Airport capacity effects of RECAT or: An airport view on RECAT

21st June 2011,
WakeNet-3 Europe RECAT Workshop at TU Berlin

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Fraport

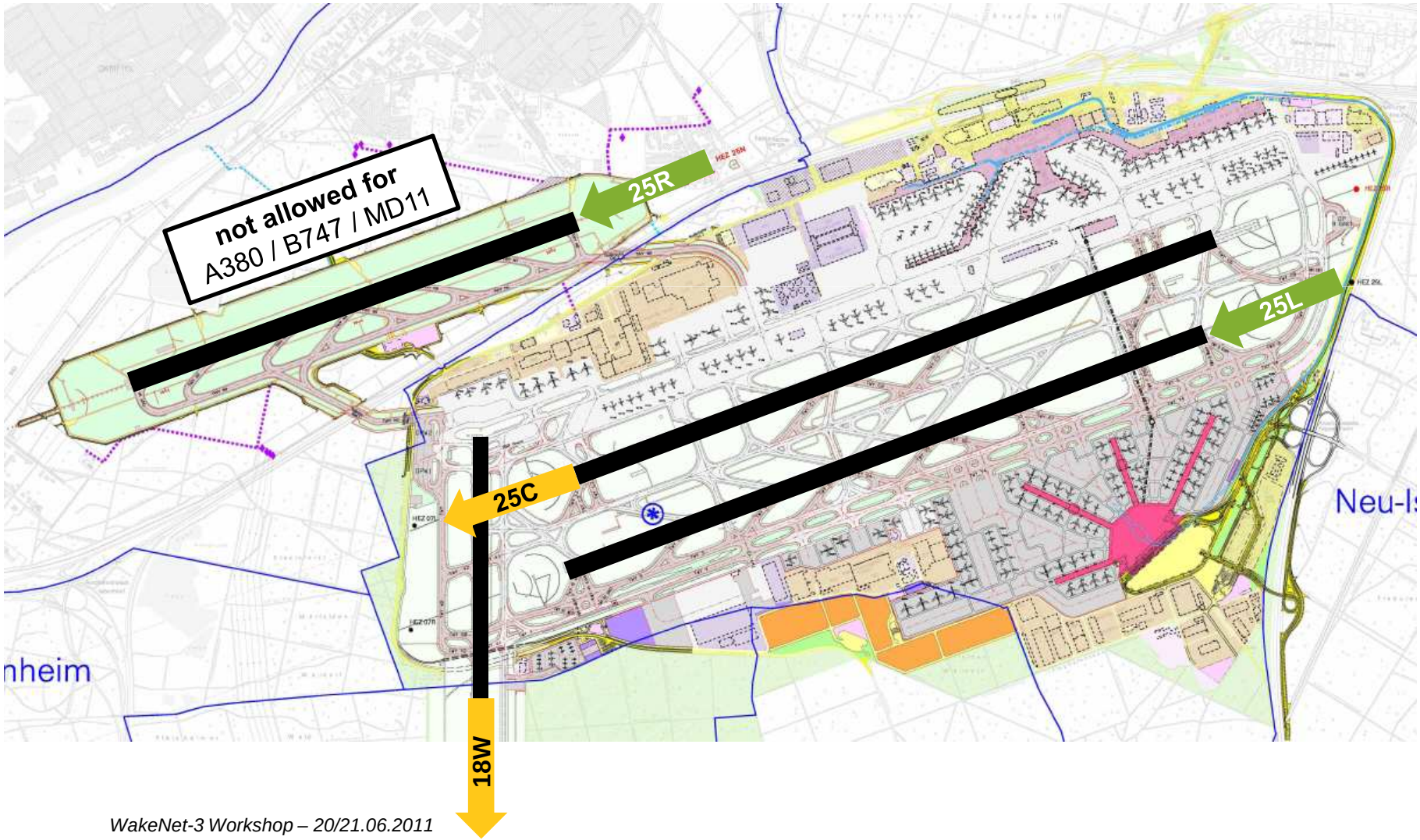
„The best way to anticipate the future is by understanding the present.“

(John Naisbitt, US-author of future studies, *1929)

Content

- **EDDF infrastructure & procedures**
- **EDDF results for RECAT**
- **RECAT vs. ROT**
- **Conclusion**

FRA rwy infrastructure Okt 2011



EDDF procedures – ICAO Doc 4444

PANS ATM – ICAO Doc 4444:

8.7.4.4. The following wake turbulence radar separation minima shall be applied to aircraft in the approach and departure phases of flight in the circumstances given in 8.7.4.4.1

Aircraft category		
Preceding aircraft	Succeeding aircraft	Wake turbulence radar separation minima
HEAVY	HEAVY	7.4 km (4.0 NM)
	MEDIUM	9.3 km (5.0 NM)
	LIGHT	11.1 km (6.0 NM)
MEDIUM	LIGHT	9.3 km (5.0 NM)

8.7.4.4.1

The minima set out in 8.7.4.4 shall be applied when:

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

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

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

EDDF procedures – BA-FVK – German ATC

BA-FVK (Manual of operations – Air traffic control services)
– Aerodrome control procedures:

„328 WAKE TURBULENCE SEPARATION

328.1 In order to minimize the hazards of wake turbulence - for flights for which an obligation to provide separation exists -the following radar separation minima shall be applied if the prescribed separation minima are lower :

Preceding Aircraft	Succeeding Aircraft	Separation Minima
HEAVY	HEAVY	4 NM
HEAVY	MEDIUM	5 NM
HEAVY	LIGHT	6 NM
MEDIUM	LIGHT	5 NM

[...]

328.3 The **separation minima mentioned above do not need to be applied, if** :

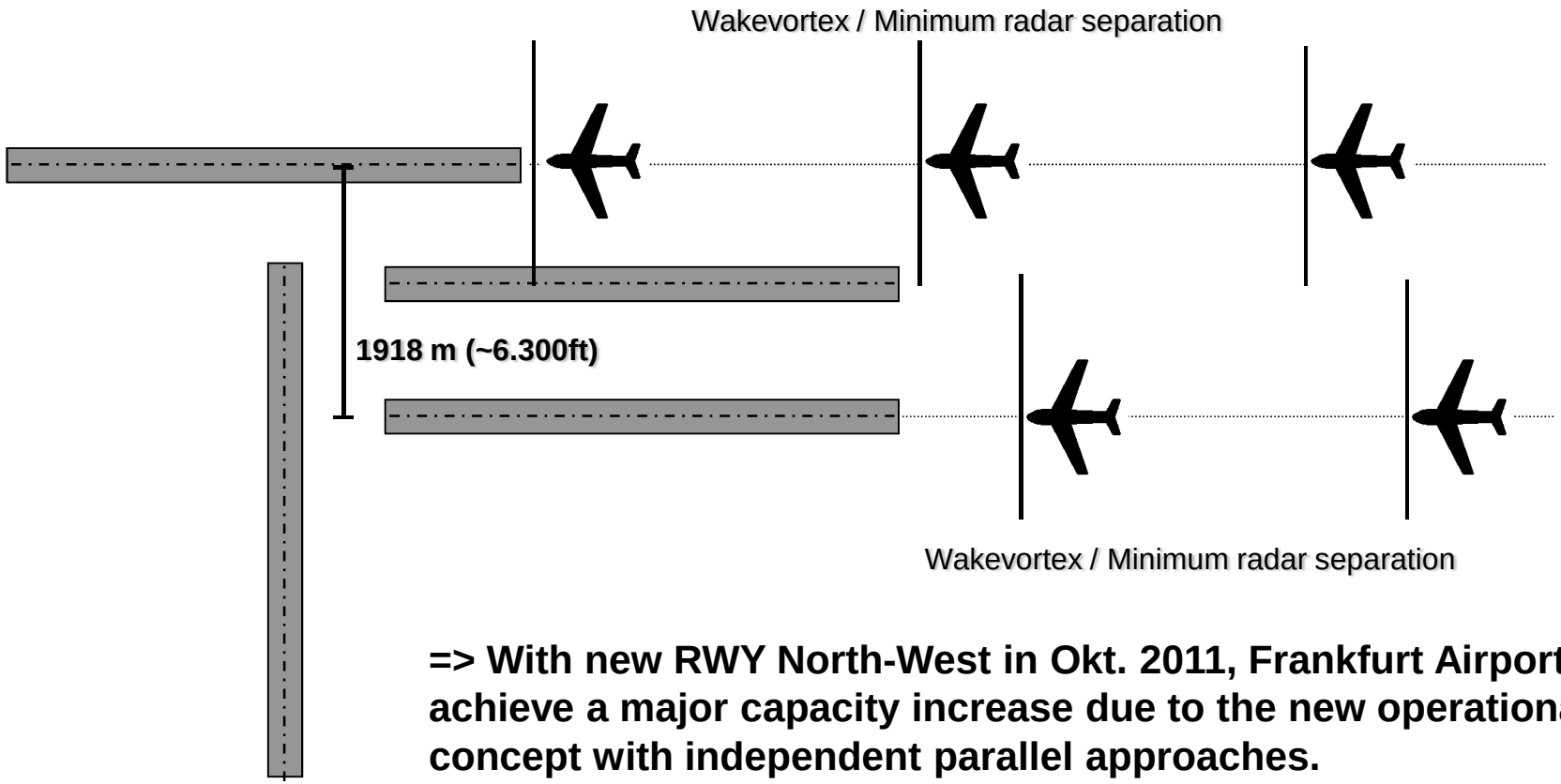
.31 the pilot of an aircraft has declared that he has the preceding aircraft in sight and will attend to an appropriate distance himself;

.32 the pilot of an aircraft renounces wake turbulence separation;

.33 the area within which wake turbulence is expected will not be penetrated."

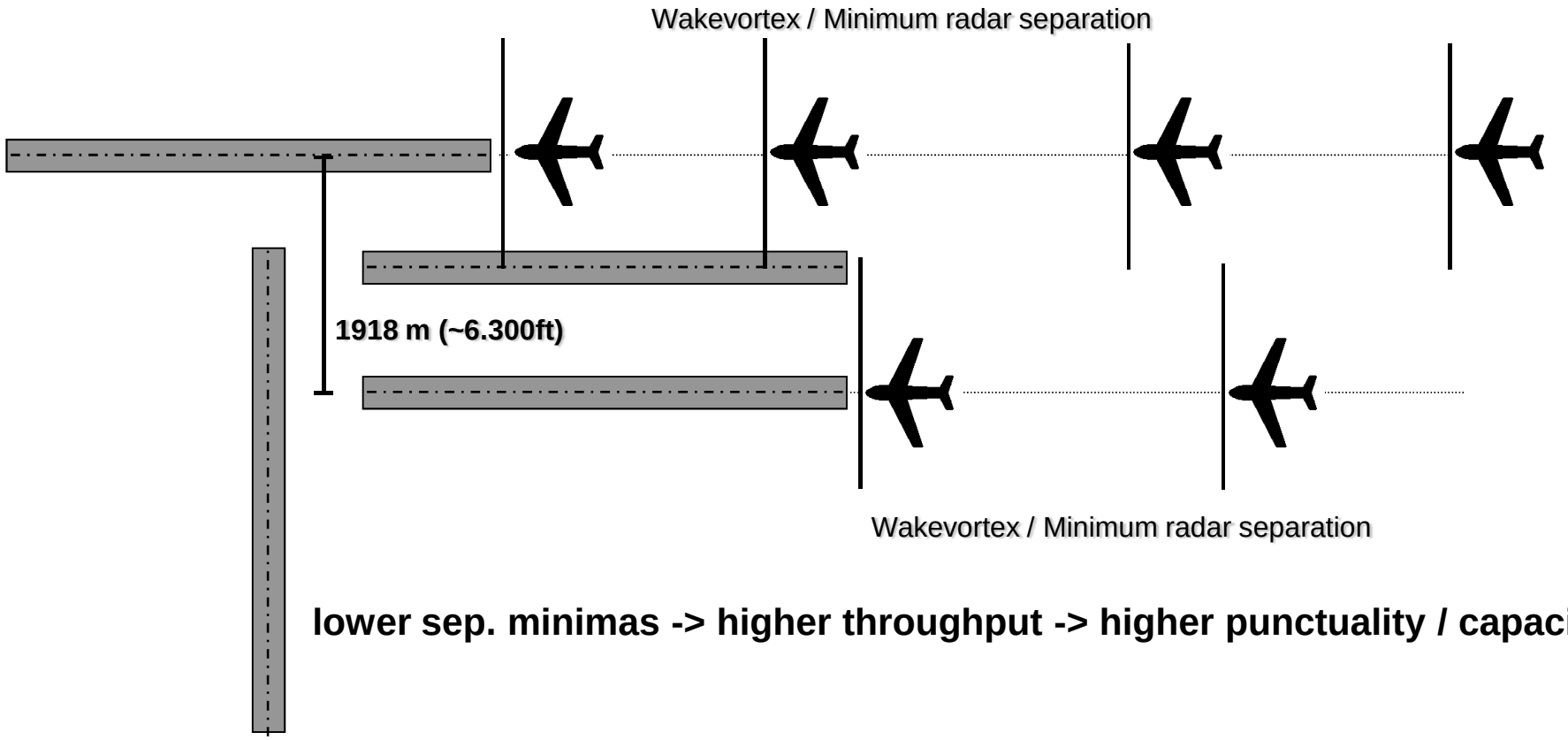
The (near) future EDDF procedures (Oct 2011) allows indepent parallel approaches in the standard operational concept ...

> 1 035 m for **independent approaches**



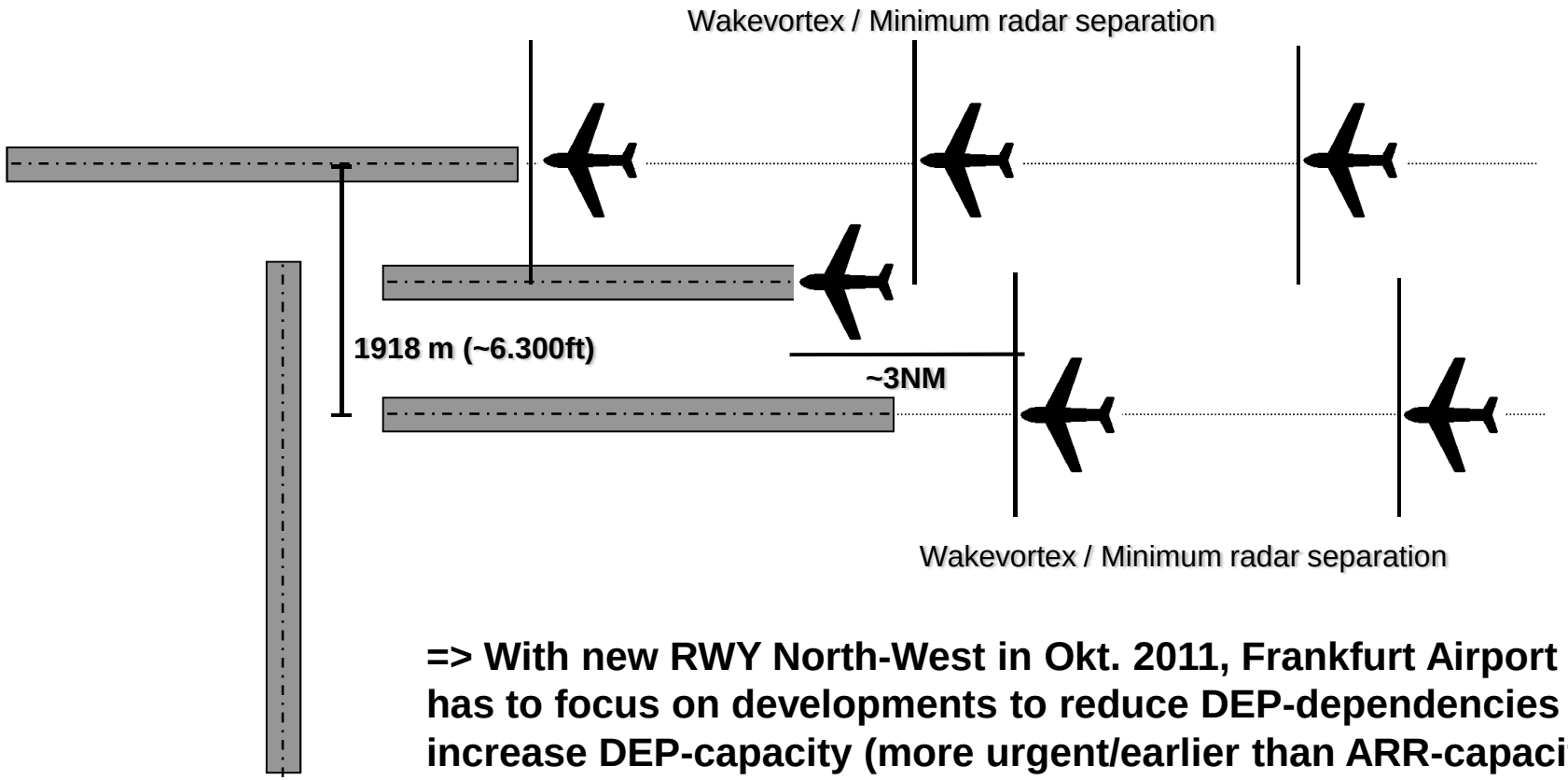
=> With new RWY North-West in Okt. 2011, Frankfurt Airport will achieve a major capacity increase due to the new operational concept with independent parallel approaches.

... and - of course - for standard operations EDDF welcomes low (intrail) separation minimas to increase capacity/punctuality ...



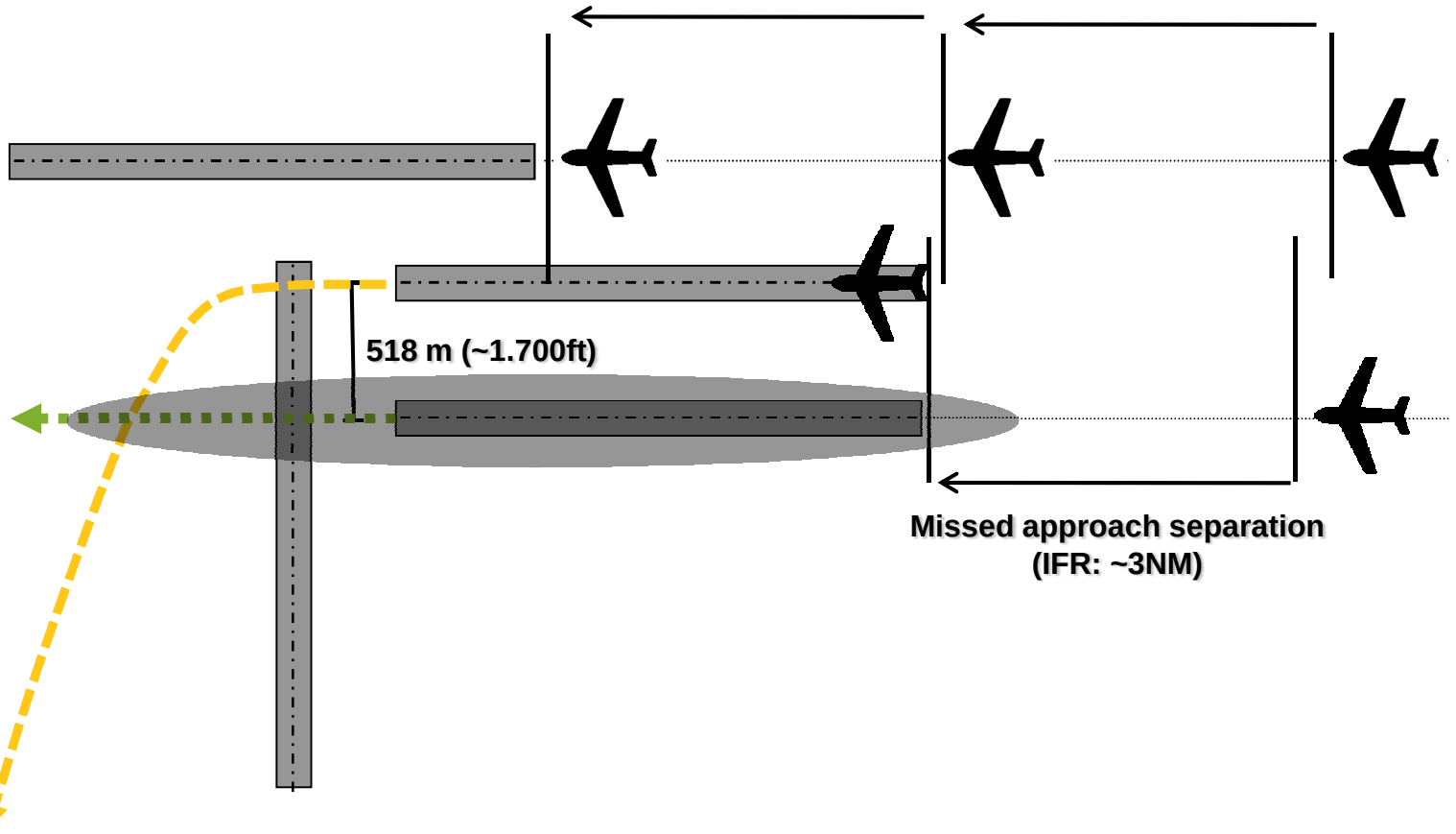
lower sep. minimas -> higher throughput -> higher punctuality / capacity

... but due to ARR/DEP dependencies on the existing parallel rwys the DEPs needs enough ARR-gaps, to be cleared for take-off.

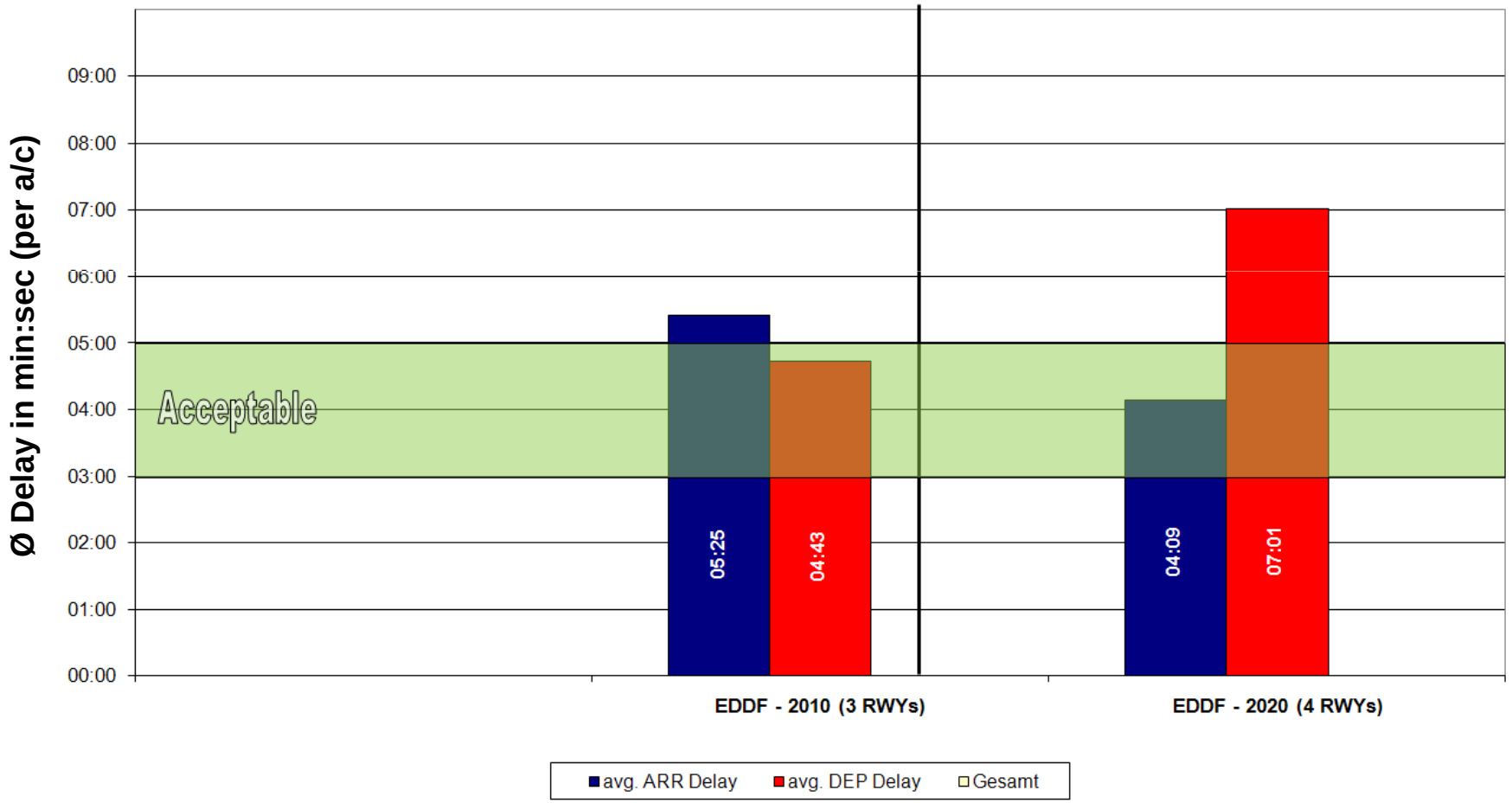


=> With new RWY North-West in Okt. 2011, Frankfurt Airport will has to focus on developments to reduce DEP-dependencies and increase DEP-capacity (more urgent/earlier than ARR-capacity).

ARR / DEP procedures at FRA
=> those „local“ circumstances should be taken into account whenever you calculate capacity gains !



EDDF has enough spare ARR capacity untill 202x due to the opening of 4th rwy (October 2011) even under IMC CAT I conditions and ICAO separation



Data based on OTSD2006 (results of fast-time simulation for the legal zoning procedure)

EDDF ARR capacity

4th rwy

?

EDDF 2010:
ARR Capacity

EDDF 2015:
ARR Capacity

EDDF 202x:
ARR Capacity

Thanks to Dr. Konopka (DFS) for the idea (WakeNet London - Feb. 2011) to visualize arr-capacity with „water in the jar“

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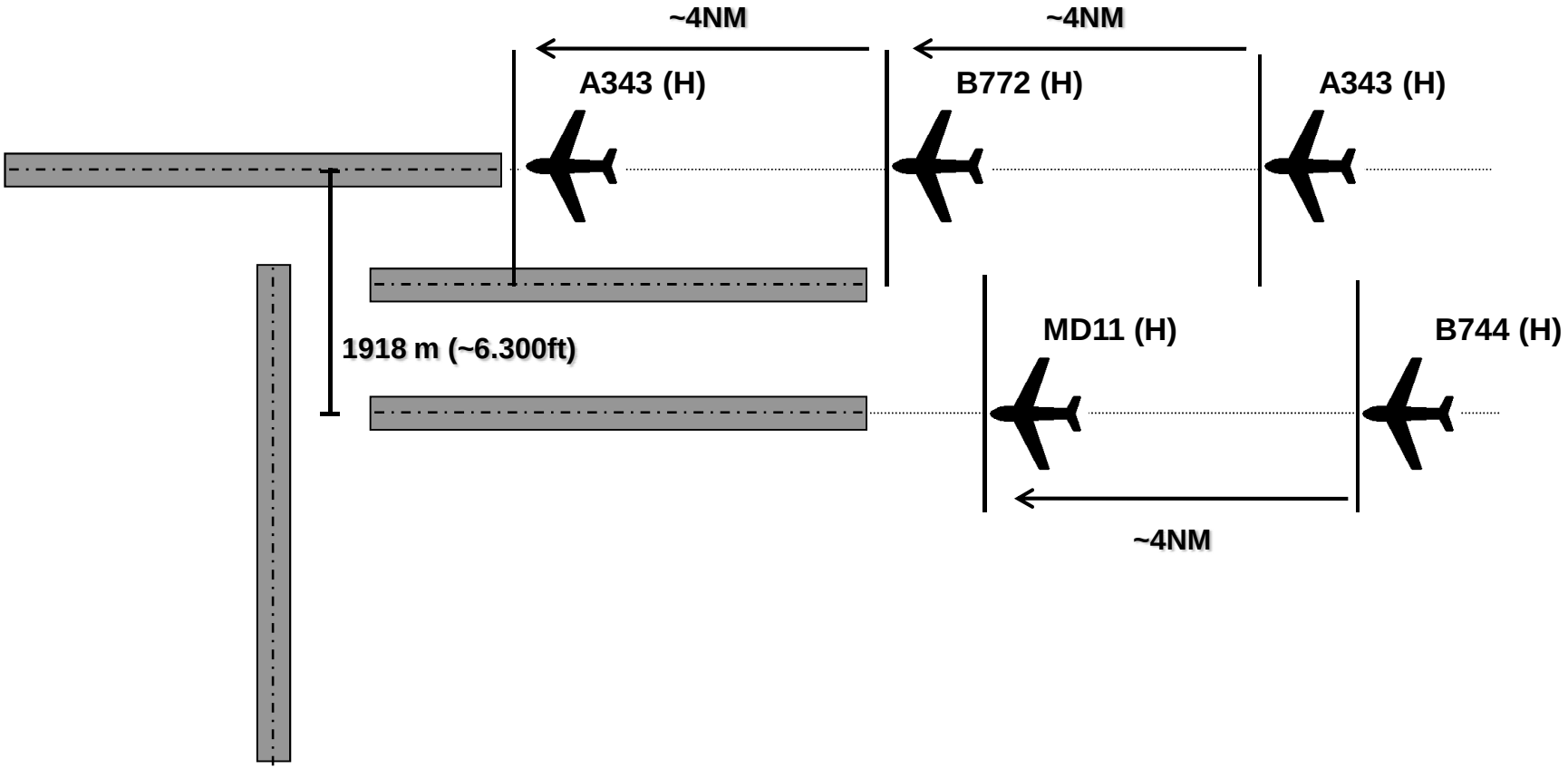
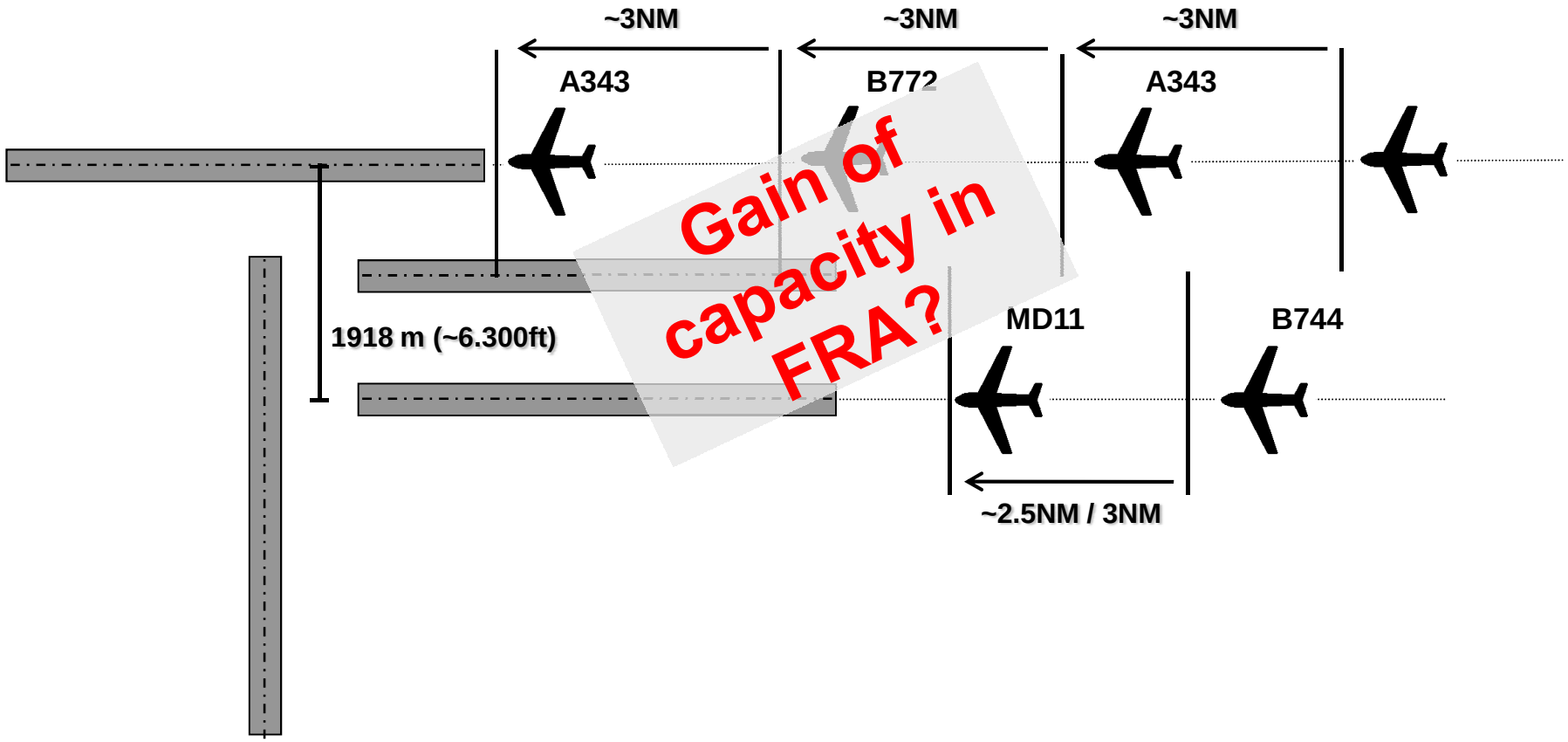
- EDDF results for RECAT
- RECAT vs. ROT
- Conclusion

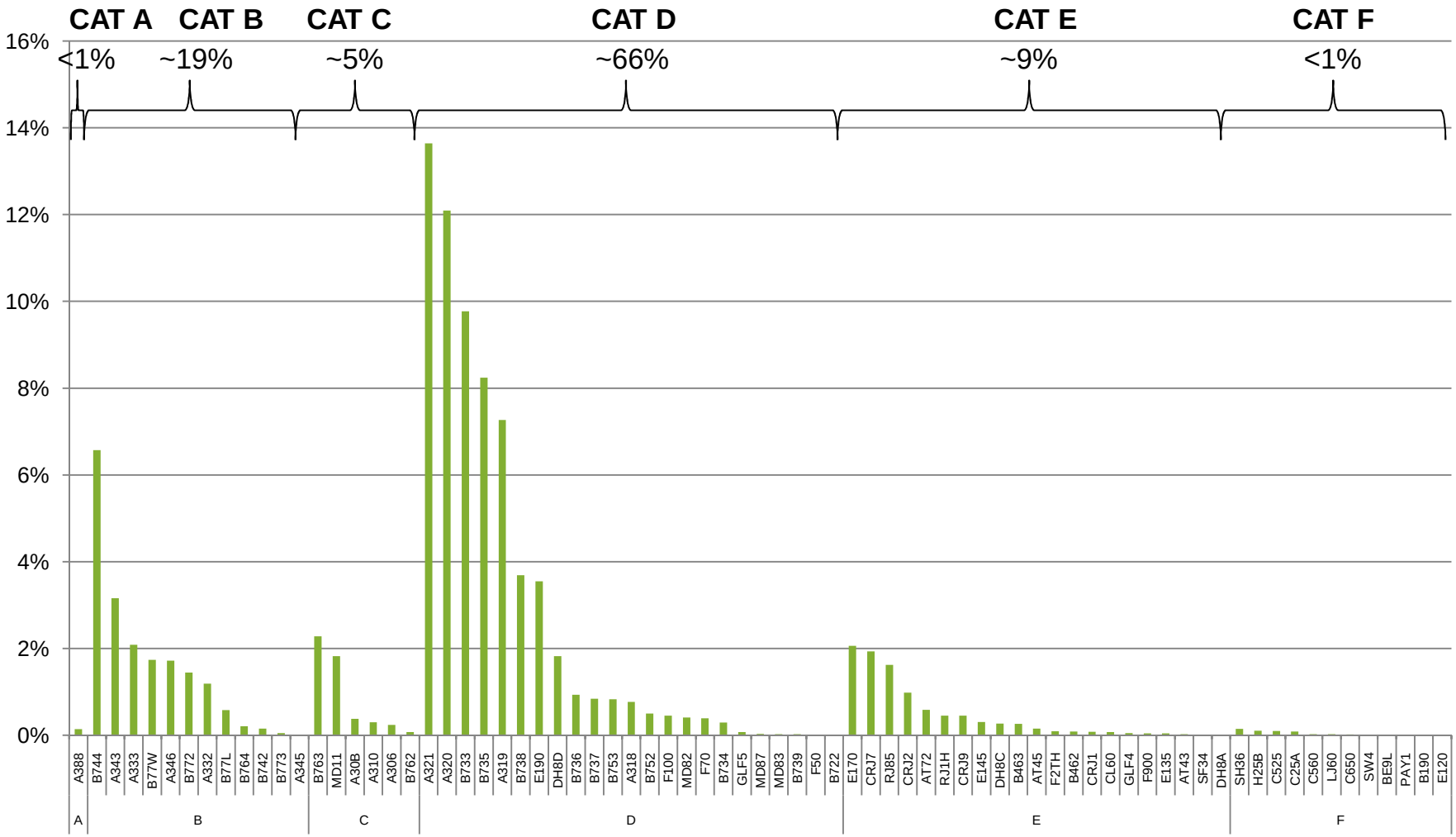
Wakevortex separation today



Wakevortex separation tomorrow due to RECAT ?

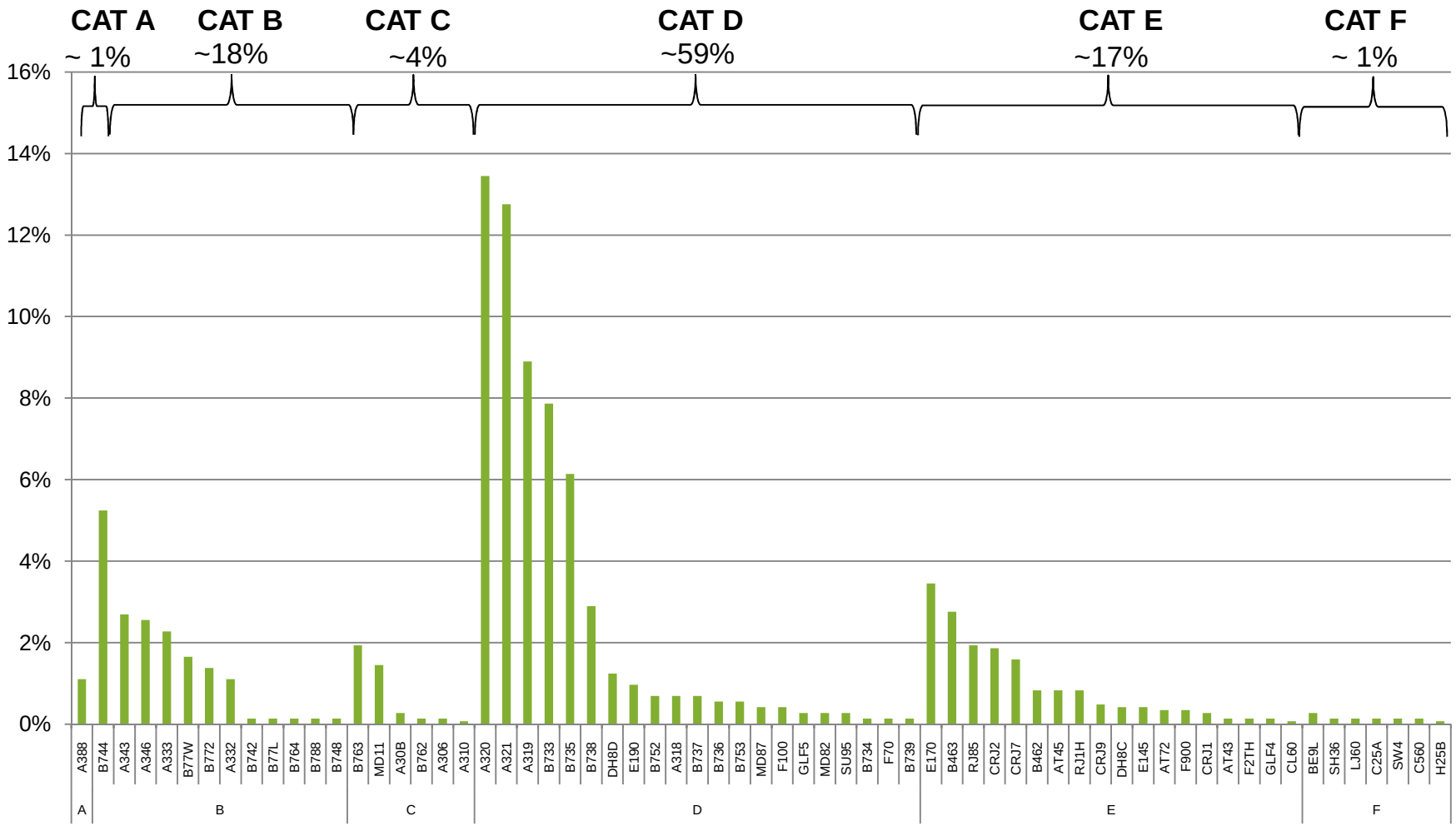


Aircraft distribution 2010 at FRA assigned to RECAT



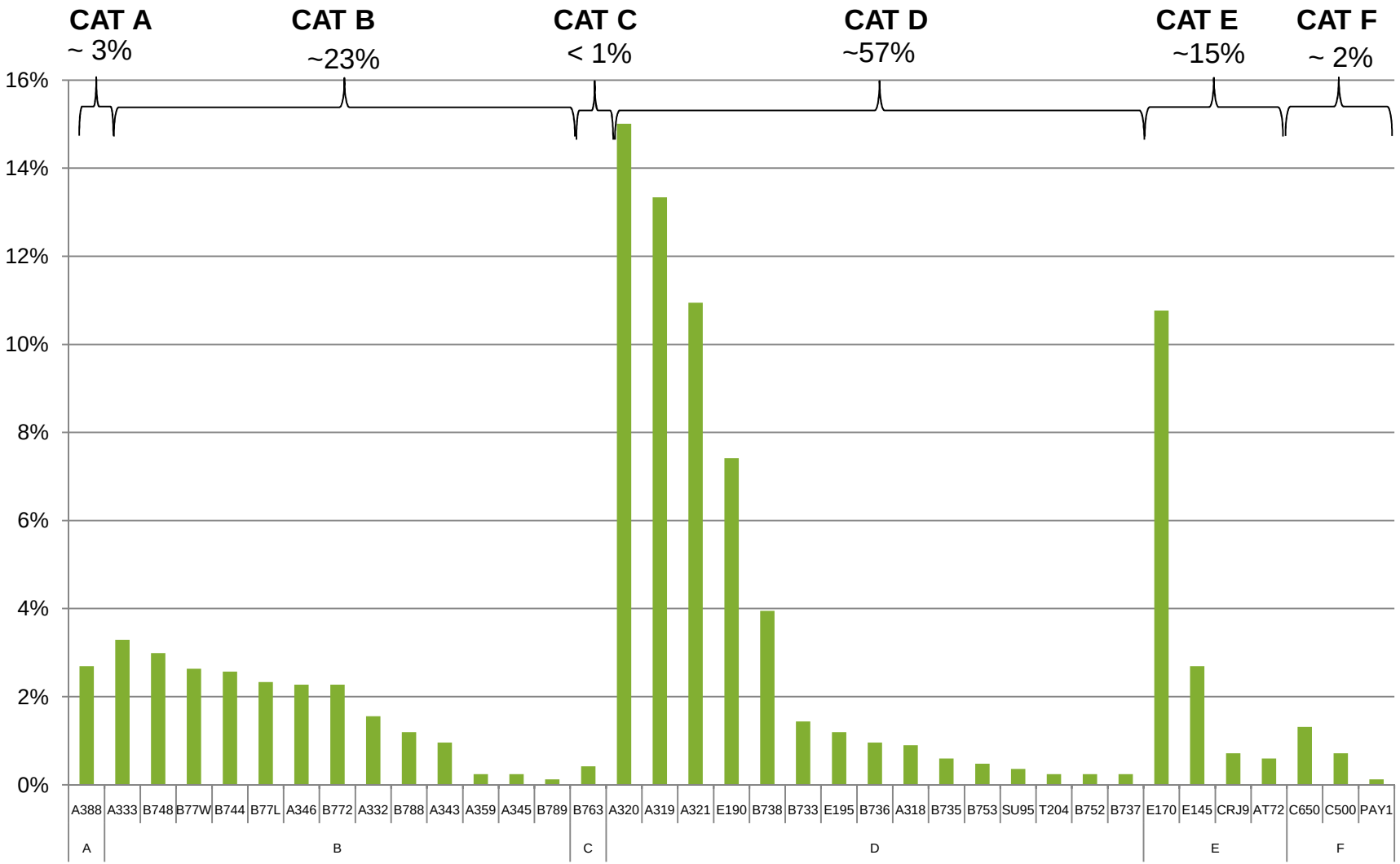
Source: Fraport 2011

Predicted aircraft distribution WS2011/12 at FRA



Source: Fraport 2011

Predicted aircraft distribution 2015 at FRA



Source: Fraport 2011

RECAT separation minimas and its propability for EDDF

RECAT

		Succeeding					
		A	**B**	**C**	**D**	**E**	**F**
Preceding	**A**	MRS	5.0	6.0	7.0	7.0	**8.0**
	B	MRS	3.0	4.0	5.0	5.0	**7.0**
	C	MRS	MRS	MRS	3.5	3.5	**6.0**
	D	MRS	MRS	MRS	MRS	MRS	**5.0**
	E	MRS	MRS	MRS	MRS	MRS	4.0
	F	MRS	MRS	MRS	MRS	MRS	MRS

The (analytical) propability for the reduced separations is

- today only ~9 % and only ~7% in the future (2015) at EDDF

RECAT – an analytical capacity „model“ (MS Excel) shows only minor capacity gain for EDDF based on the actual and forecasted traffic mix

- **EDDF results for RECAT – analytical model**

Separation minima multiplied with group propability => avg. separation

<u>FRA2011 (with 4 rwys) -- average separation (with interarr-buffer 1NM):</u>

ICAO: ~4.07 NM => 34.4 ARR (per h & rwy)

RECAT: ~3.96 NM => 35.4 ARR (per h & rwy)

due to more heavy traffic and CAT-changes from now a days to near future:

<u>FRA2015 (with 4 rwys) -- average separation (with interarr-buffer 1NM):</u>

ICAO: ~4.17 NM => 33.6 ARR (per h & rwy)

RECAT: ~4.10 NM => 34.2 ARR (per h & rwy)

Simulationrun I and II
Parametersources

Parameters
Run I

Results were presented at LHR WakeNet workshop

Source: http://www.eurocontrol.int/

Parameters
Run II

Results will be presented at this WakeNet workshop

Source: http://www.wakenet.eu

Run II: General wakevortex separation parameters

ICAO

		Succeeding			
		A380	**Heavy**	**Medium**	**Light**
Preceding	**A380**	MRS	6.0	7.0	8.0
	Heavy	MRS	4.0	5.0	6.0
	Medium	MRS	MRS	MRS	5.0
	Light	MRS	MRS	MRS	MRS

RECAT

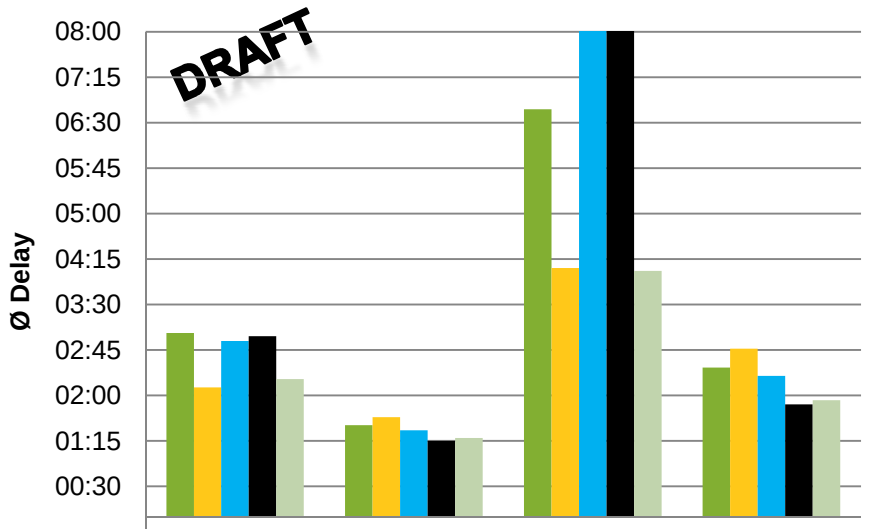
		Succeeding					
		A	**B**	**C**	**D**	**E**	**F**
Preceding	**A**	MRS	**5.0**	**6.0**	**7.0**	**7.0**	**8.0**
	B	MRS	**3.0**	**4.0**	**5.0**	**5.0**	**7.0**
	C	MRS	**MRS**	**MRS**	**3.5**	**3.5**	**6.0**
	D	MRS	MRS	MRS	MRS	MRS	**5.0**
	E	MRS	MRS	MRS	MRS	MRS	**4.0**
	F	MRS	MRS	MRS	MRS	MRS	**MRS**

Super	**Heavy**		**Medium**		**Light**
A	**B**	**C**	**D**	**E**	**F**
A380	*B744*	*MD11*	*B753*	*DH8C*	*E120*
	A346	*B763*	*B752*	*AT72*	*B190*
	B773	*A306*	*B739*	*RJ100*	*C650*
	B772		*B738*	*RJ85*	*H25B*
	A343		*B737*	*B463*	*C525*
	A333		*B736*	*B462*	
	A332		*A319*	*E170*	
			A318	*DH8B*	
			A321	*DH8A*	
			A320	*CRJ9*	
			B722	*AT45*	
			MD83	*AT43*	
			MD82	*GLF4*	
			F50	*CRJ7*	
			B734	*SF34*	
			B733	*CRJ2*	
			B735	*CRJ1*	
			E190	*E45X*	
			B717	*E145*	
			GLF5	*E135*	
			CD95		
			CD93		
			DH8D		
			F100		

Run II: Results

1. Baseline scenario
    a. ICAO separation
    b. increased radar separation to facilitate dep‘s

2. RECAT scenario
    a. RECAT on RWY 25L & 25R
    b. RECAT on RWY 25R, ICAO on RWY 25L
    c. RECAT on RWY 25R, increased ICAO on RWY 25L (see 1-b)

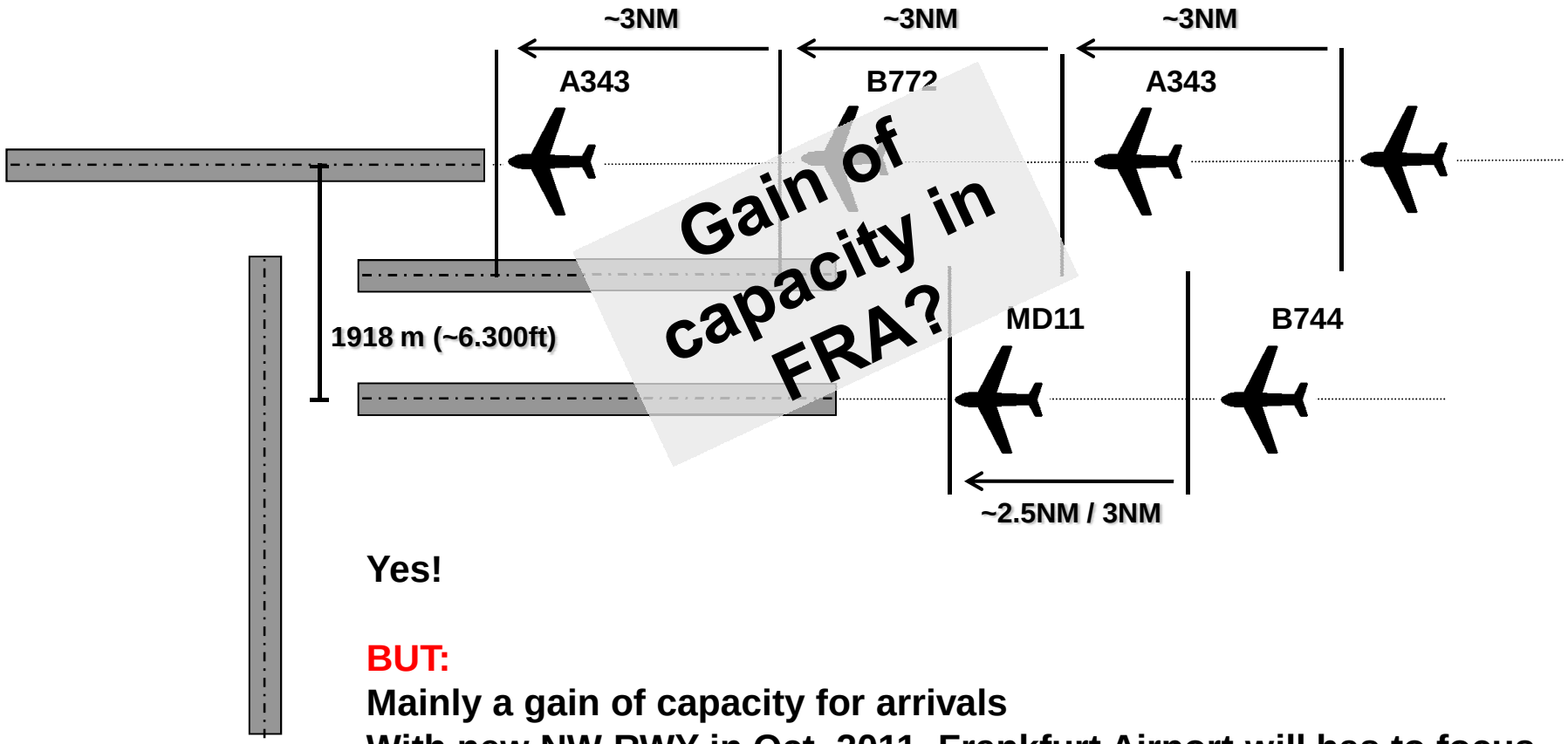


	DEP	ARR	DEP	ARR
	declared capacity 88 mvts/h		declared capacity 100 mvts/h	
S1a	03:02	01:31	06:43	02:28
S1b	02:08	01:39	04:06	02:46
S2a	02:54	01:26	09:25	02:19
S2b	02:59	01:15	09:13	01:51
S2c	02:16	01:18	04:03	01:55

Conclusion Run II

- CAT C group with the highest benefit on paper according to the separation matrix
  - Separation reduction possible in 2/3 cases if CAT C is preceeding
- In 2010 only 5% of FRAs traffic could be assigned to CAT C
- Our flightplan forecast predictes a constant decrease of CAT C aircraft in FRA to less than 1% in 2015
- Benefits in 2015 mainly due to:
  - a higher arrival density and in consequence a higher level of efficiency of RECAT
  - a rising amount of CAT B traffic

Wakevortex separation tomorrow?



Yes!

BUT:

Mainly a gain of capacity for arrivals

With new NW-RWY in Oct. 2011, Frankfurt Airport will has to focus on developments to reduce DEP-dependencies and increase DEP-capacity and those simulations didn‘t take ROT or ATC controller acceptance for RECAT into account.

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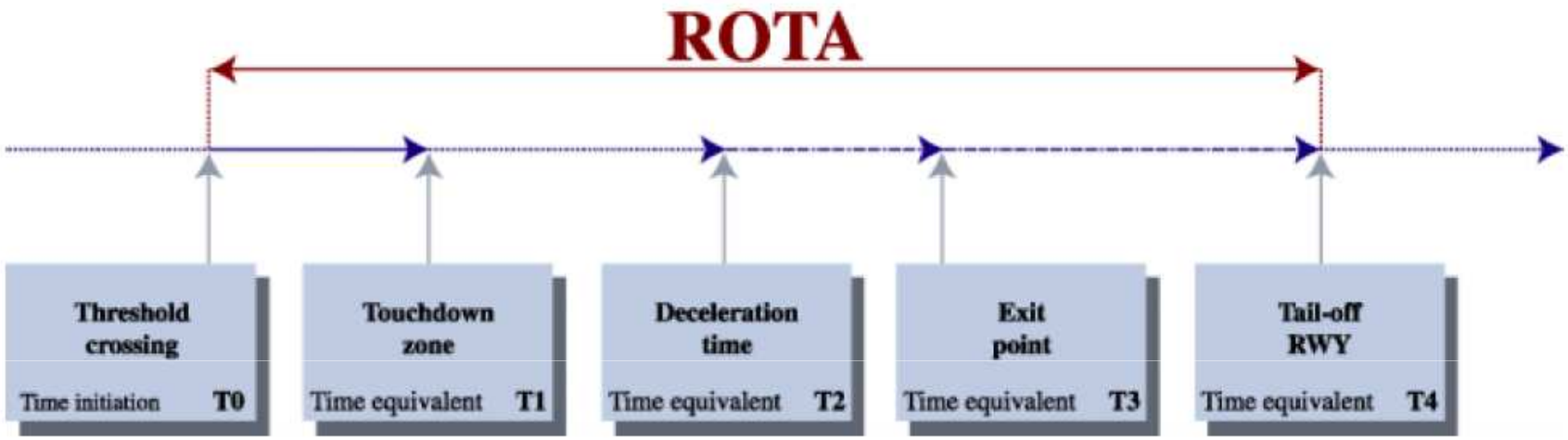
Runway Occupancy Time



ROTA: The time interval between crossing the threshold and the aircraft's tail vacating the runway.

⇒ Leading A/C has to vacated the RWY untill the following A/C is allowed to land

⇒ EDDF has calculated ROTs based on MLAT data (realdata, sample size 85.000 ARR !) and typical approach speeds to evaluate the influence on RECAT

RECAT minima vs Runway Occupancy Time ?
The rwy occupancy time as a lower boundary for separation minimas shouldn‘t be forgotten.

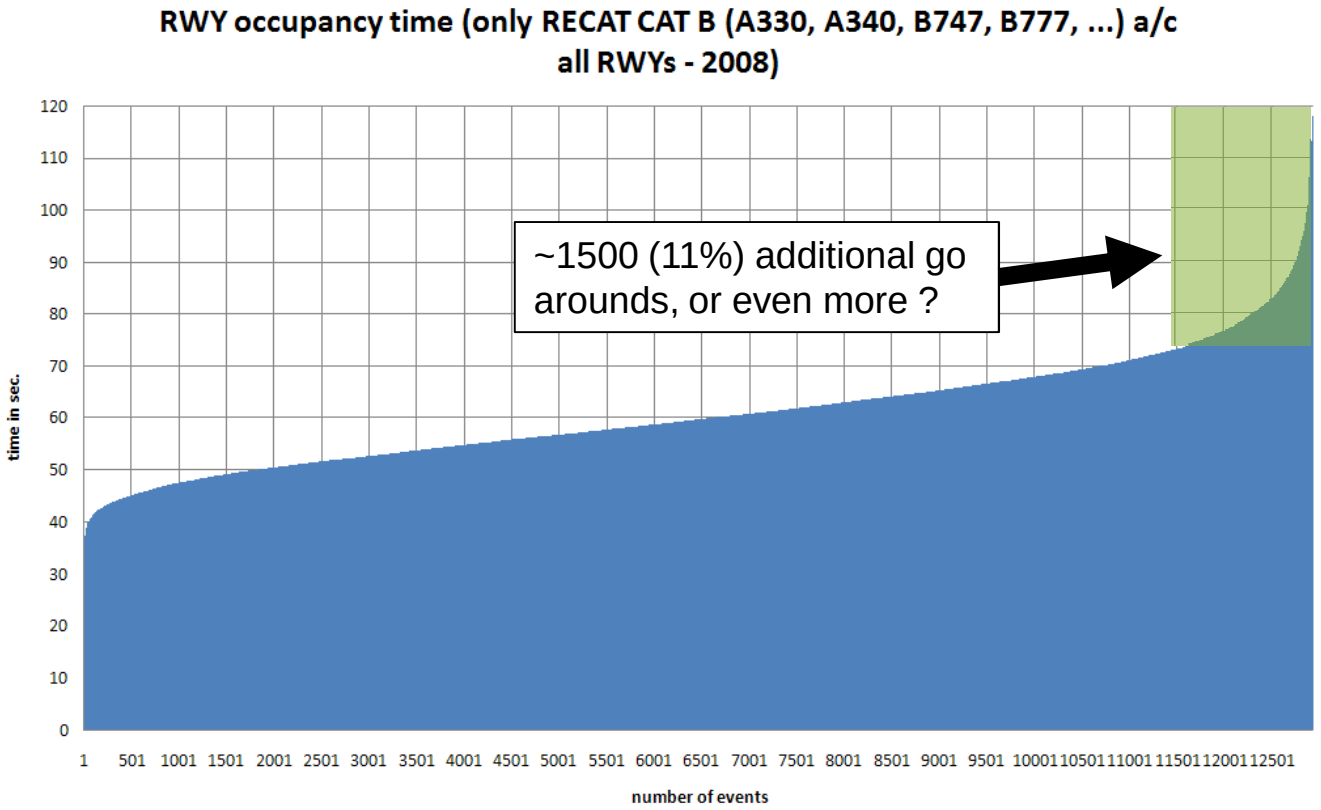
RECAT

		Succeeding					
		A	**B**	**C**	**D**	**E**	**F**
Preceding	**A**	MRS	**5.0**	6.0	7.0	7.0	**8.0**
	B	MRS	**3.0**	4.0	5.0	5.0	**7.0**
	C	MRS	**MRS**	**MRS**	**3.5**	**3.5**	**6.0**
	D	MRS	MRS	MRS	MRS	MRS	**5.0**
	E	MRS	MRS	MRS	MRS	MRS	**4.0**
	F	MRS	MRS	MRS	MRS	MRS	**MRS**

Question: what is the ROT for CAT B (B744, A343, A346, B772, B773, A332, A333) and for CAT C (MD11, B763, A306) at EDDF ?

ROT of CAT B at EDDF

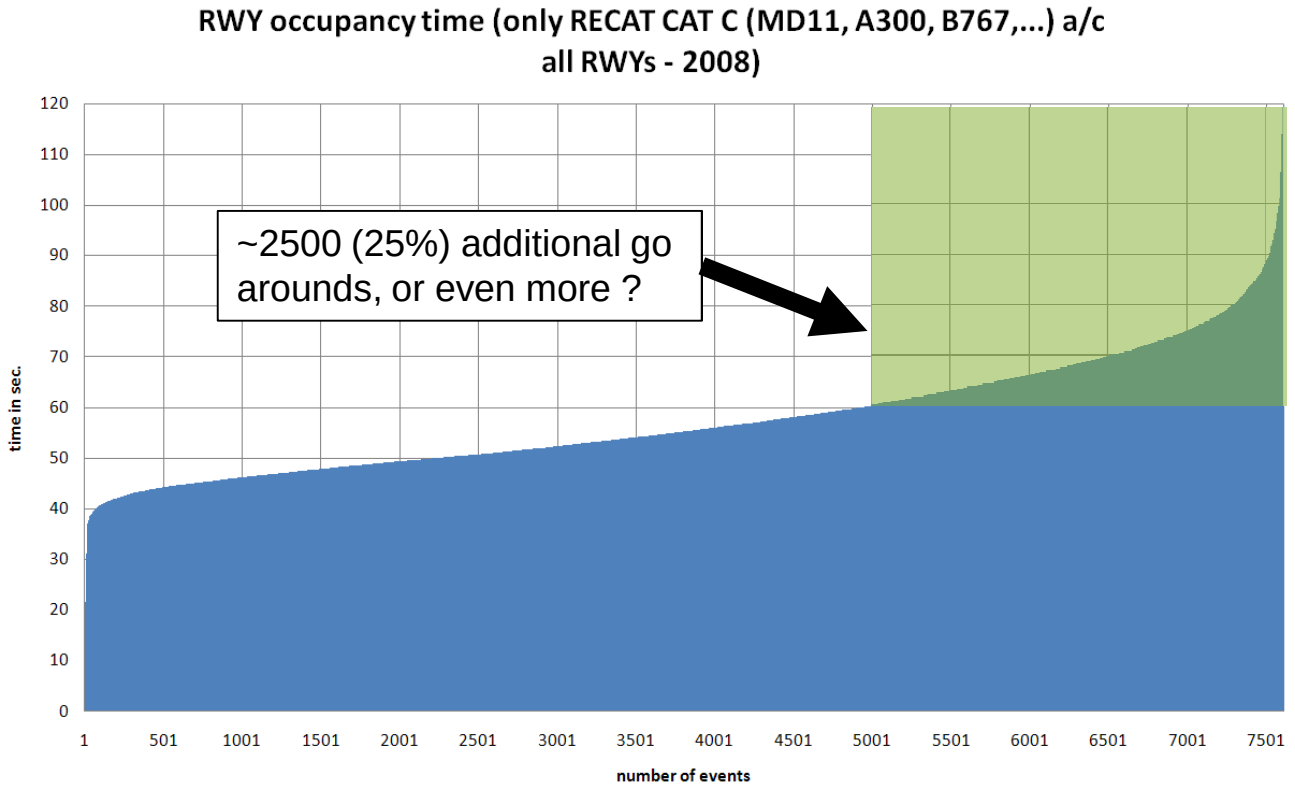
- ICAO „CAT B“-Separation of 3,0 NM means ~75 secs between two arrivals



(draft) EDDF ROT data analysis – (parts of) year 2008 --
sample size RECAT B = 13.000 events

ROT of CAT C at EDDF

- ICAO „CAT C“-Separation with MRS means ~60 secs between two arrivals



(draft) EDDF ROT data analysis – (parts of) year 2008 --
sample size RECAT C = 7.500 events

RECAT minima vs Runway Occupancy Time ?

- reduction of separation minimas (at EDDF) is limited by the runway occupancy times as a lower boundary

- reducing ARR separation for CAT B/C according to RECAT could have a major impact on the numbers of missed approaches
(leader has not vacated the rwy -> follower will go around)
-> loss of expected capacity gain !

=> RECAT (or further research / capacity analysis) should take (besides other local circumstances) the necessary ROT into account !

Content

- EDDF infrastructure & procedures
- EDDF results for RECAT
- RECAT vs. ROT
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Conclusion (i)

- **EDDF will have a major increase in ARR-capacity by opening the 4th (ARR-only) RWY in October 2011**
- **Due to the dependencies in the 4-RWY-system, EDDF needs methods to increase DEP-capacity more urgent than for ARR-capacity**
- **All changes to reduce separation minimas (e.g. wake vortex separation) are welcomed ...**
- **... but the influence by changing ARR-separation on the DEP-capacity and the ROT has to be taken into account.**
- **Don‘t compare the benefits by looking in the „textbook“ – compare against reality and local circumstances – and that‘s even more complex as it seems at the first glance (not only in EDDF)...**

Conclusion (ii)

- **Further research on RECAT should take care of ROT as a lower boundary for separation minima (when capacity gains are discussed)**

- **Due to**

  - the available ARR capacity at EDDF (with opening 4th rwy),
  - the low capacity gain of RECAT for EDDF,
  - the necessary effort for ATC-controllers (3x3 matrix -> 6x6 matrix)
  - and the necessary ROT for CAT B/C a/c,

  Fraport & German ATC & DLH concluded not to force the implementation of RECAT (Phase I) at EDDF at the moment
  (decission by OPS Management – 19. April 2011)

=> RECAT Phase 1 will not be „pushed forward“ by Fraport, DFS and DLH for implementation at EDDF at the moment.

Conclusion (iii) – some questions for discussion

- **What is the capacity effect of RECAT for DEPs ?**
  (or for combinations of ARR<->DEP, DEP<->ARR)

- **Which airports (or ANSP) have estimated/calculated the capacity effects for themselves ?**
  (e.g. LHR, AMS, CDG, FRA, ATL, EWR, JFK, ORD & SFO)
  (-> maybe a topic for a special airport/ANSP workshop ?)

- **Does ATC controllers need help by new systems to handle a 6x6 matrix instead of a 3x3 matrix and is this in the focus of SESAR / NextGen ? Or a 25x25 matrix ?**
  - **for RECAT Phase I, and especially II and III ?**
    (will ATC controllers accept those tools & change of philosophy)
    (how often has those tools to update/recalculate the sequence)
    (who will develop those tools ? Each ANSP itself ? Or SESAR ?)

“Learn the past, watch the present, and create the future.”

Any Questions ?

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Thank you for your patience and attention ;-)

Run I: General wakevortex separation parameters

ICAO

		Succeeding			
		A380	**Heavy**	**Medium**	**Light**
Preceding	**A380**	MRS	6.0	7.0	8.0
	Heavy	MRS	4.0	5.0	6.0
	Medium	MRS	MRS	MRS	5.0
	Light	MRS	MRS	MRS	MRS

RECAT

		Succeeding				
		A380	**HH**	**UM**	**MM**	**LM**
Preceding	**A380**	MRS	6	6	7	8
	HH	2.5	2.5	4	5	6
	UM	2.5	2.5	2.5	5	5
	MM	2.5	2.5	2.5	2.5	4
	LM	2.5	2.5	2.5	2.5	2.5

Source: Eurocontrol

Aircraft Wakegroup Allocation

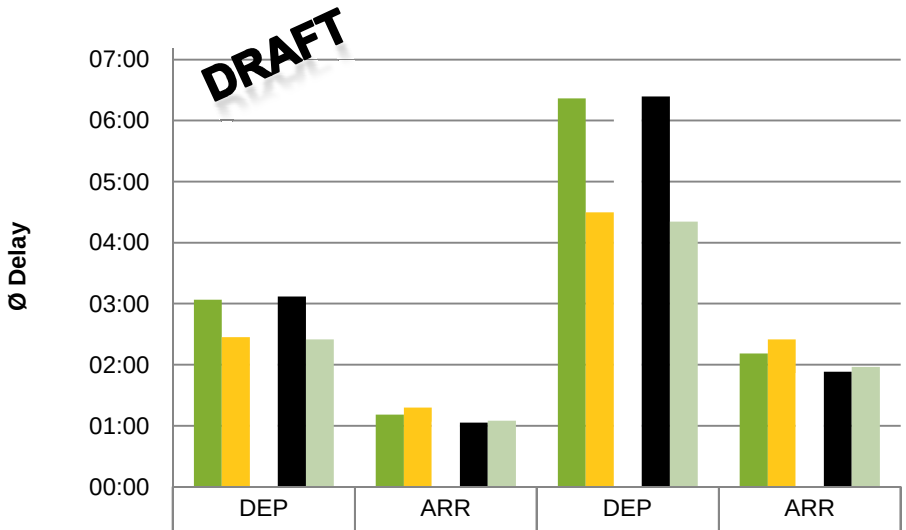
Heavy (HH) ≥ 250t (excl. A380)**
250t > **Upper Medium (UH)** ≥ 120t
120t > **Medium (MM)**≥ 40t
40t > **Lower Medium (LM)** ≥ 7t*
7t > **Small (SS)***

* Group was not considered. AC lighter than 7t are assigned as LM
** A380 assigned to an own group

Run I: Results

1. Baseline scenario
    a. ICAO separation
    b. increased radar separation to facilitate dep‘s

2. RECAT scenario (2.5NM)
    a. RECAT on RWY 25L & 25R
    b. RECAT on RWY 25R, ICAO on RWY 25L
    c. RECAT on RWY 25R, increased ICAO on RWY 25L (see 1-b)



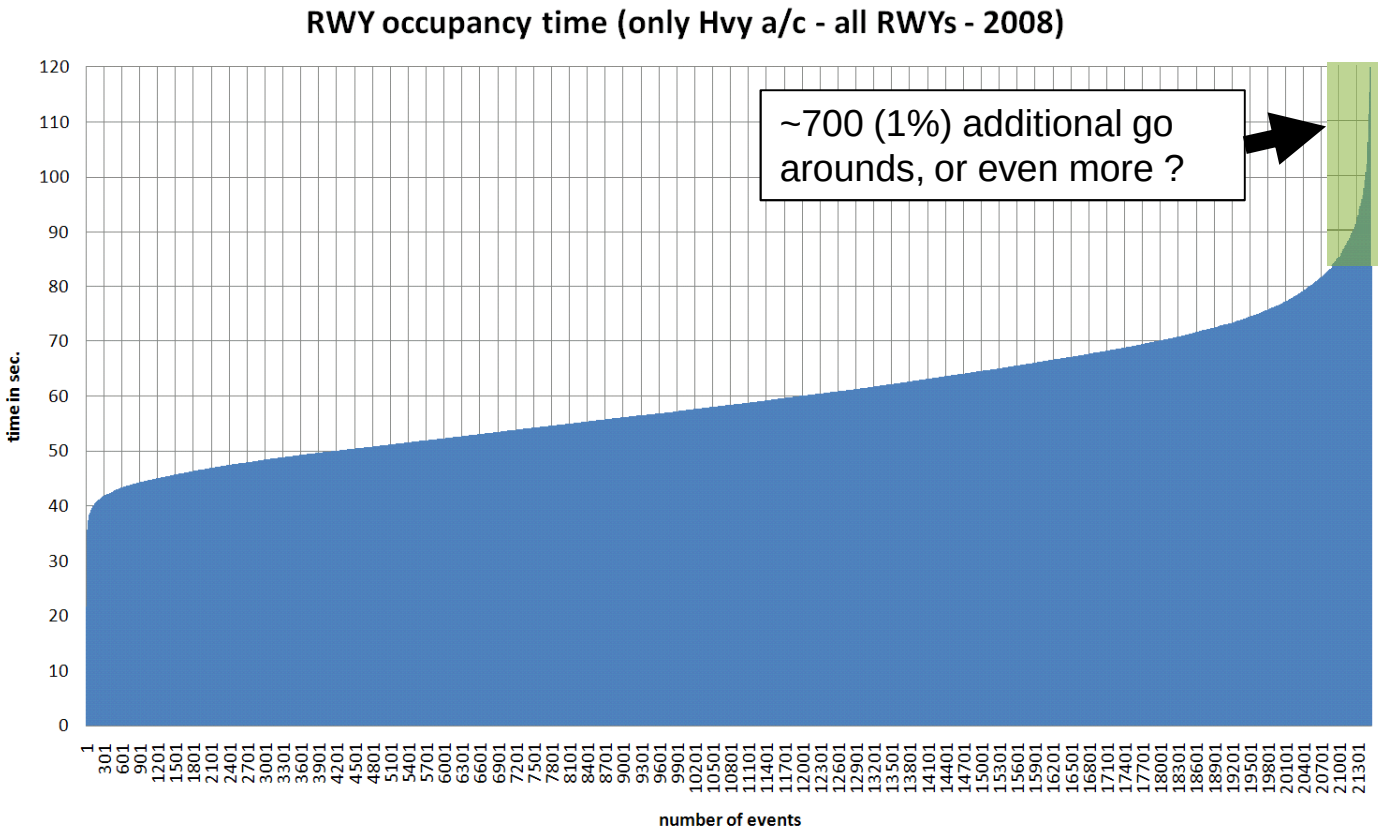
	declared capacity 88 mvts/h		declared capacity 100 mvts/h	
	DEP	ARR	DEP	ARR
Baseline 1a	03:04	01:11	06:22	02:11
Baseline 1b	02:27	01:18	04:30	02:25
RECAT 2a	02:58	01:04	06:20	01:52
RECAT 2b	03:07	01:03	06:24	01:53
RECAT 2c	02:25	01:05	04:21	01:58

Conclusion Run I

- Every tested RECAT-szenario resulted in a reduction of arrival delay, but in most instances at depature delay charge
- Best results could be achieved if RECAT is only applied to the independet NW-RWY
- Arrival / Departure constraints between the close parallel RWYs limit the impact of RECAT
- If used sensibly nearly equal departure delay situation can be monitored as in a non RECAT-szenario
- Most advantages in saturated arrival situation

The rwy occupancy time as a lower boundary for separation minimas shouldn‘t be forgotten.

- Hvy-Hvy-Separation of 4NM means ~100 secs between two arrivals
- Reducing Separation by 0.5 NM => reduction of 15 sec => ~85 secs



(draft) EDDF ROT data analysis – (parts of) year 2008
sample size H+M+L = 85.000

RECAT – analytical capacity „model“ (MS Excel) for 2015

Approach speed						
vHVY	vMED					
140	140	kts				
140	140	0	head wind component			
Trafficmix						
CAT A	B	C	D	E	F	
3,0%	23,0%	1,0%	57,0%	15,0%	1,0%	
average arr speed						
140	vAVG					
259,28	km/h					
72,0222222	m/s					
105,311571	**sec**					
34,1842777	**ARR / hr and rwy**					

Separation minima (NM)

	A	B	C	D	E	F
A	2,5	5	6	7	7	8
B	2,5	3	4	5	5	7
C	2,5	2,5	2,5	3,5	3,5	6
D	2,5	2,5	2,5	2,5	2,5	5
E	2,5	2,5	2,5	2,5	2,5	4
F	2,5	2,5	2,5	2,5	2,5	2,5

Separation propability

	A	B	C	D	E	F
A	0,1%	0,7%	0,0%	1,7%	0,5%	0,0%
B	0,7%	5,3%	0,2%	13,1%	3,5%	0,2%
C	0,0%	0,2%	0,0%	0,6%	0,2%	0,0%
D	1,7%	13,1%	0,6%	32,5%	8,6%	0,6%
E	0,5%	3,5%	0,2%	8,6%	2,3%	0,2%
F	0,0%	0,2%	0,0%	0,6%	0,2%	0,0%

	A	B	C	D	E	F
A	0,00225	0,0345	0,0018	0,1197	0,0315	0,0024
B	0,01725	0,1587	0,0092	0,6555	0,1725	0,0161
C	0,00075	0,00575	0,00025	0,01995	0,00525	0,0006
D	0,04275	0,32775	0,01425	0,81225	0,21375	0,0285
E	0,01125	0,08625	0,00375	0,21375	0,05625	0,006
F	0,00075	0,00575	0,00025	0,01425	0,00375	0,00025

average separation	3,09545	1
with buffer	4,09545	