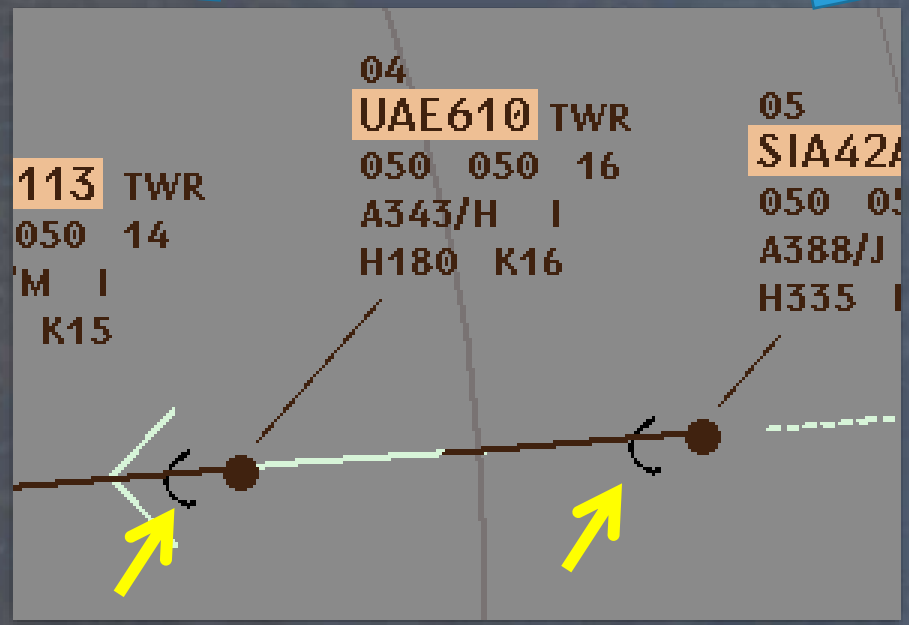


Final Target Distance (FTD) indicator for distance-based minima on final approach

Minimum Surveillance / Radar Separation

Wake Turbulence Distance-Based Separation (DBS) Minima

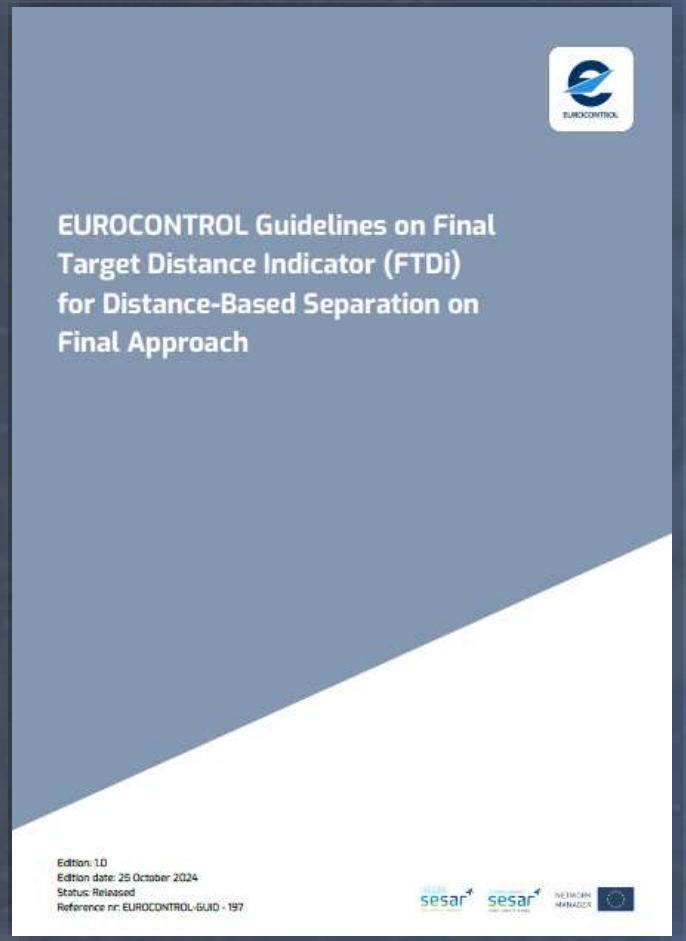
A-ROT / Gap Distance-Based **spacing** Minima



DBS tool / FTDi

Functionality becomes available by ATC System Providers

https://www.eurocontrol.int/publication/ftdi-solution



https://www.eurocontrol.int/publication/eurocontrol-guidelines-final-target-distance-indicator-ftdi-distance-based-separation

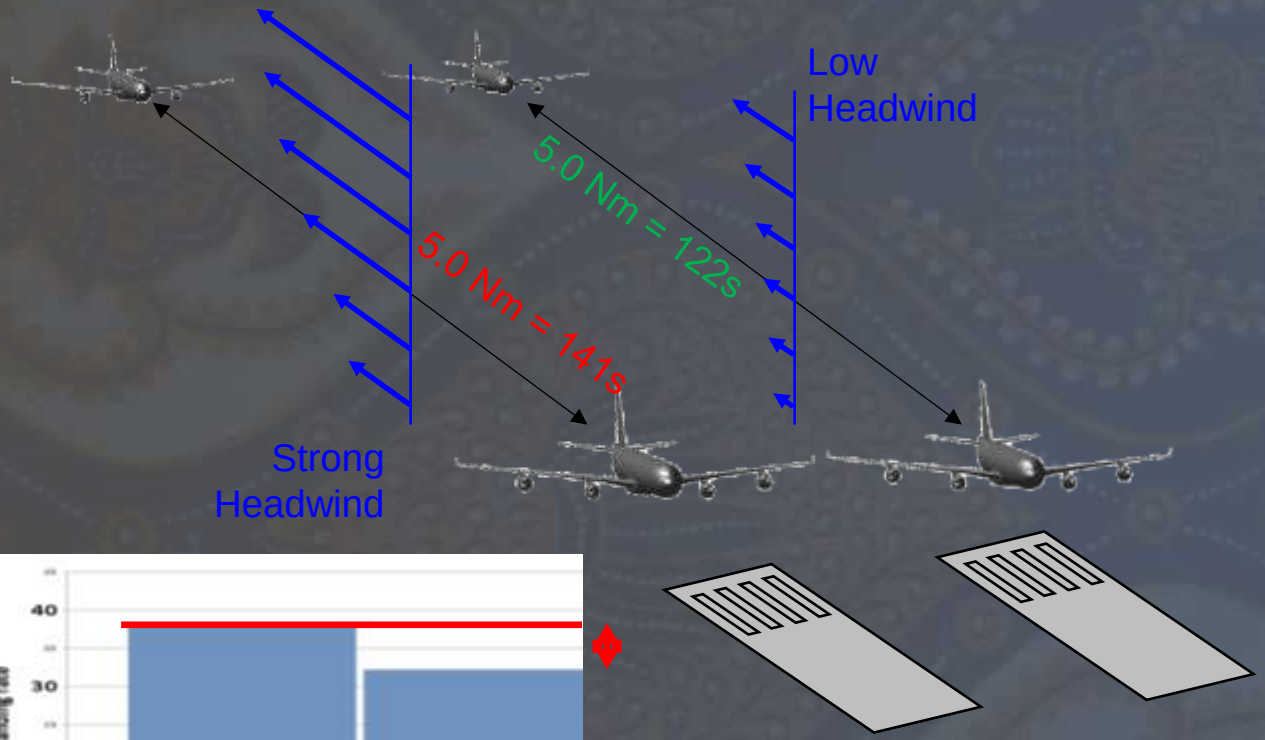
Time-Based Separation (TBS)

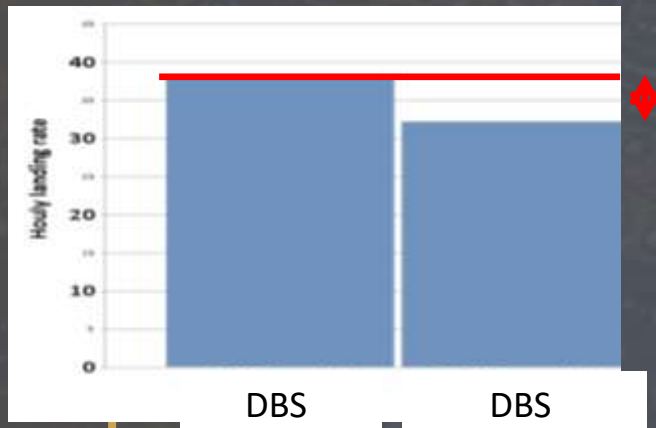
Optimising separation standards

Time-Based Separation (TBS)

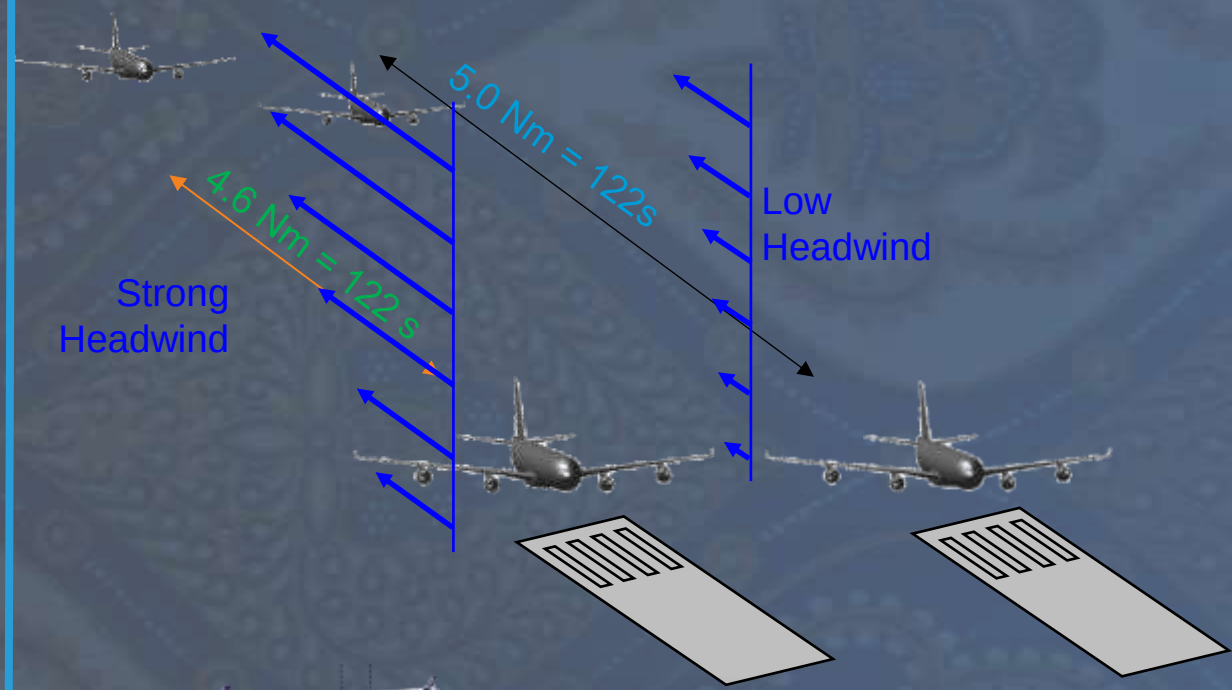
SESAR Sol#64

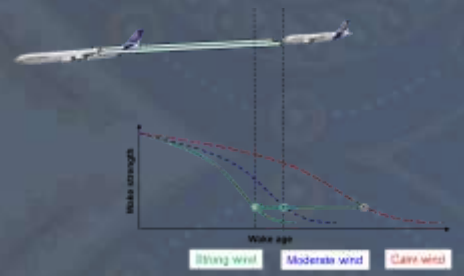
Strong headwind increases time separation for constant distance applied





TBS permits the reduction of distance separations, while maintaining constant time across headwind conditions





Time-Based Separation with Final Target Distance (FTD) indicator

Headwind mitigation

Resilience to headwind

Predictability & Efficiency

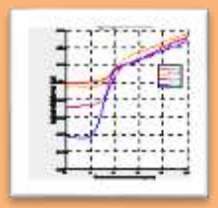
System evolution

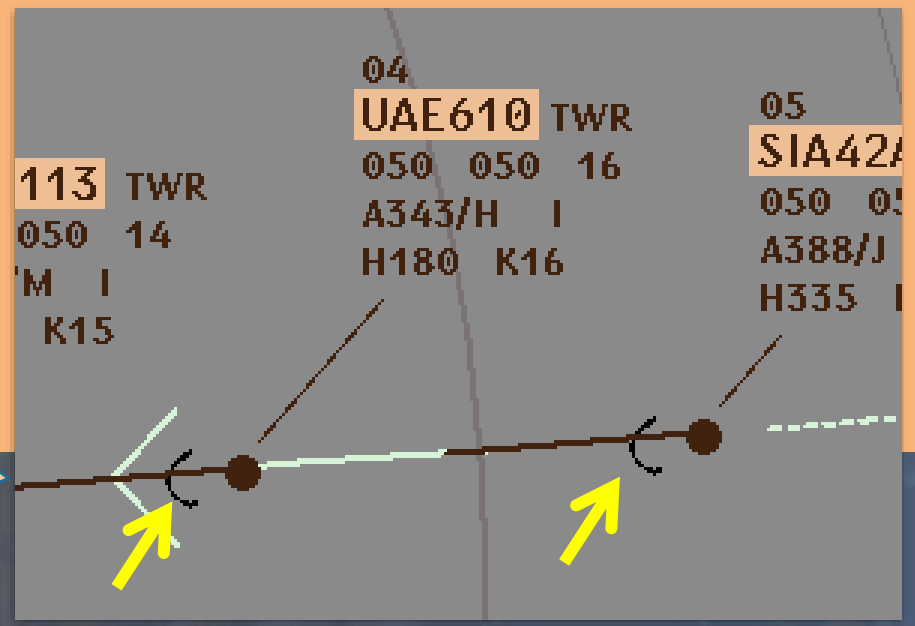
Level 1

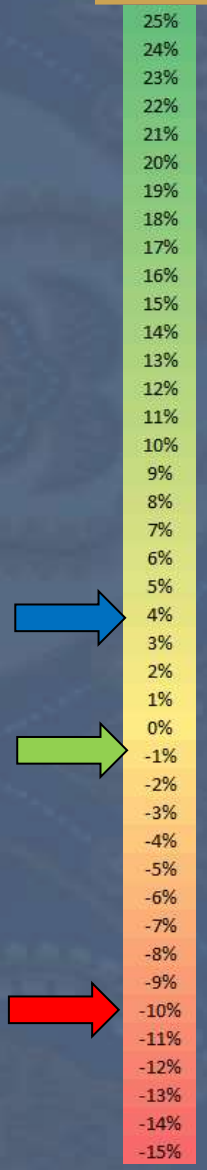
Level 2

Level 3

- Full time based separation (TBS) tool including HMI, wind profile and aircraft speed behaviour







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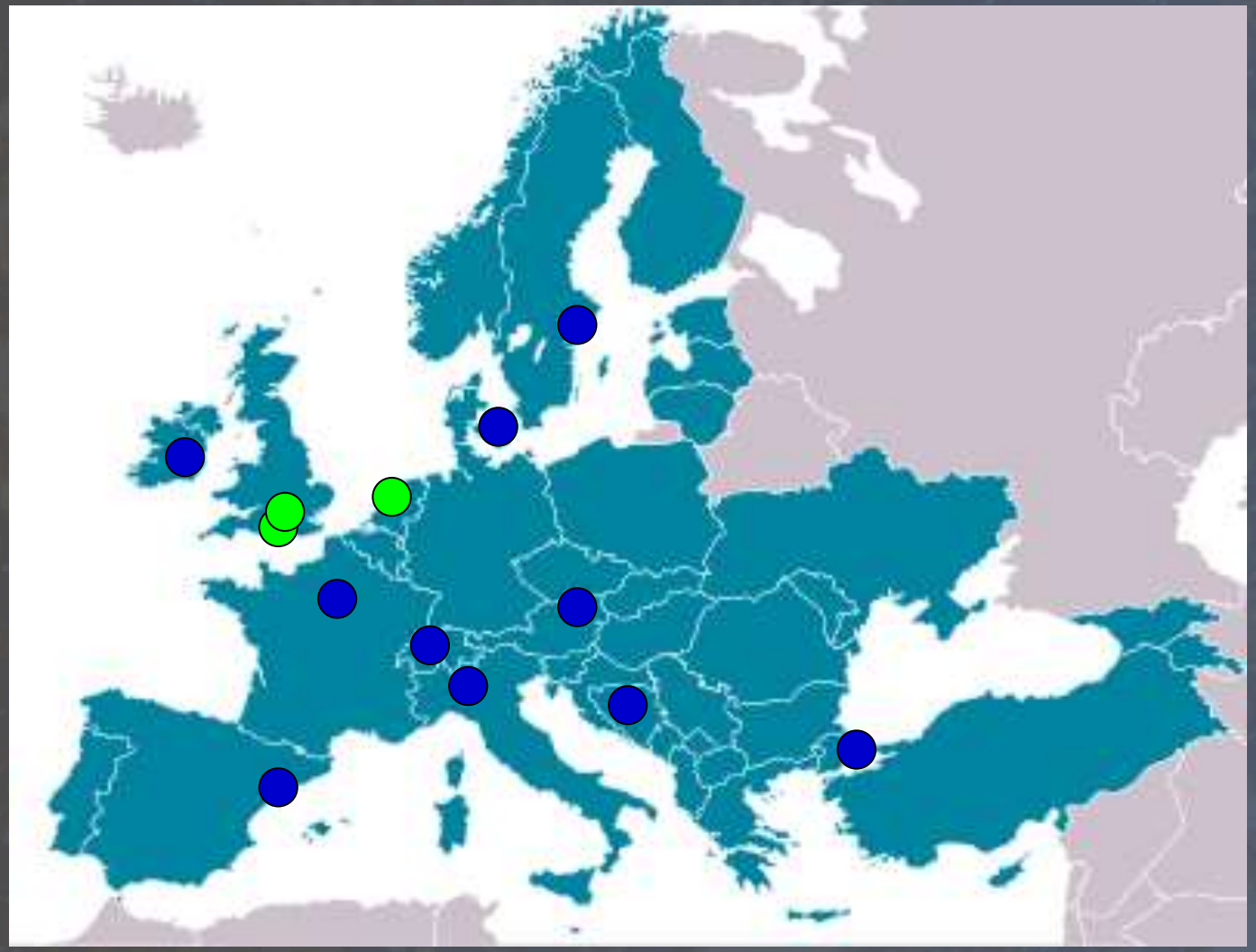
TBS (& ORD) Deployment view



- ✓ London Approach to Heathrow
- ✓ Amsterdam
- ✓ Gatwick

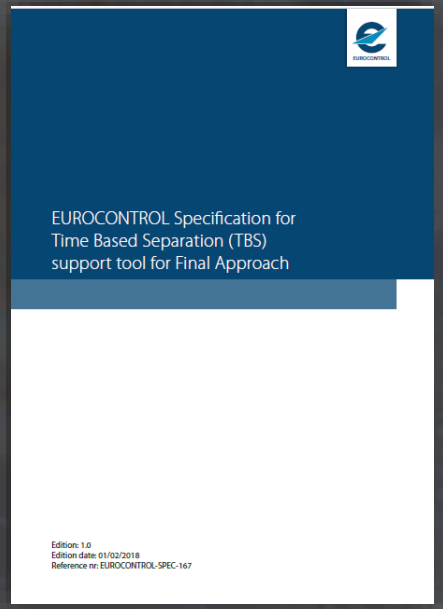
Arrivals (in conjunction with RECAT-EU = eTBS)

Deployment interests/plans:

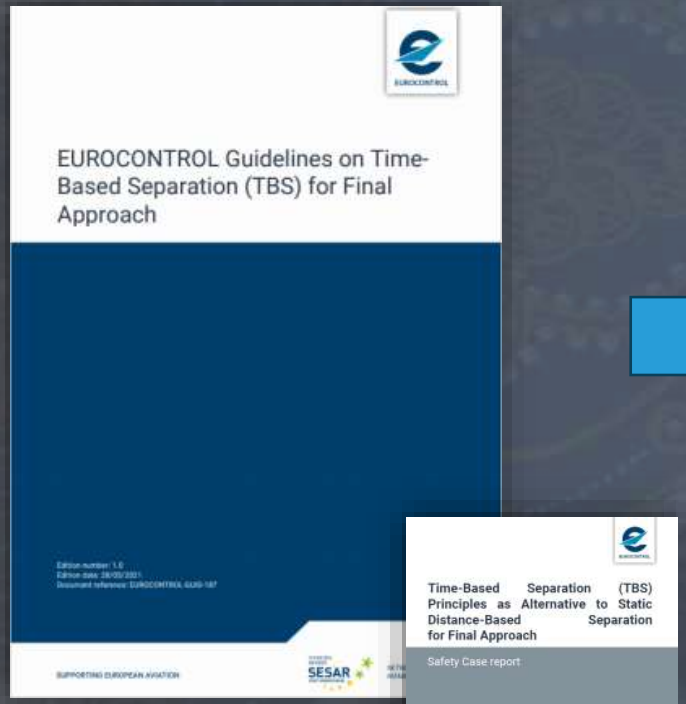
- Vienna / Copenhagen / Dublin / Stockholm / Zagreb
- Barcelona
- Istanbul
- Paris CDG
- Zurich
- ..

EUROCONTROL SPEC & GUID

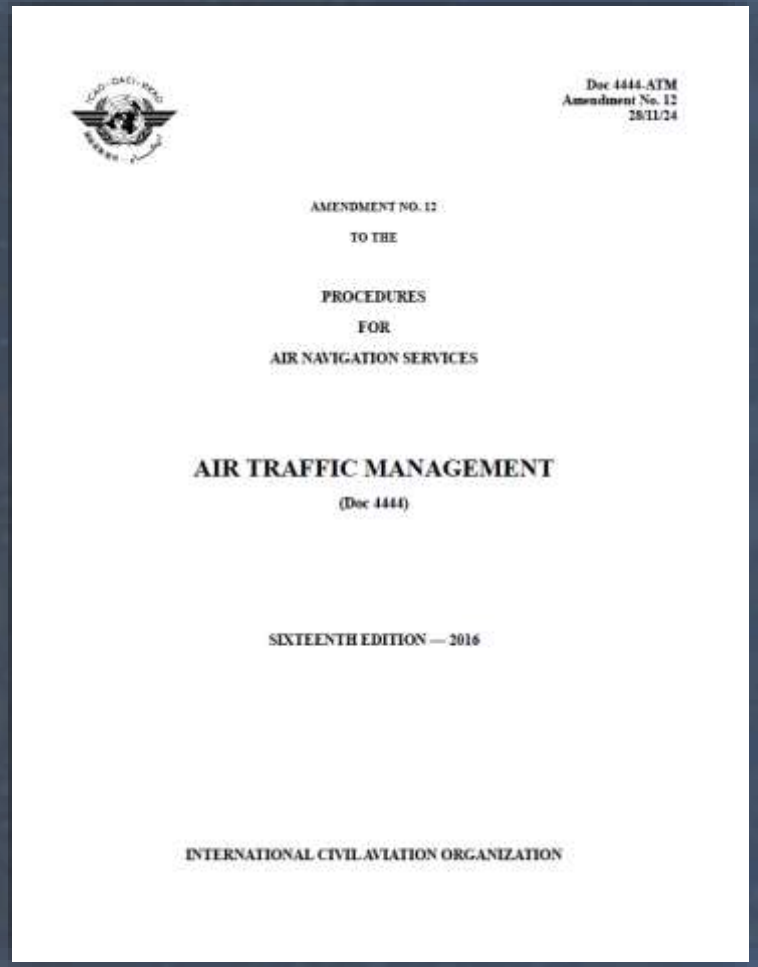
TBS Specification SPEC-167



TBS Guidelines (GUID-187)



https://www.eurocontrol.int/publication/eurocontrol-guidelines-time-based-separation-tbs-final-approach



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ORD – Optimised Runway Delivery

Supporting / Optimising separation delivery

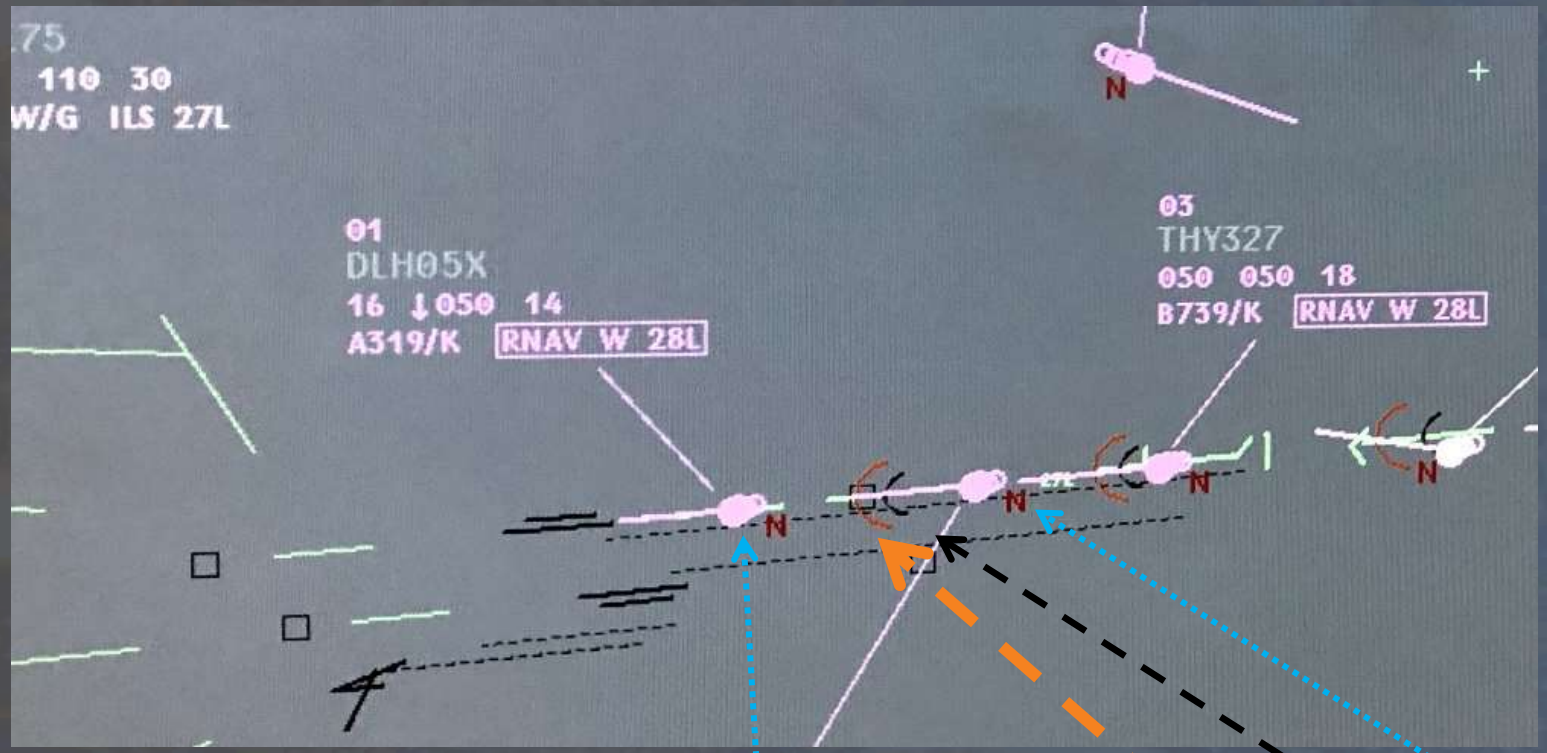
Compression Effect

Optimum separation delivery also requires efficient anticipation of “the compression effect” caused by aircraft speed reduction in final approach phase

Compression Effect

Optimum separation delivery also requires efficient anticipation of “the compression effect” caused by aircraft speed reduction in final approach phase

TBS-ORD Separation Distance Indicators (EUROCONTROL LORD Demonstrator)



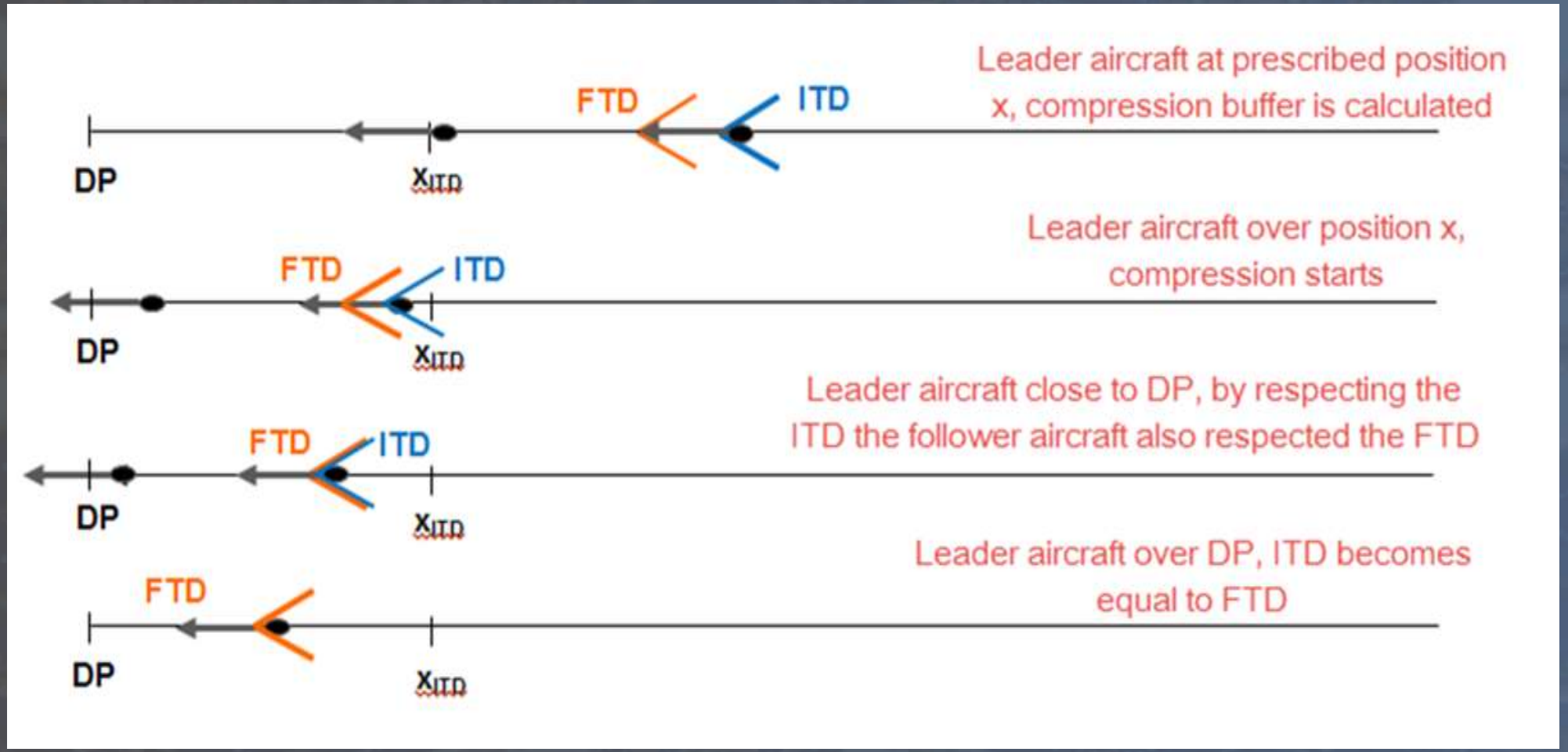
TBS delivery **necessitates Distance Indicators**

ATCOs applies **spacing buffers** for **managing compression on final and ensuring separation compliance** till landing

Compression buffer = Initial Target Distance (ITD)

Separation to be delivered = Final Target Distance (FTD)

Separation Spacing Indicators – FTD & ITD logic

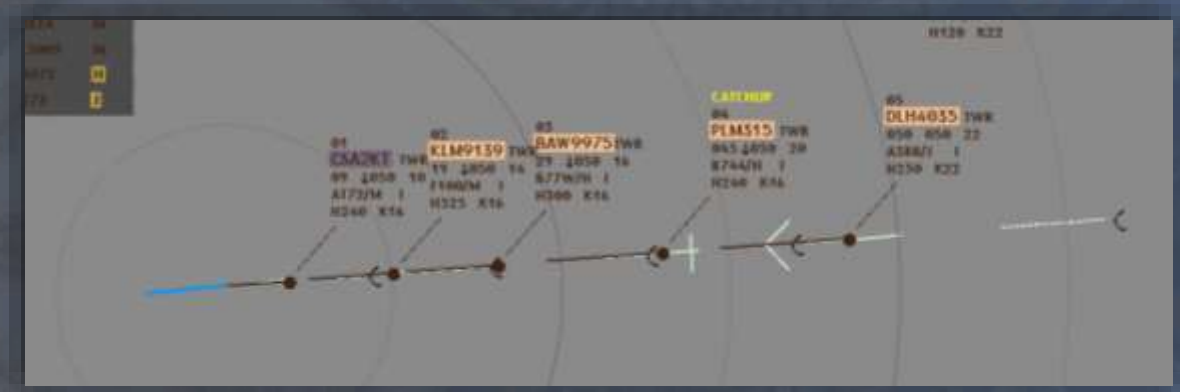


Safety Alerting functions

Automatic FTD pop up

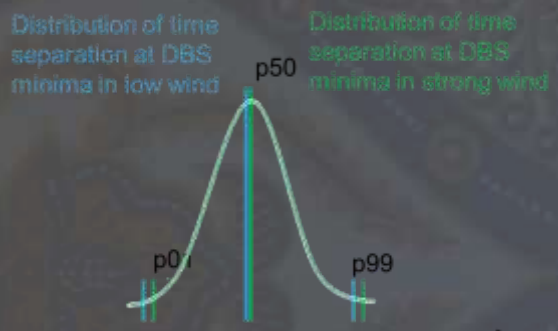
Speed alert

Sequence alert



Catch-up warning

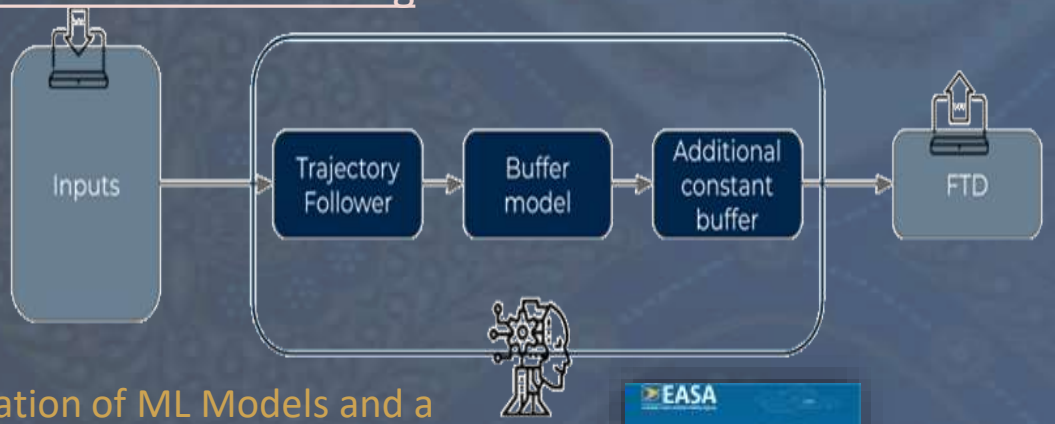
Enhanced Optimised Runway Delivery (eORD) Calibration with AI/ML

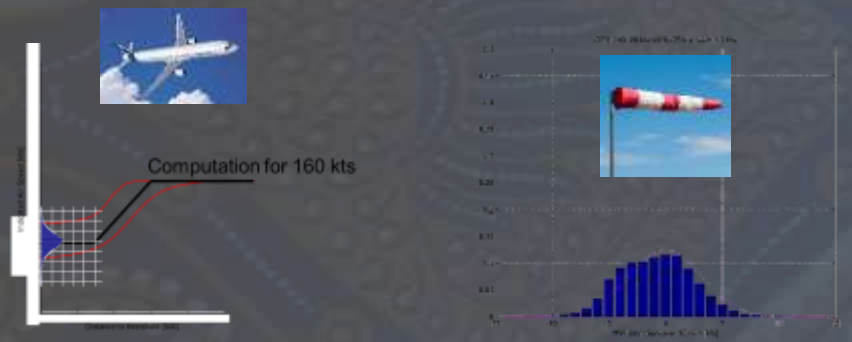


Need to match TBS distribution

Use of Machine Learning for Enhanced Prediction

https://www.eurocontrol.int/publication/eurocontrol-coast-calibration-optimised-approach-spacing-tool-use-machine-learning





Variability in aircraft approach speed & wind
Sources of uncertainties

Training and validation of ML Models and a methodology to use them for the calculation of TBS-ORD Indicators

OSD – Optimised Spacing on Departure
DDI – Dynamic Departure Indicators

Supporting / Optimising separation delivery

ICAO

Optimised Spacing on Departure (OSD)

SESAR PJ02.01.02

Optimised Separation Departure

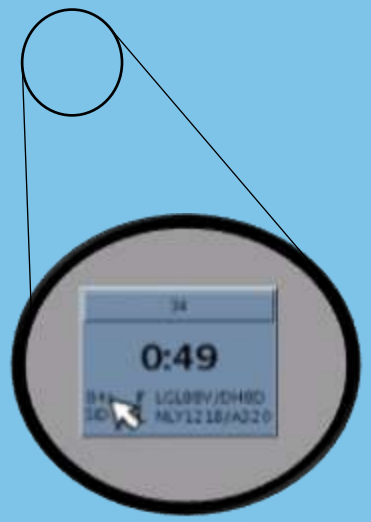
System evolution

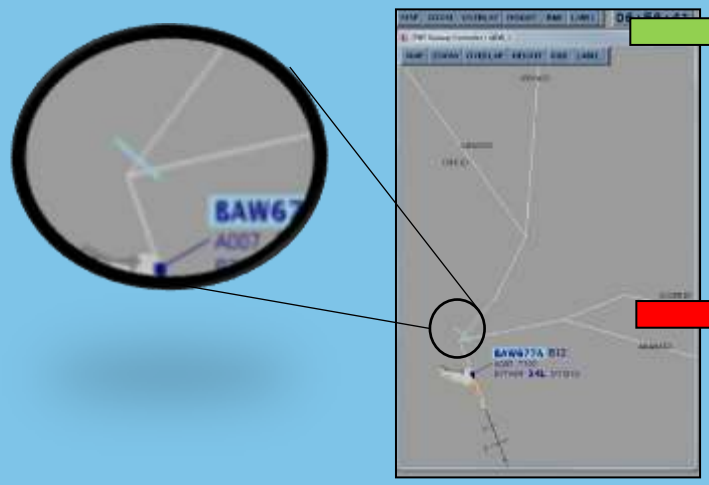
Level 1

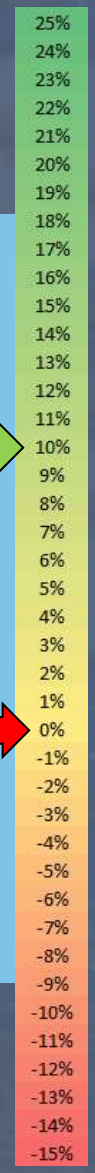
Level 2

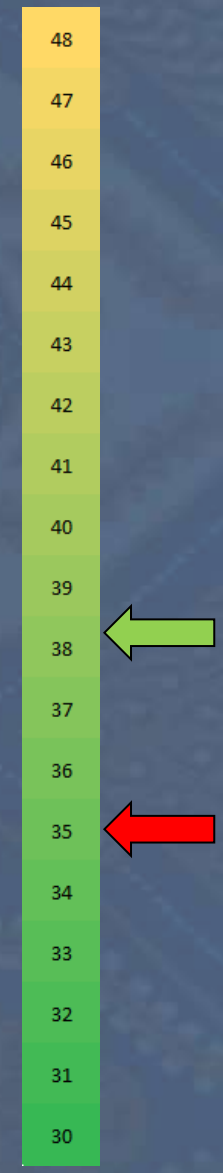
Level 3

Use of Dynamic Departure Indicators (DDI) – Time or Distance







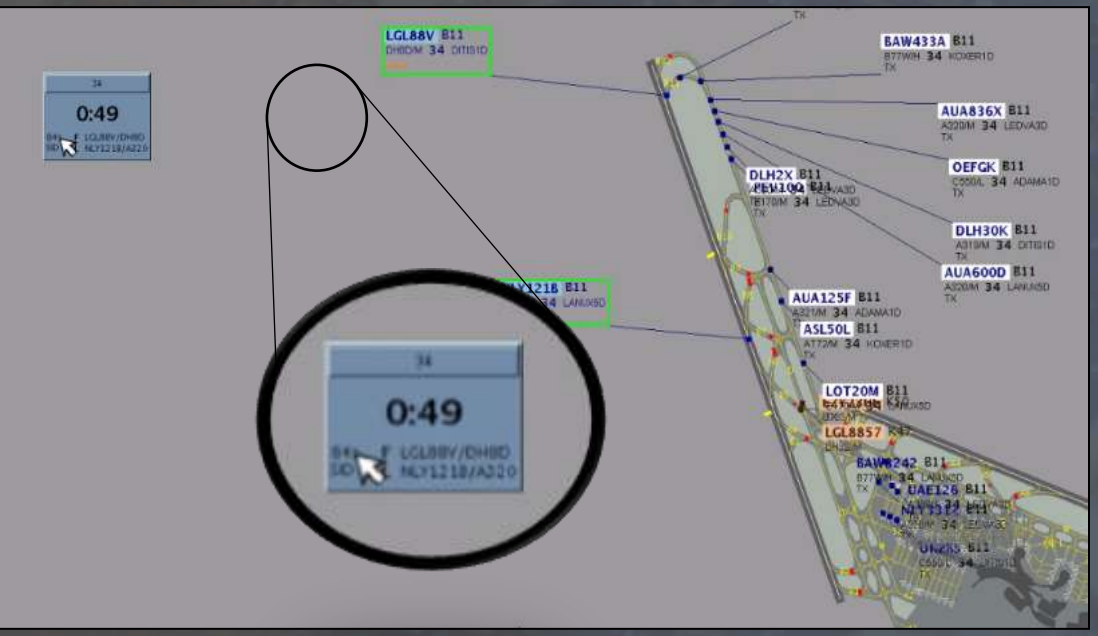


Optimised Spacing on Departure (OSD)

SESAR PJ02.01.02

- ✓ Consistent spacing management
- ✓ Increase safety
- ✓ Reduced workload

Use of Dynamic Departure Indicators for Time spacing – DDI-T



- Advisory to Tower DEP RWY controller for the optimised timing of Take-Off Clearance Delivery
- Integrating applicable DEP separation minima constraints
- Optimised delivery against separation minima, based on prediction of rolling time, climb trajectory, and estimated reaction time
- Assist in ensuring airborne separation minimum, and prevention of catch-up risk

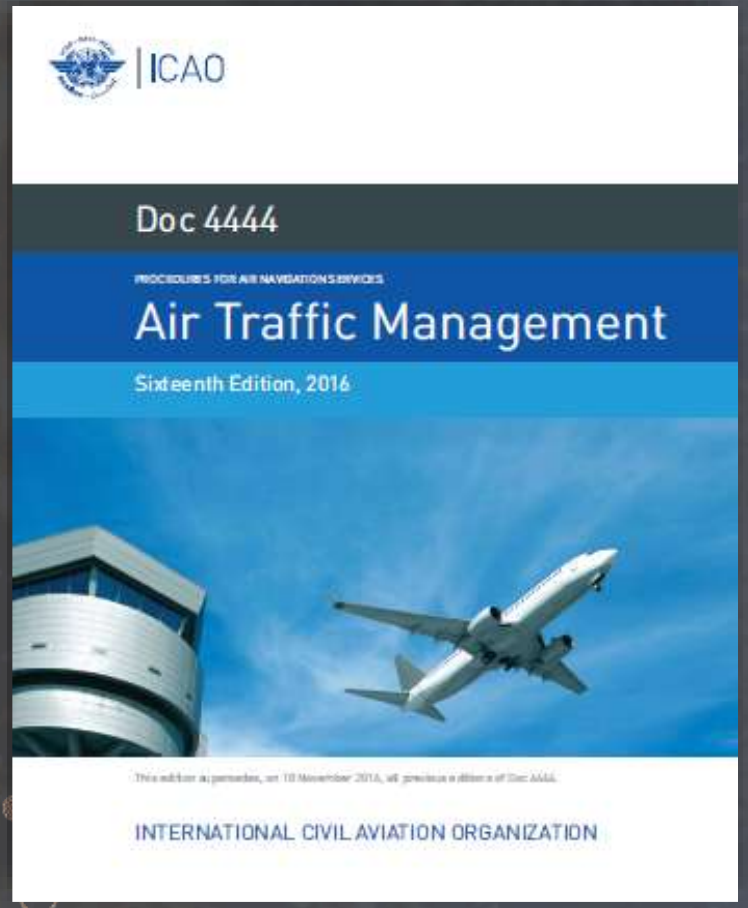
DEP THP increase: +10% or more*

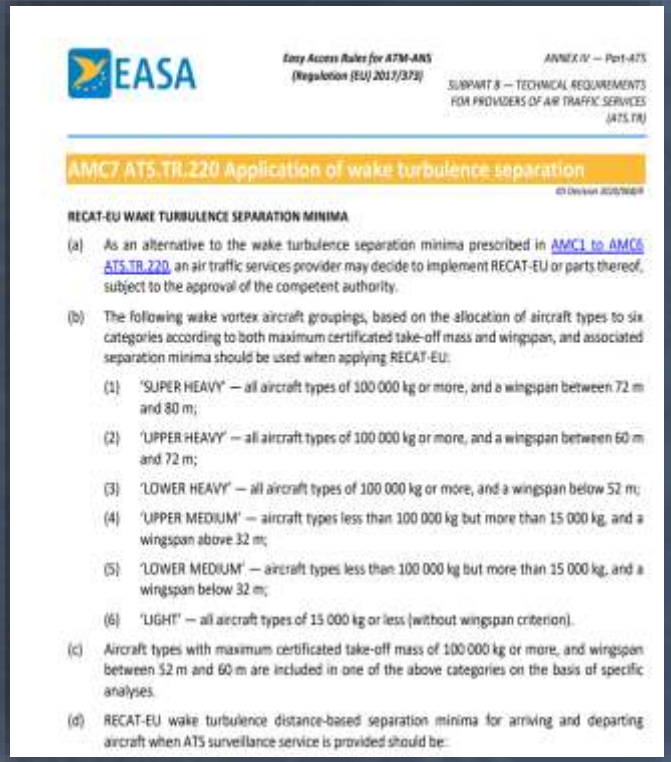
Reference and guidance material

Optimising separation standards

Supporting / Optimising separation delivery

ICAO WTG
RECAT-EU - Optimised wake separation for ARR & DEP





EASA

Easy Access Rules for ATM-ANS (Regulation (EU) 2017/373)

ANNEX IV — Part-ATS

SUBPART B — TECHNICAL REQUIREMENTS FOR PROVIDERS OF AIR TRAFFIC SERVICES (ATS.TR)

AMC7 ATS.TR.220 Application of wake turbulence separation

RECAT-EU WAKE TURBULENCE SEPARATION MINIMA

(a) As an alternative to the wake turbulence separation minima prescribed in AMC1 to AMC6 ATS.TR.220, an air traffic services provider may decide to implement RECAT-EU or parts thereof, subject to the approval of the competent authority.

(b) The following wake vortex aircraft groupings, based on the allocation of aircraft types to six categories according to both maximum certificated take-off mass and wingspan, and associated separation minima should be used when applying RECAT-EU:

(1) 'SUPER HEAVY' — all aircraft types of 100 000 kg or more, and a wingspan between 72 m and 80 m;

(2) 'UPPER HEAVY' — all aircraft types of 100 000 kg or more, and a wingspan between 60 m and 72 m;

(3) 'LOWER HEAVY' — all aircraft types of 100 000 kg or more, and a wingspan below 52 m;

(4) 'UPPER MEDIUM' — aircraft types less than 100 000 kg but more than 15 000 kg, and a wingspan above 32 m;

(5) 'LOWER MEDIUM' — aircraft types less than 100 000 kg but more than 15 000 kg, and a wingspan below 32 m;

(6) 'LIGHT' — all aircraft types of 15 000 kg or less (without wingspan criterion).

(c) Aircraft types with maximum certificated take-off mass of 100 000 kg or more, and wingspan between 52 m and 60 m are included in one of the above categories on the basis of specific analyses.

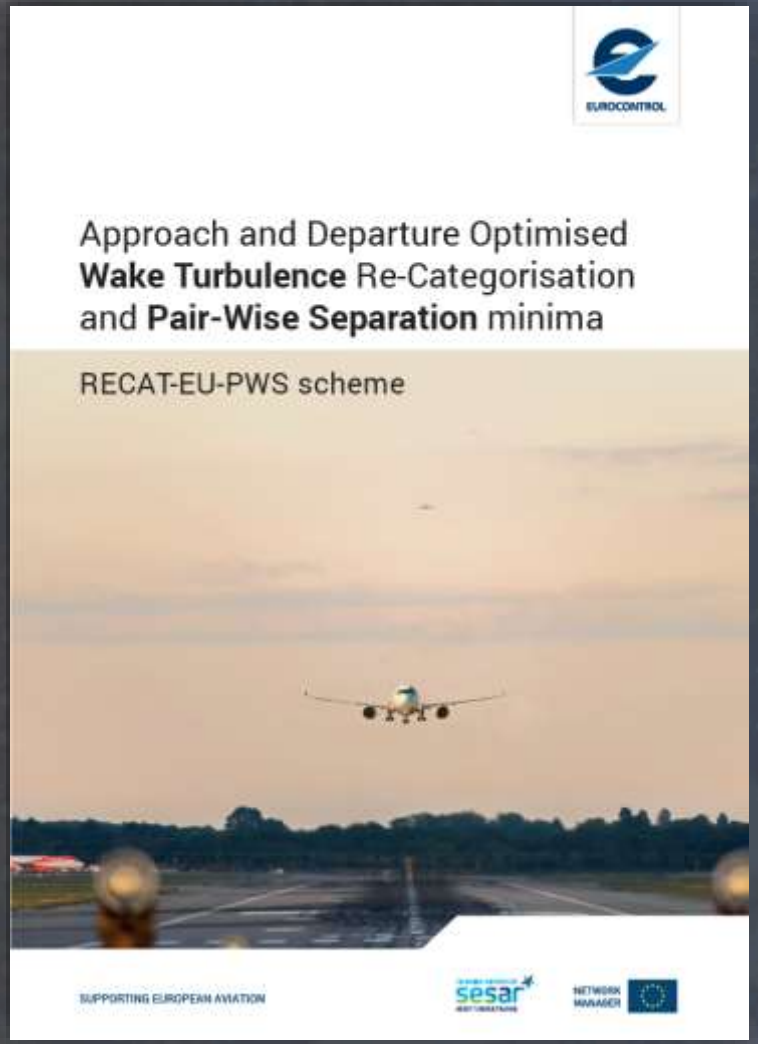
(d) RECAT-EU wake turbulence distance-based separation minima for arriving and departing aircraft when ATS surveillance service is provided should be:

ICAO - EASA

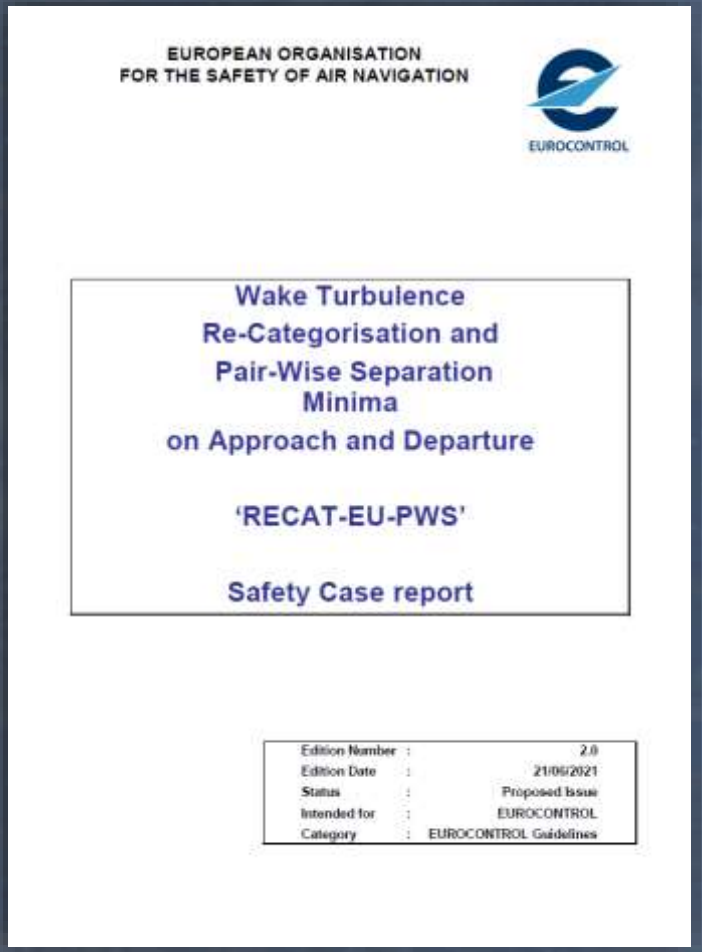
https://www.eurocontrol.int/publication/european-wake-turbulence-categorisation-and-separation-minima-approach-and-departure

Wake Pair-Wise Separation (PWS) for ARR & DEP

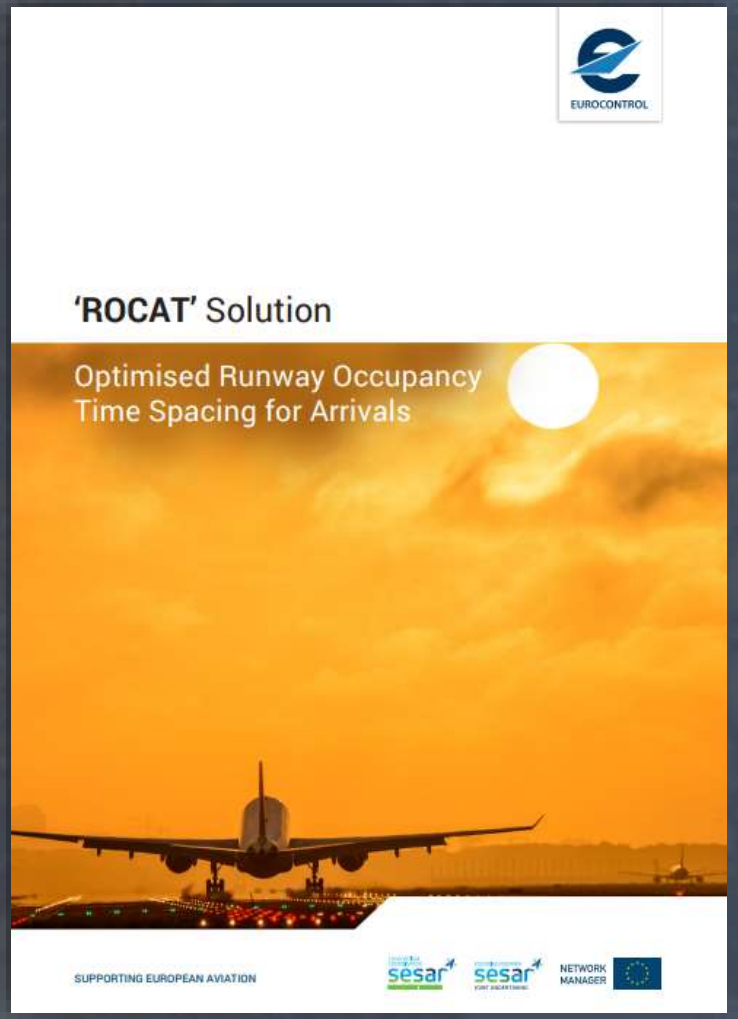
SESAR solution
PJ02.01.04 (ARR)
PJ02.01.06 (DEP)



https://www.eurocontrol.int/publication/recat-eu-pws-scheme



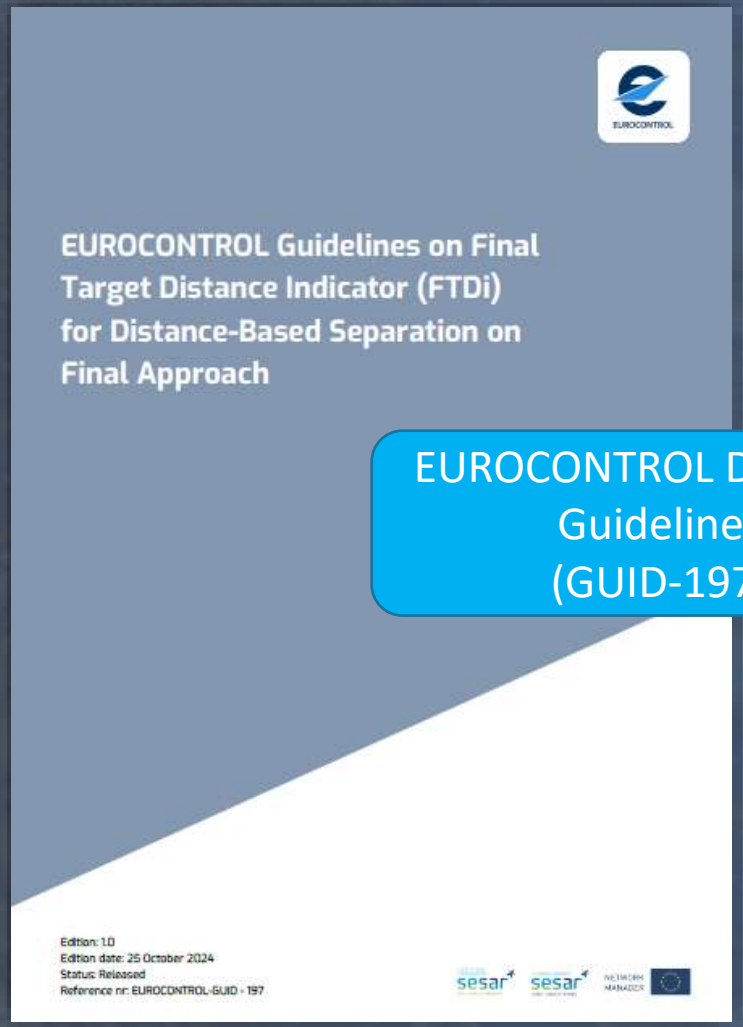
ARR ROCAT (iROT) – Optimised spacing based on local ROT Characterisation



https://www.eurocontrol.int/publication/optimised-runway-occupancy-time-spacings-arrivals

ARR DBS support tool / FTDi

https://www.eurocontrol.int/publication/ftdi-solution

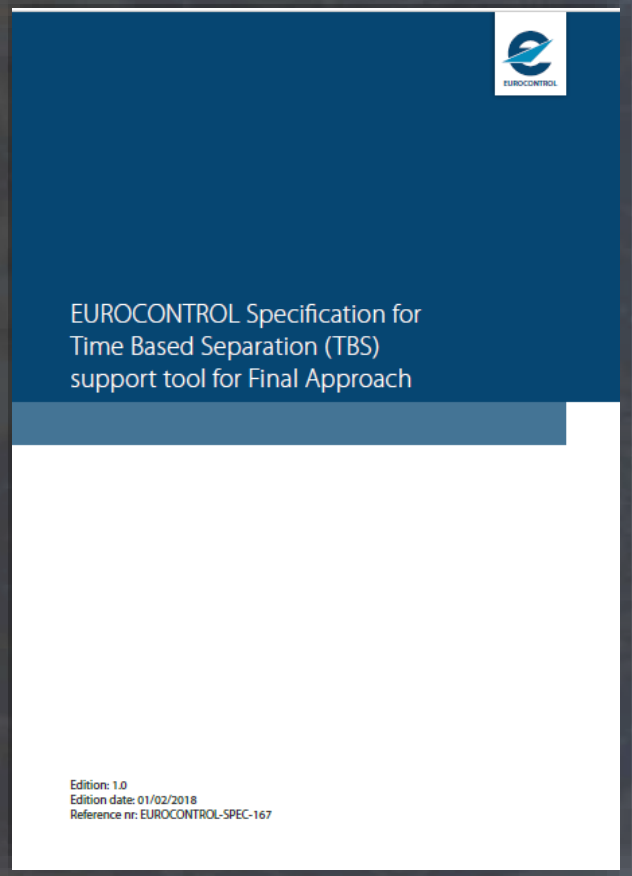


EUROCONTROL DBS/FTDi Guidelines (GUID-197)

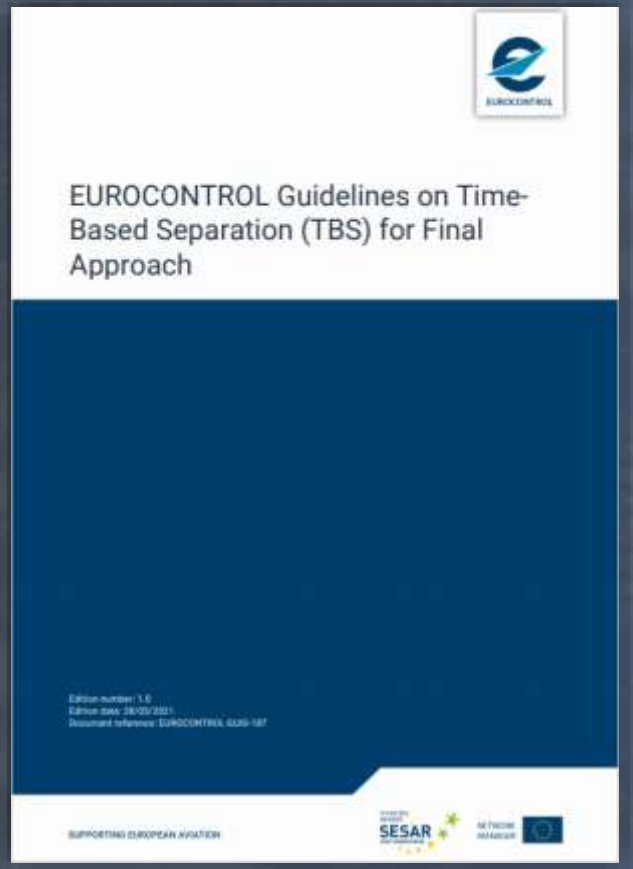
https://www.eurocontrol.int/publication/eurocontrol-guidelines-final-target-distance-indicator-ftdi-distance-based-separation

Time-Based Separation (TBS) on final Approach

EUROCONTROL TBS Specification
SPEC-167



EUROCONTROL TBS Guidelines (GUID-187)



https://www.eurocontrol.int/publication/eurocontrol-guidelines-time-based-separation-tbs-final-approach

TBS with ORD (Optimised Runway Delivery) on final approach

EUROCONTROL TBS-ORD Guidelines (GUID-196)

https://www.eurocontrol.int/publication/eurocontrol-guidelines-time-based-separation-tbs-final-approach

Thank you!

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