



Supporting
European
Aviation



Reduced wake turbulence separation minima between departures from Closely Spaced Runway Entry Taxiways

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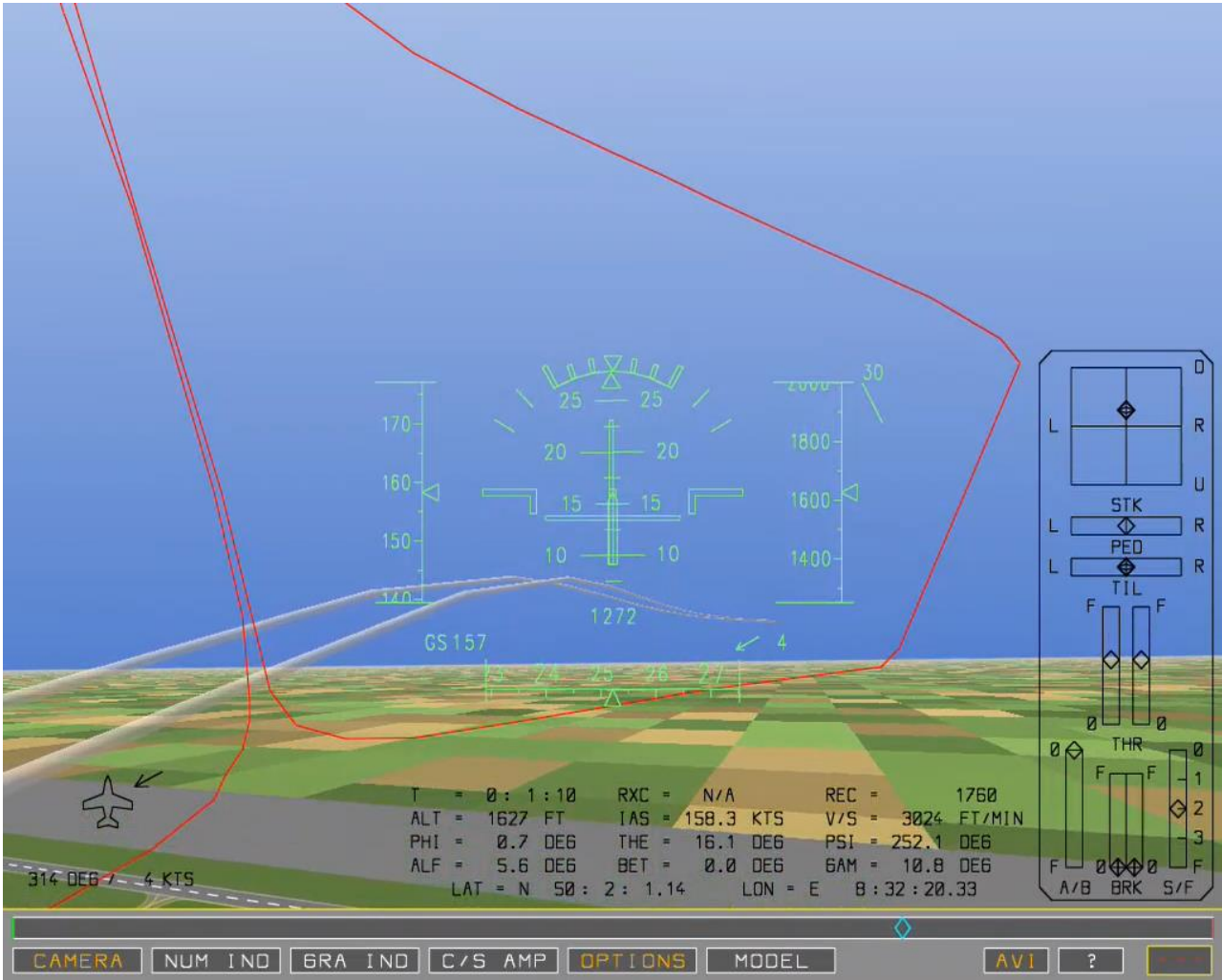
02 December 2025



NETWORK
MANAGER



Wake turbulence physics and separation needs



Simulation by TU Berlin



Wake Turbulence Separation between consecutive departures
(ICAO PANS-ATM Doc 4444)

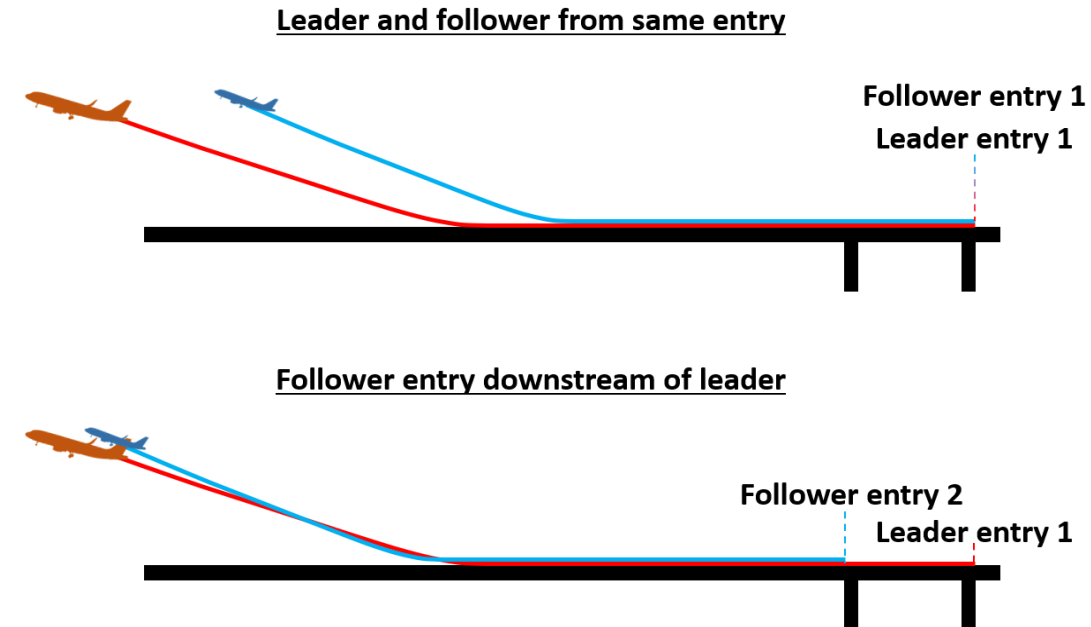
	J	H	M	L
J		120 s	180 s	180 s
H			120 s	120 s
M				120 s
L				

Wake Turbulence separation for intersection departures

ICAO PANS-ATM Doc 4444 :

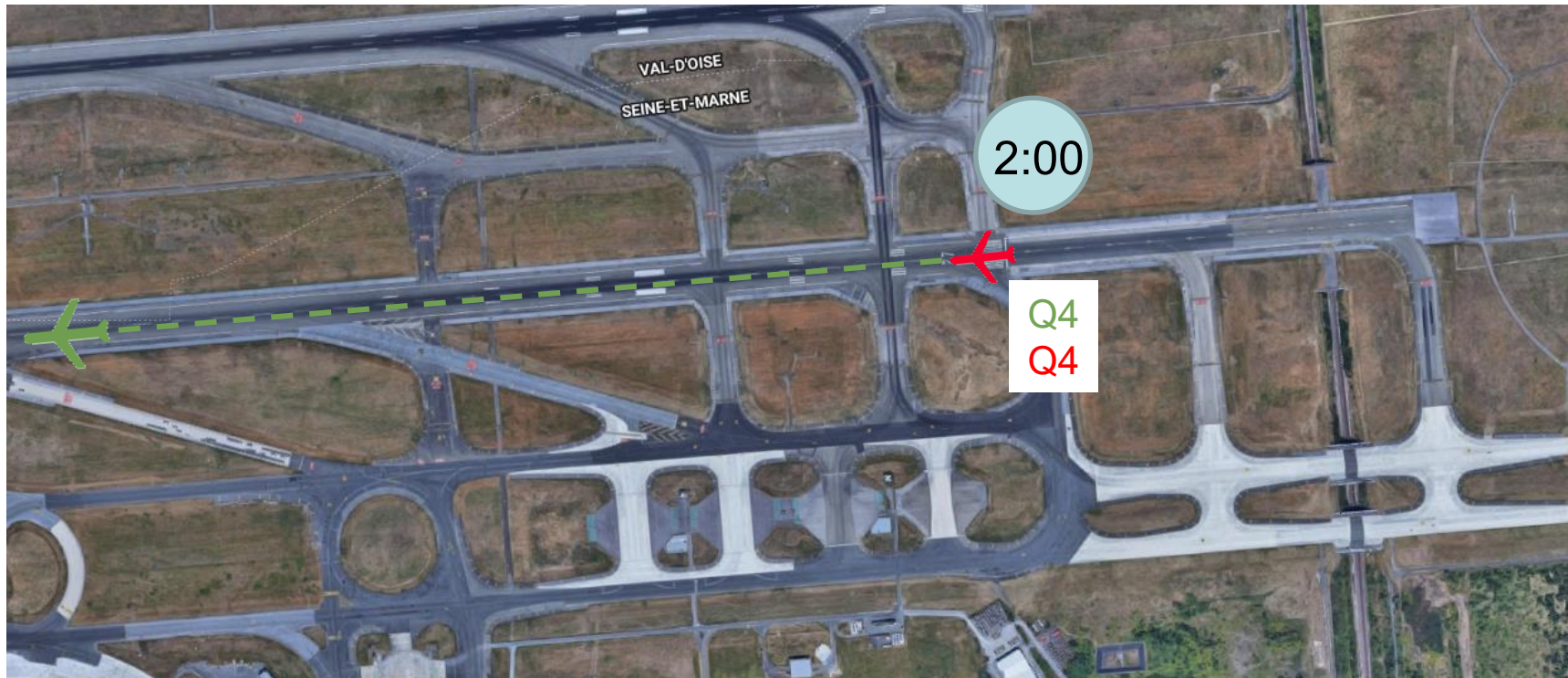
Additional minute of time separation if follower departs from an **intermediate part / entry of the runway**.

	J	H	M	L
J		120 +60 s	180 +60 s	180 +60 s
H			120 +60 s	120 +60 s
M				120 +60 s
L				



- ➡ Increased holding time
- ➡ Reduced departure throughput
- ➡ Decreased flexibility in runway entry usage during peaks

Today: 2 min for H-M both from Q4



Today: 3 min for H from Q4 followed by M from Q3



Today: 3 min also for H from Q6 followed by M from Q3



BRETSEP: <3 min for H from Q4 followed by M from Q3 ?



Optimisation background

- Is the additional minute over-conservative?
 - Today: Irrespective of the distance between intermediate runway entry and take-off point
 - Reduction of 'extra' wake separation for close entry pairs

- In US: up to 500ft (~152m), FAA applies same separation minima as same entry

Ref: FAA ORDER JO 7110.65Z, § 3-9-7. b. 2.

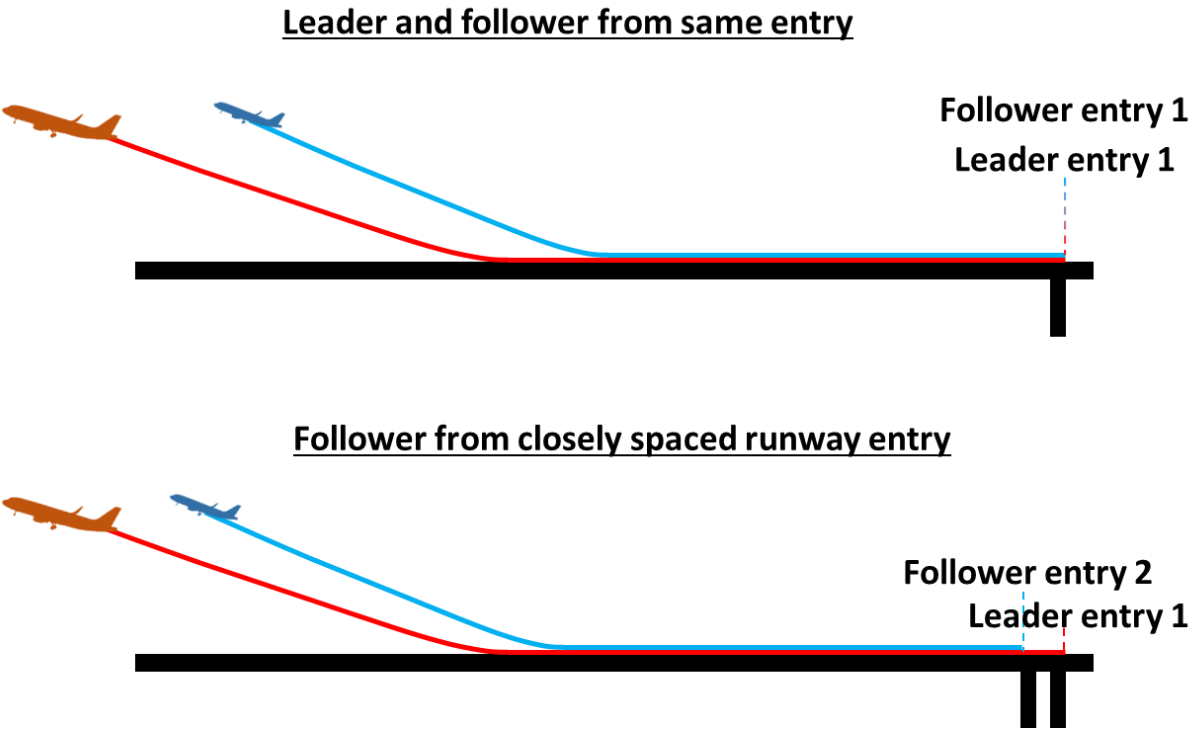
“BRETSEP” concept / solution

BRETSEP= reduction of separation increase for closely spaced runway entries

	J	H	M	L
J		120 +XX s	180 +XX s	180 +XX s
H			120 +XX s	120 +XX s
M				120 +XX s
L				

→ Additional time is defined as a function of the risk:

- distance between the line-up / runway entry points, and
- the leader-follower category pairs



Palma de Mallorca use case

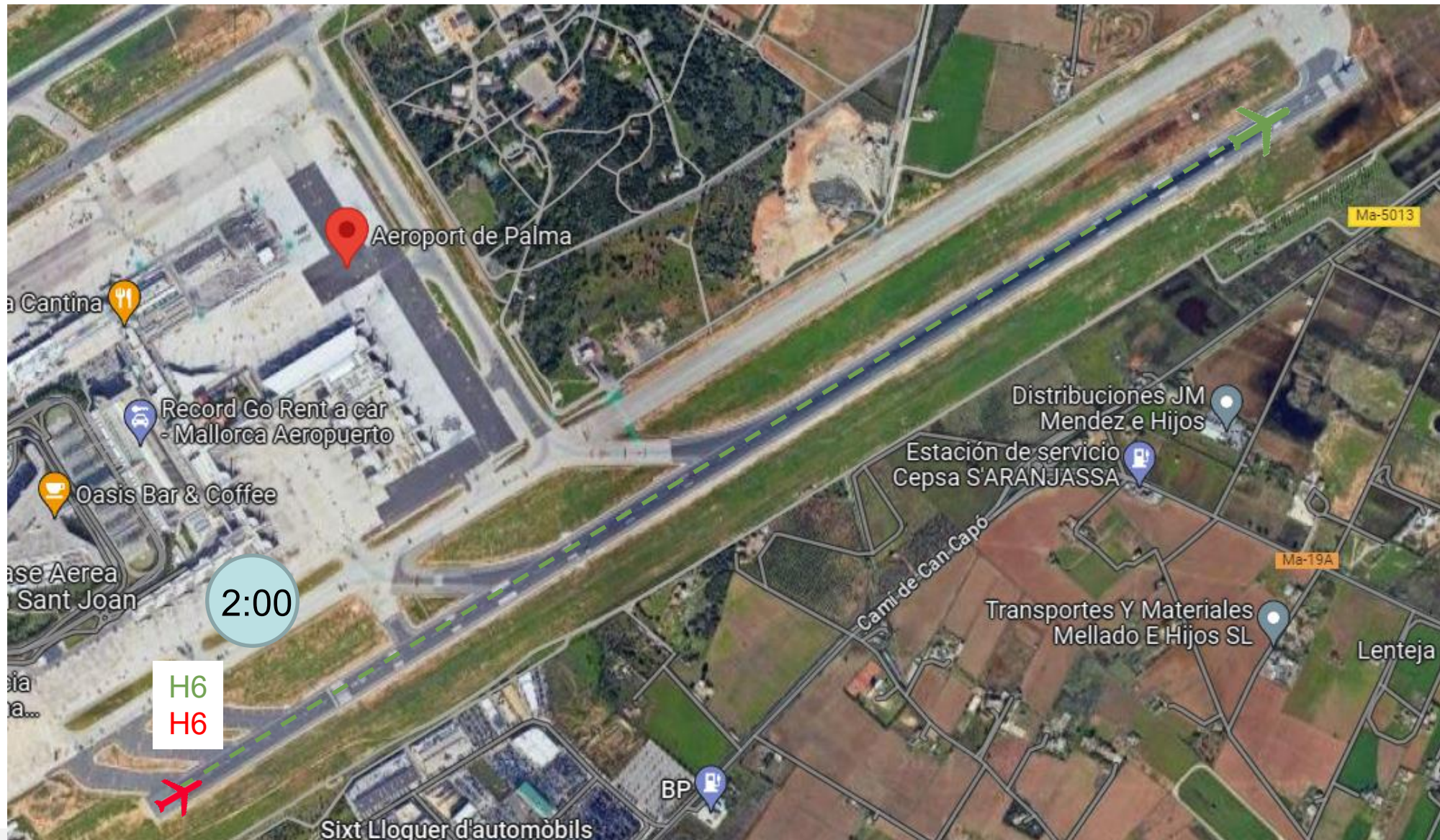


LEPA RWY06R layout

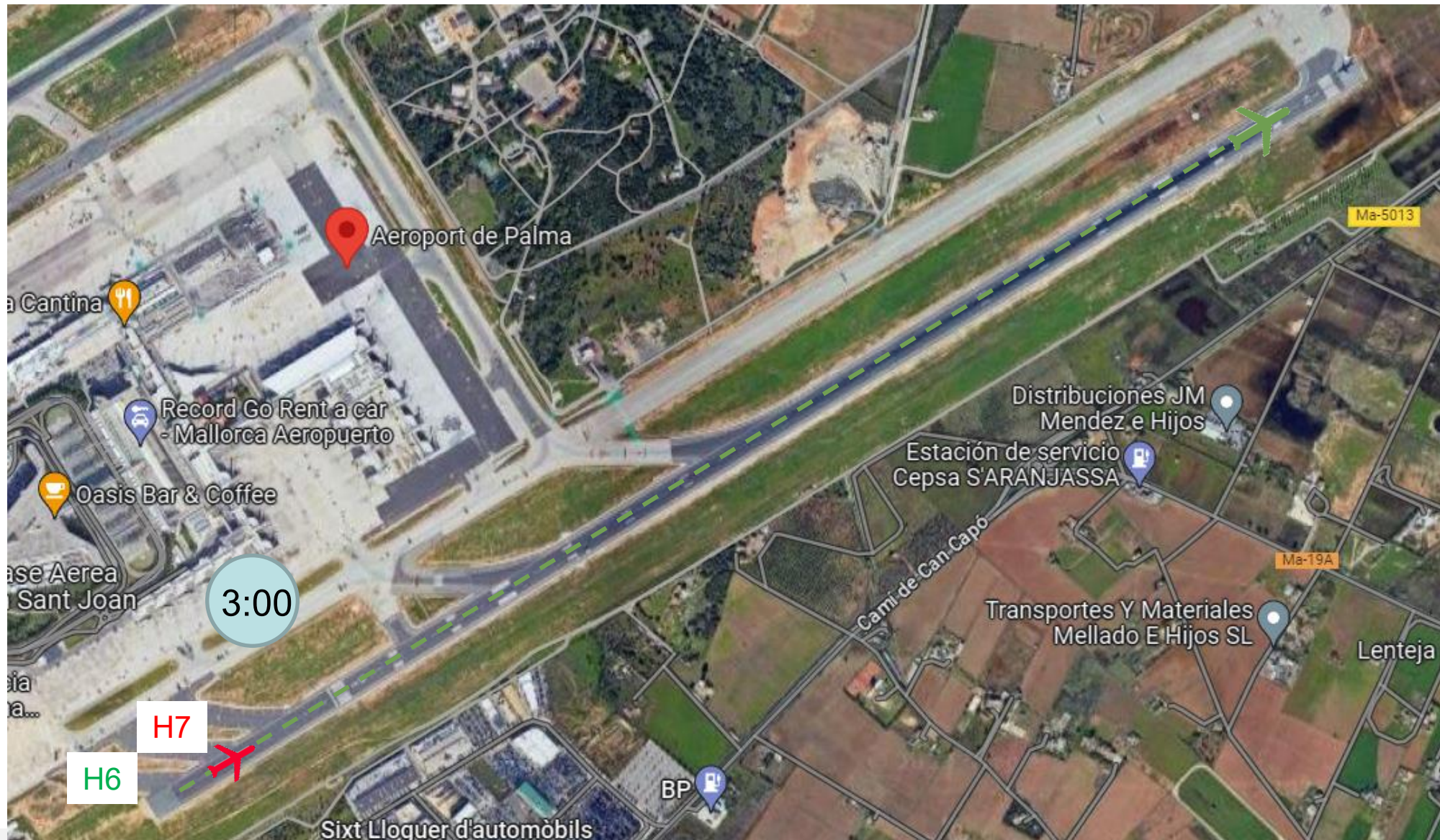


Entry point	TORA [m]	TODA [m]	Distance to previous HP [m]
06R (H6)	3000	3060	
06R INT H7	2812	2872	188
06R INT H8	2680	2740	132
06R INT S3	2390	2450	290

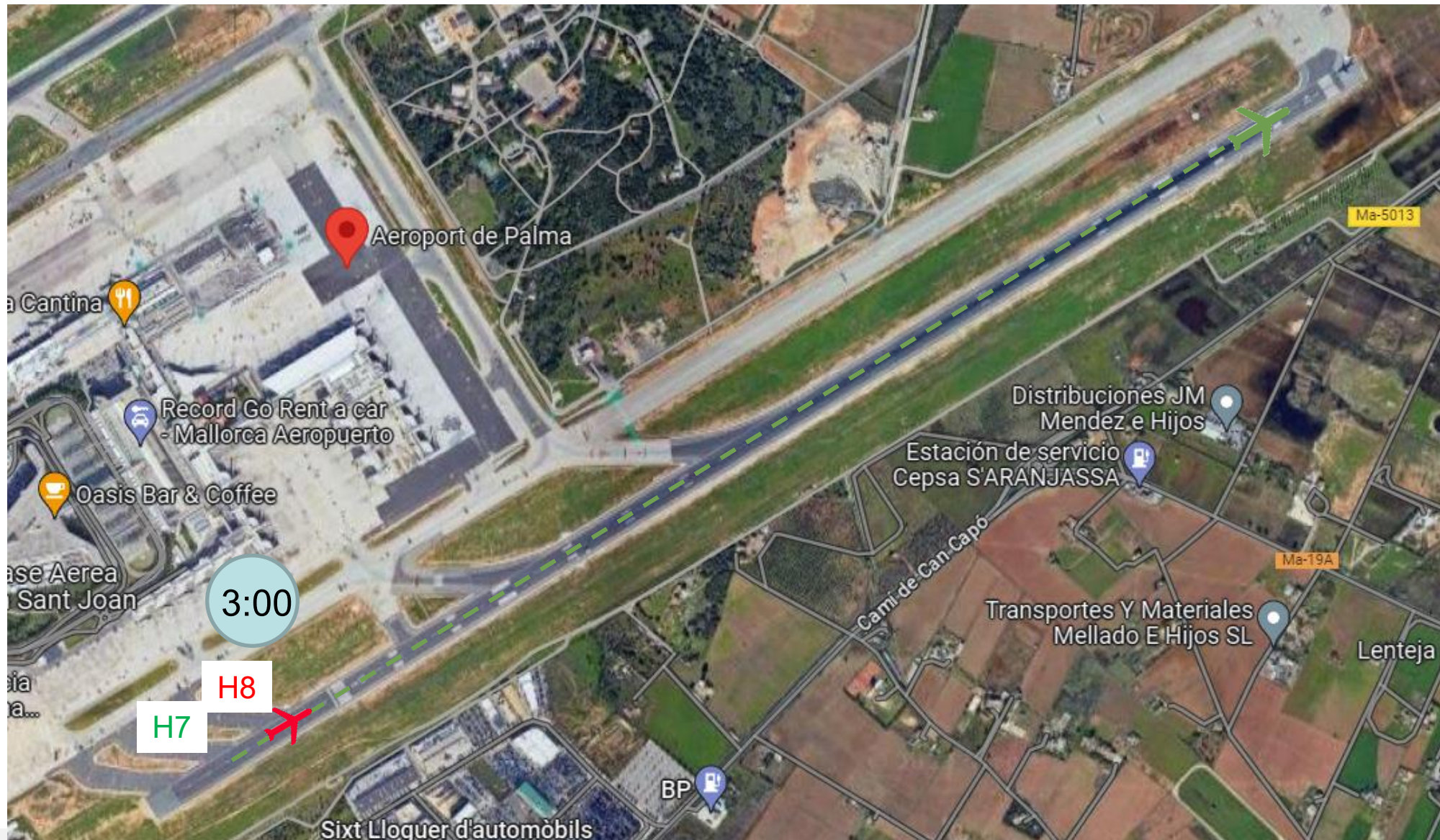
Today: 2 min for H-M both from H6



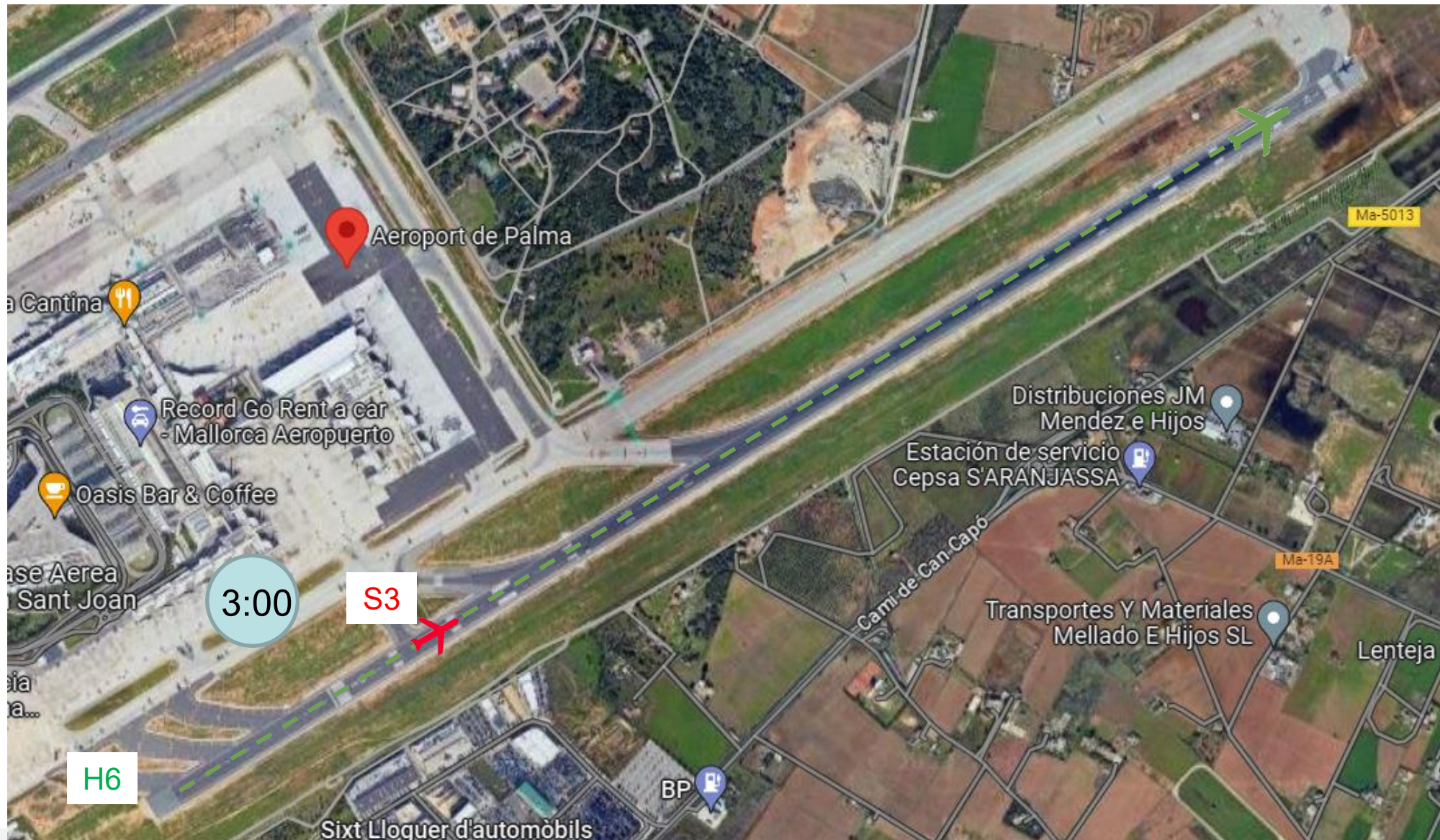
Today: 3 min for H from H6 followed by M from H7



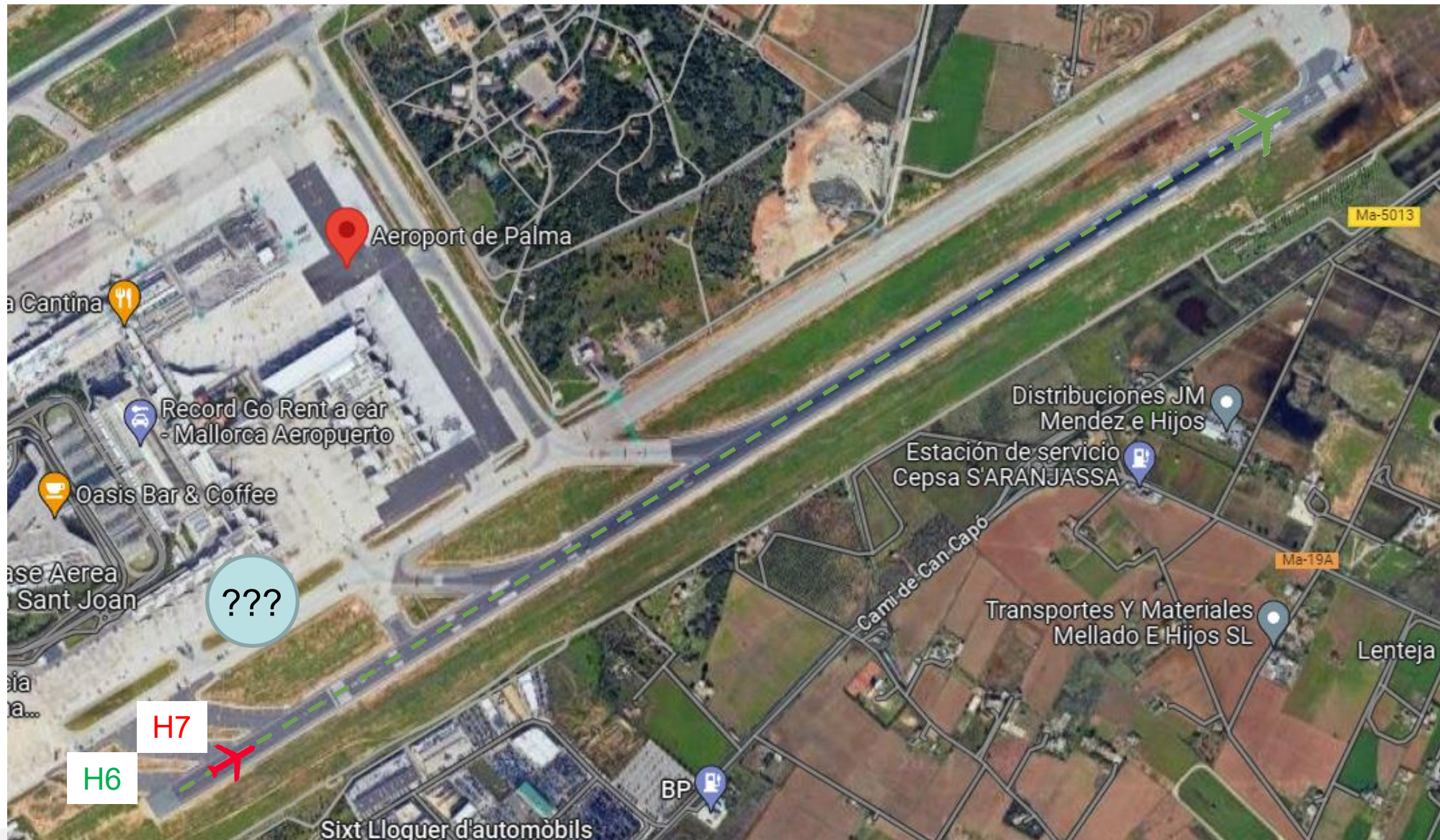
Today: 3 min for H from H7 followed by M from H8



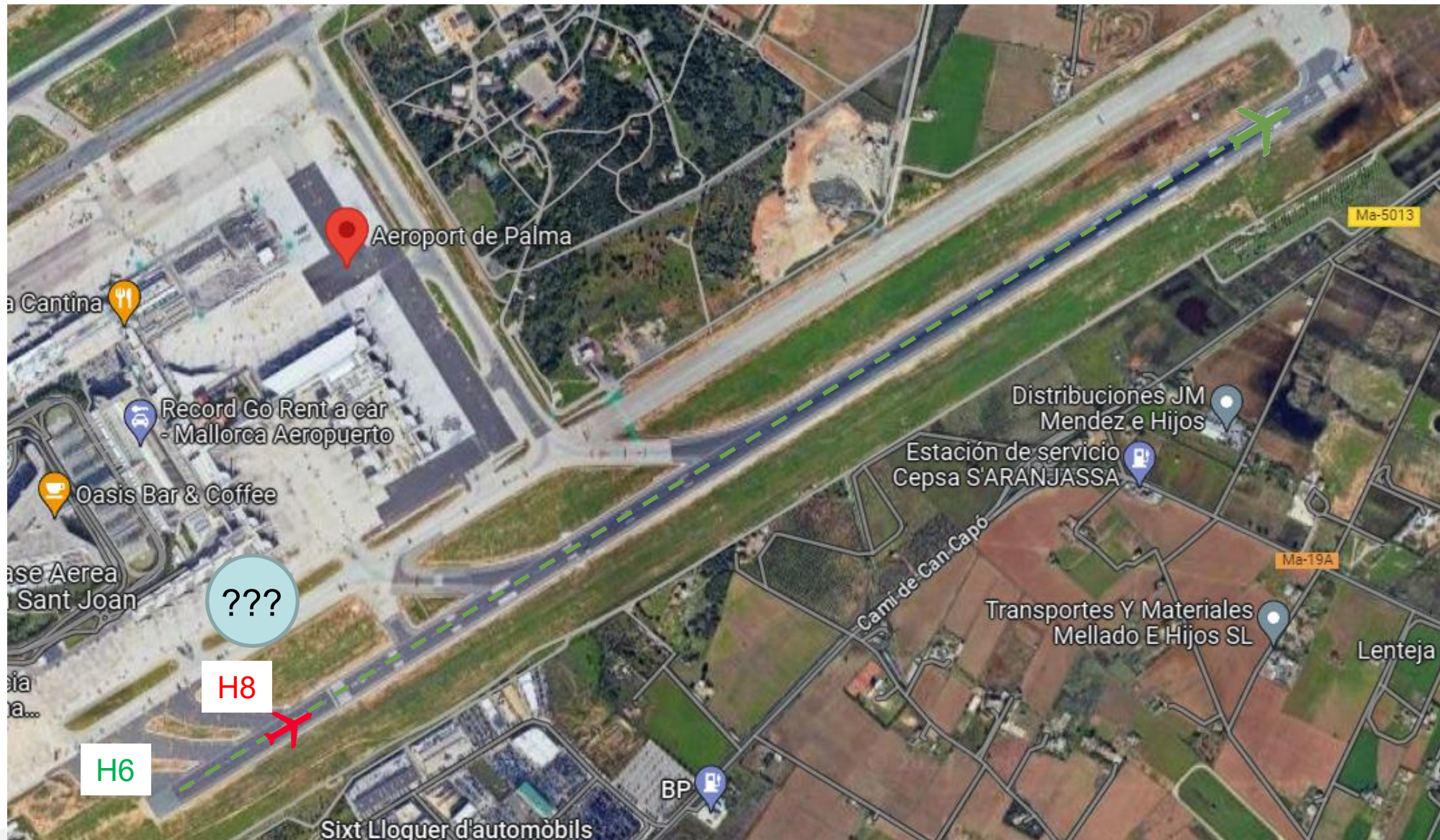
Today: 3 min for H from H6 followed by M from S3



BRETSEP: <3 min for H from H6 followed by M from H7 ?



BRETSEP: <3 min for H from H6 followed by M from H8 ?



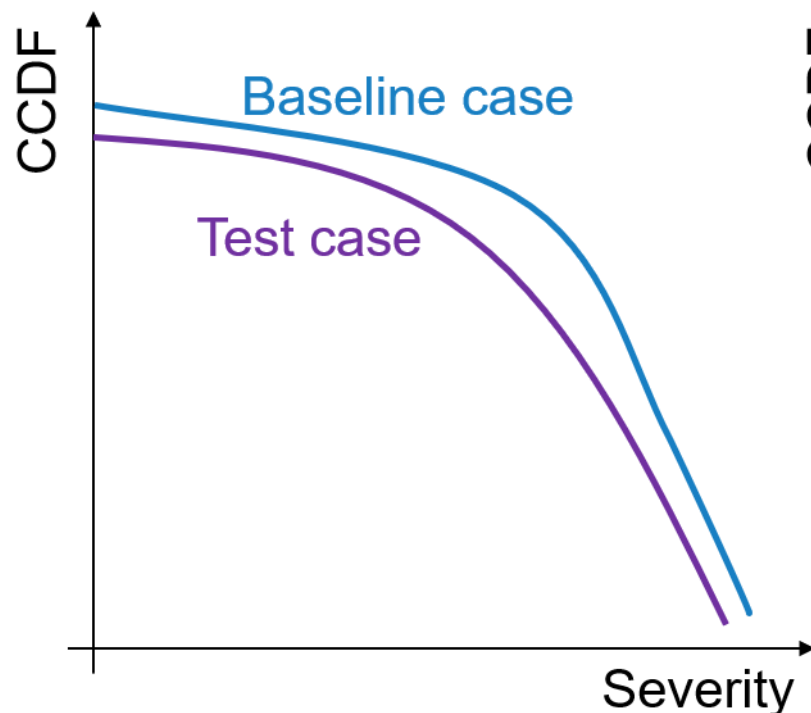
Risk assessment methodology

Relative comparison, for wake constrained pairs, between:

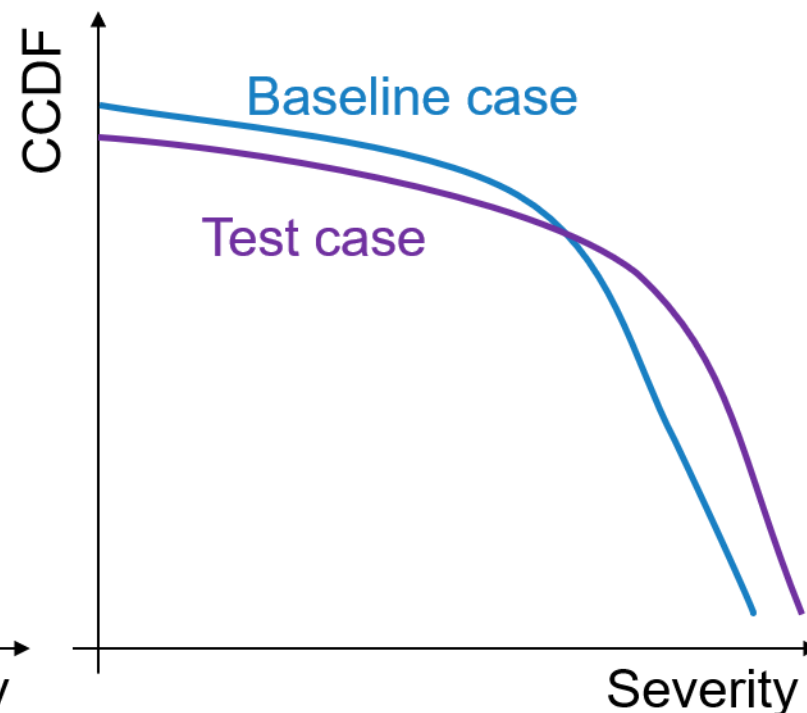
- wake encounter risks in today's operations,
- wake encounter risks modelled with reduced extra time separation.

→ Based on Paris-CDG WIDAO methodology

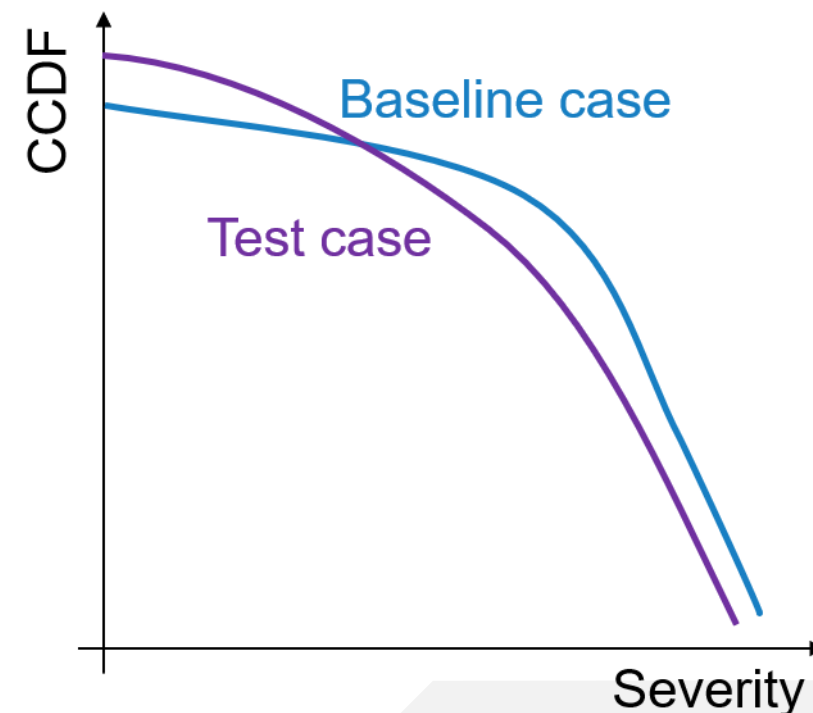
✓ Acceptably safe



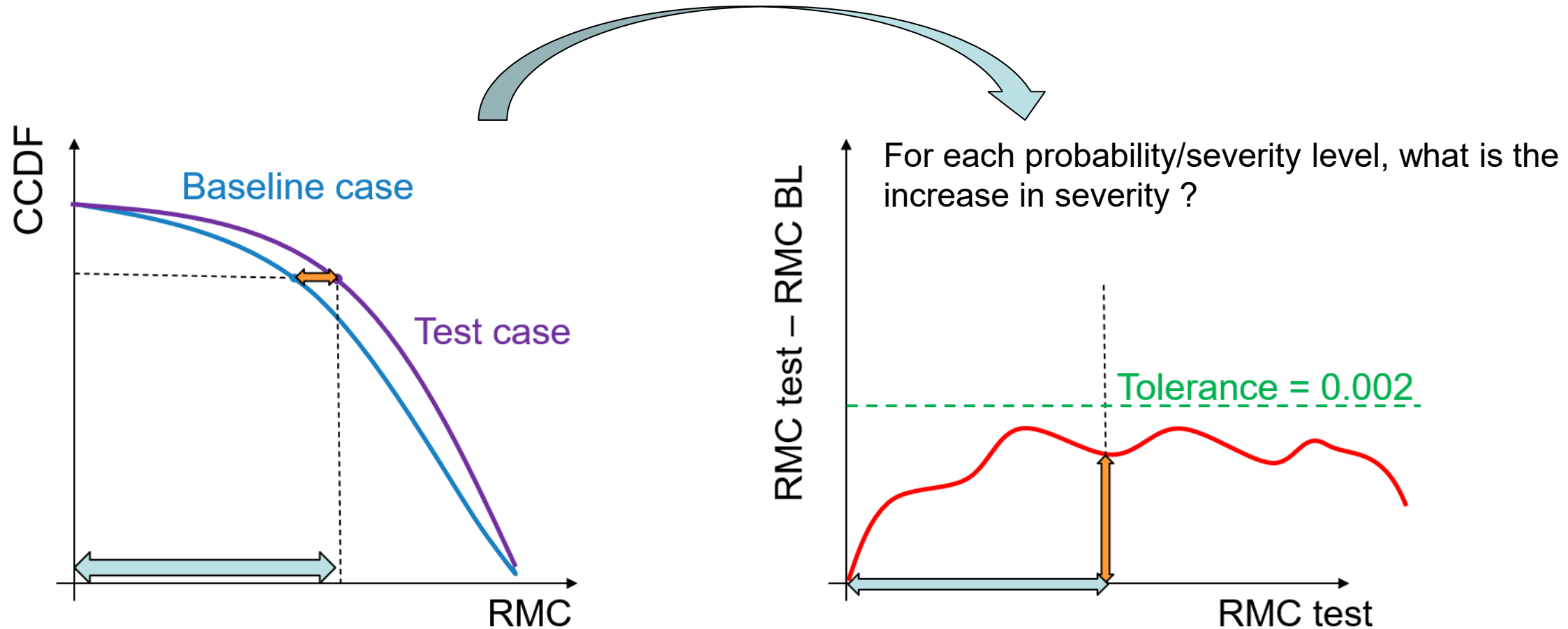
✗ Not acceptably safe



✓ Can be acceptable if justified



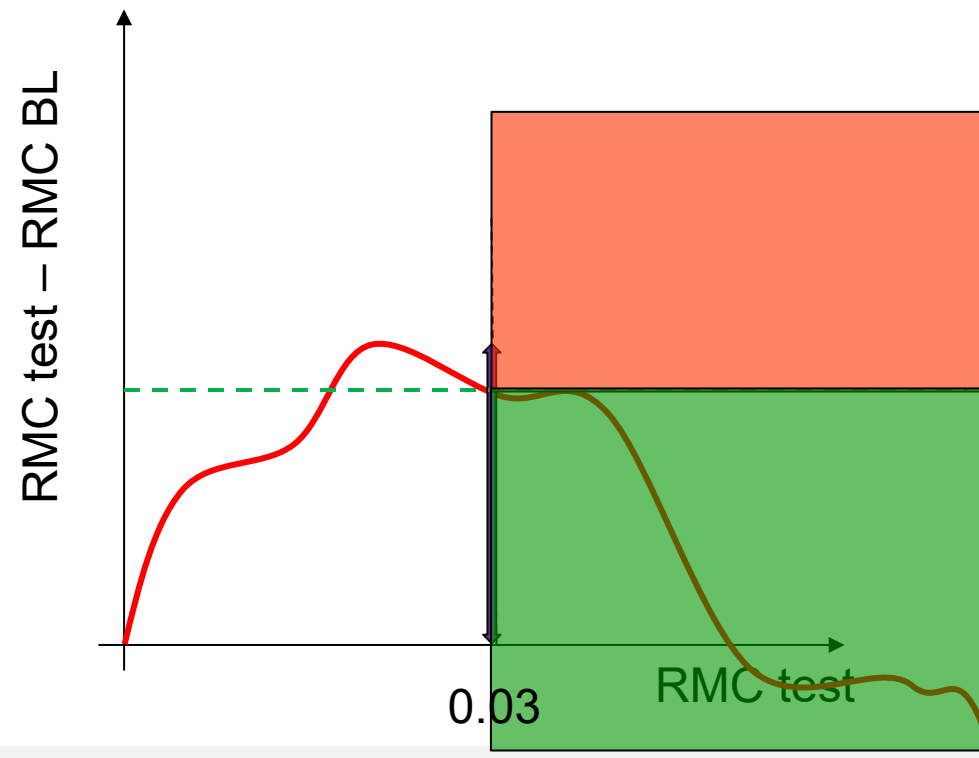
Risk assessment methodology



- Same metric as in RECAT-EU
- Allows characterizing risk increase compared to reference

Risk assessment methodology

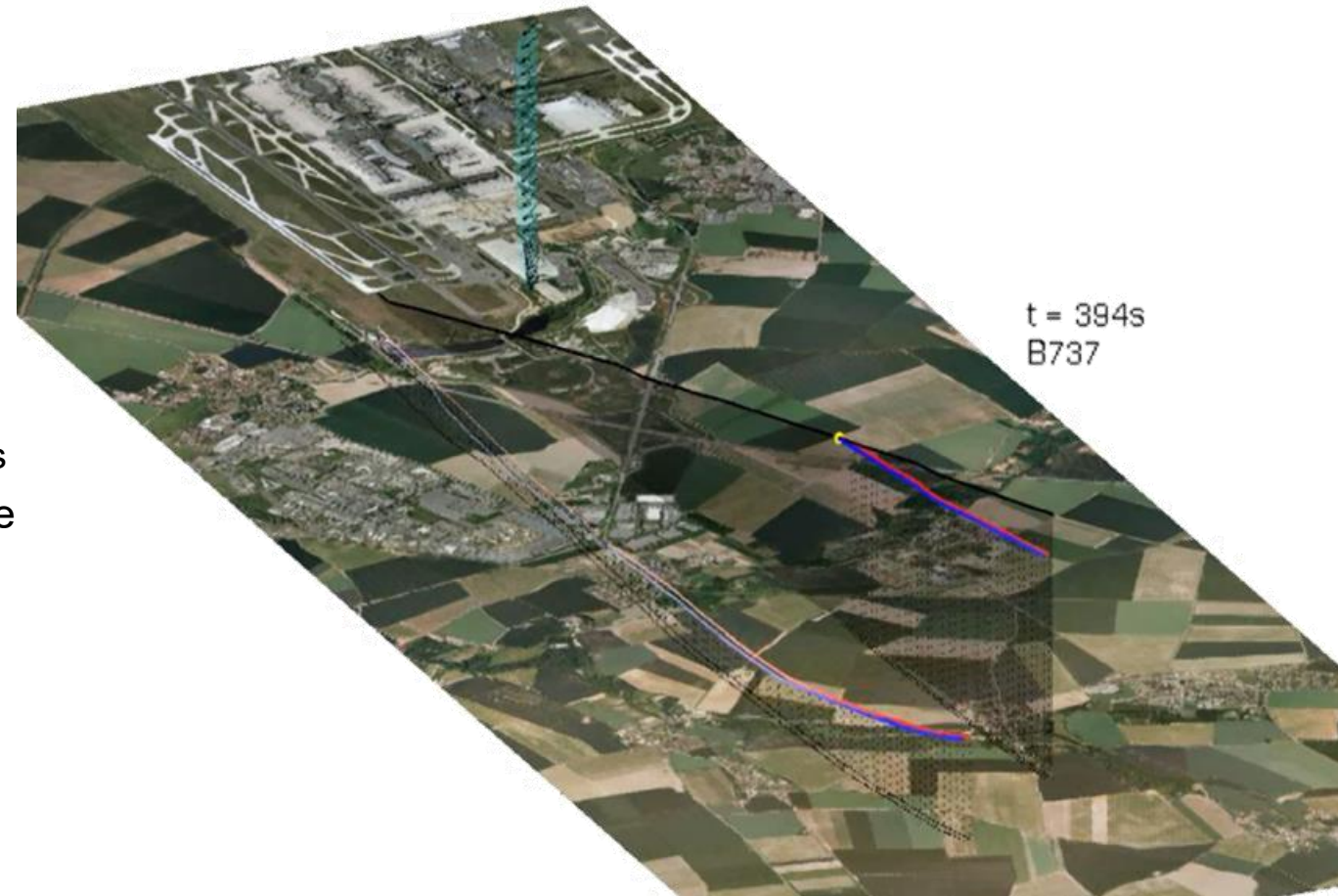
- A test case is then considered as acceptably safe if
 - For severity levels larger than $RMC = 0.03$ (value established as threshold for wake encounter to be significant)
 - The severity increase does not exceed the defined tolerance.



WAKE4D simulations

- Inputs
 - Aircraft tracks for various aircraft
 - Wind measurements

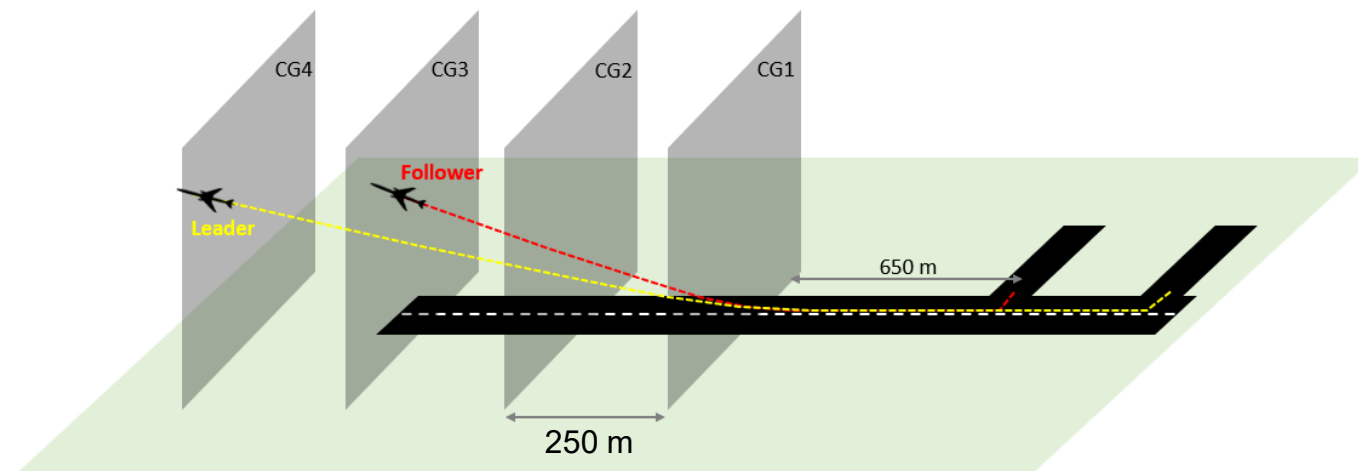
- Outputs
 - Simulation of the 3D wake evolution
 - for various aircraft
 - flying in typical measured wind conditions
 - WT risk assessment compared to a baseline

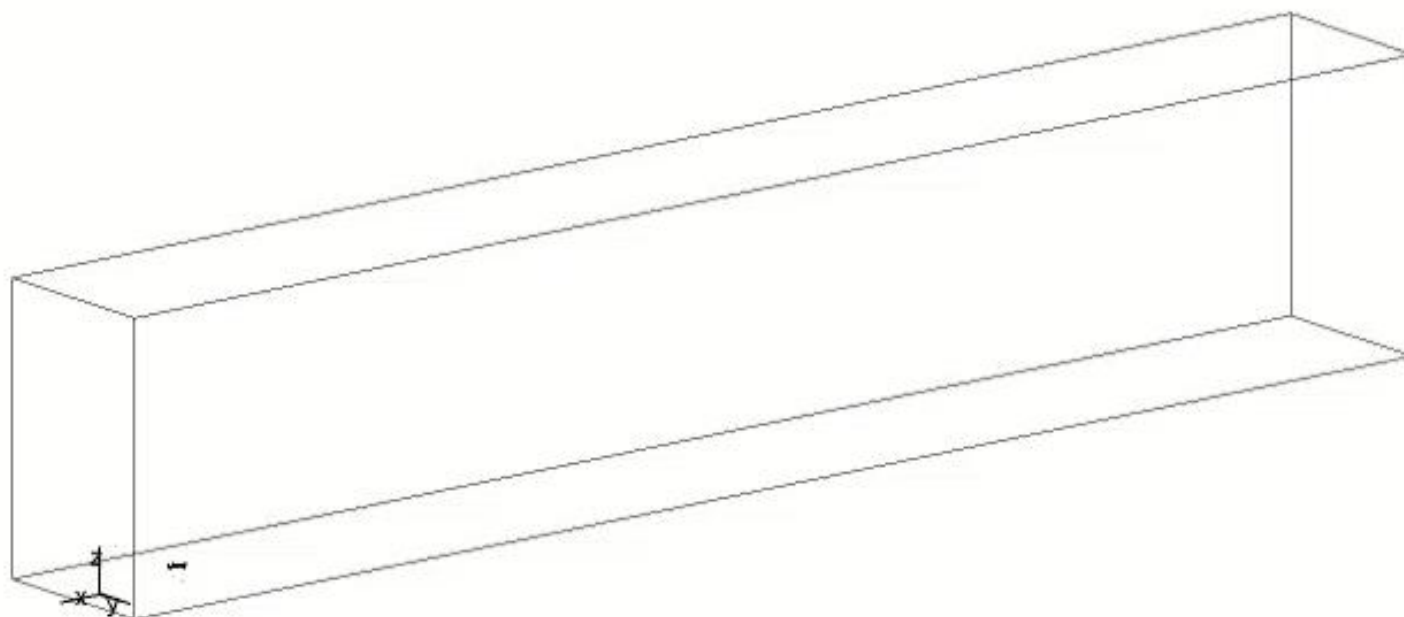


I. De Visscher, G. Winckelmans, T. Lonfils, L. Bricteux, M. Duponcheel, and N. Bourgeois, The WAKE4D simulation platform for predicting aircraft wake vortex transport and decay: Description and examples of application, AIAAASE Conference, paper AIAA 2010-7994, 2010.

Control gate definition

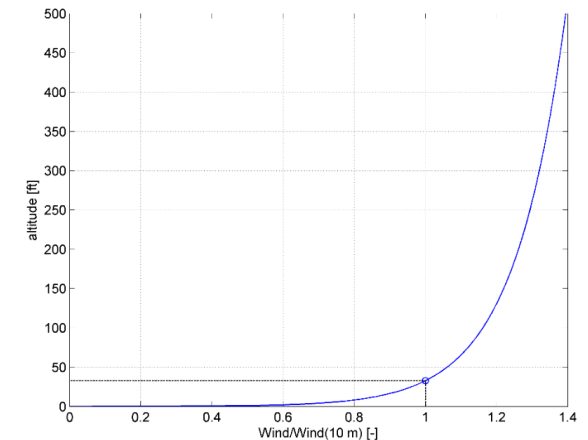
- Risk assessed in fixed planes across and perpendicular to the aircraft trajectories(=“control gates”).
- Control gates covering full departure path up to 3000 ft and separated by 250 m





WAKE4D input files

- Various leader aircraft types
- Aircraft trajectory
 - Realistic model calibrated on local data
 - 50 trajectories generated for each flight with variation of Take-off mass and related rolling time, distance, take-off speed
- Met inputs
 - ICAO standard atmosphere
 - Wind profile
 - Different HW/XW combinations
 - For each wind conditions, 20 runs with variation on wind values
- For PMI study : 4 leaders x 50 trajectories x 58 wind conditions x 20 deterministic runs = 232,000 4-D runs



Follower and encounter modelling

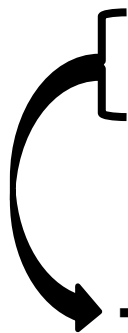
- Frequent Medium followers
 - covering various aircraft sizes and performances
 - 50 different trajectories
- Calculation of the probability of encounter using
 - Vortex 2-D positions from WAKE4D Monte-Carlo results
 - Probability of the follower to be at that position (assuming Normal distribution in both direction)
- Calculation of associated severity
 - Vortex circulation from from WAKE4D Monte-Carlo results
 - Follower characteristics (speed, span, aspect ratio)
 - using Rolling Moment Coefficient (RMC) as metric



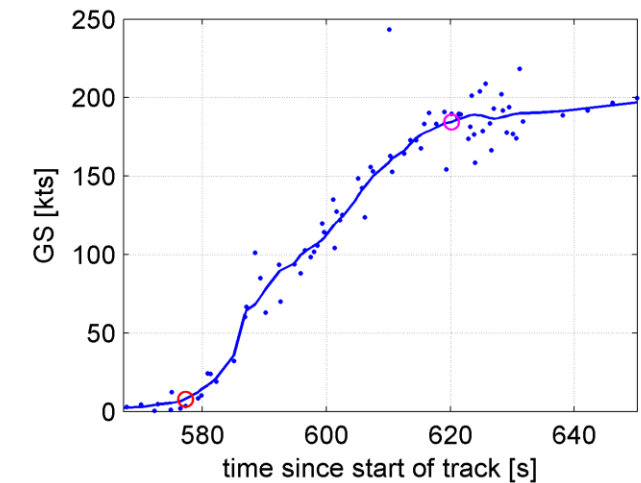
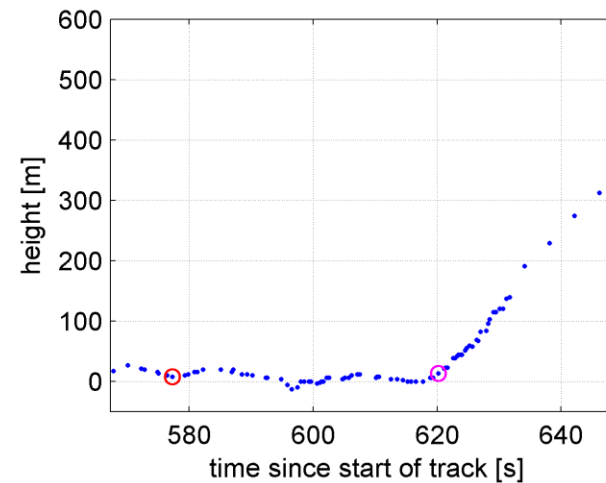
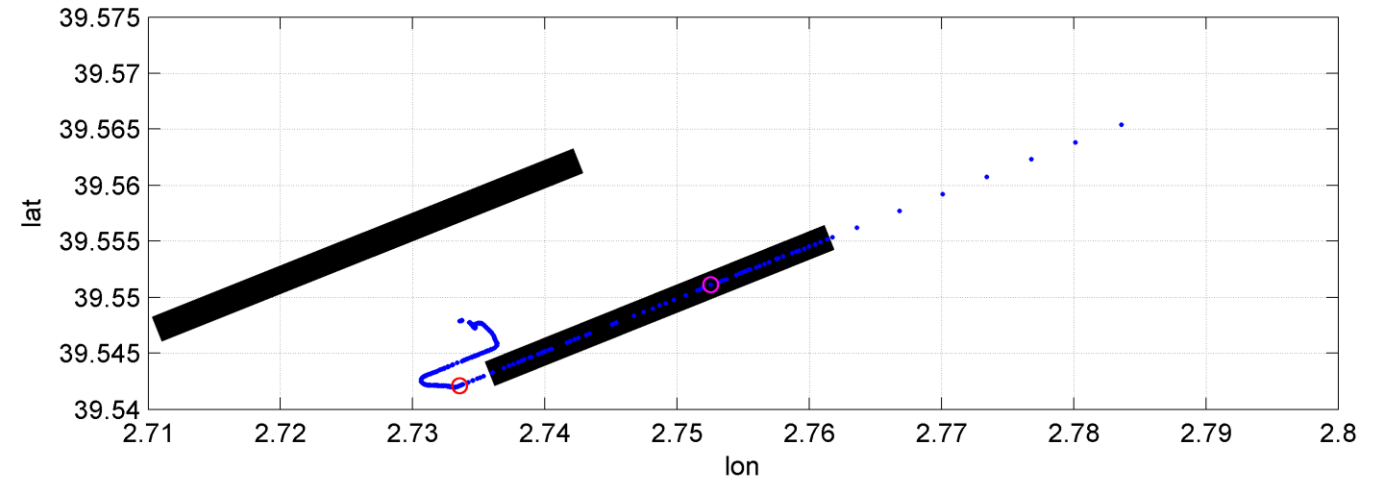
Surveillance data analysis

→ Extract all relevant take-off parameters:

- Departure runway
- Runway Entry point
- Start of rolling time and position
- Take-off time, speed and position
- Initial climb rate



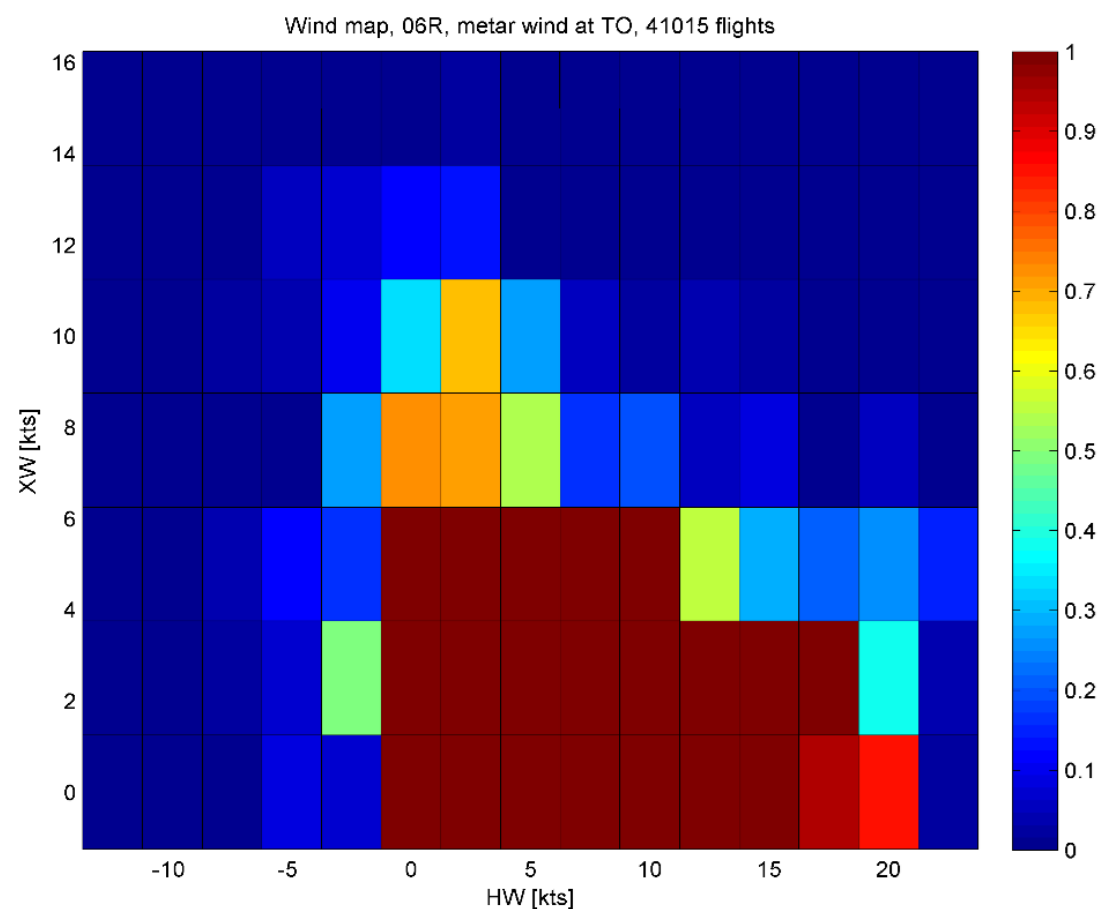
→ Rolling time and distance



Wind data

Wind information (speed, direction) for same period as surveillance data

→ Extract wind at take-off time



In order to limit the number of simulations only most frequent wind conditions are selected.

Data filtering

- Tracks with climb rates lower than 3 deg or larger than 20 deg
- Tracks performing a rolling take-off

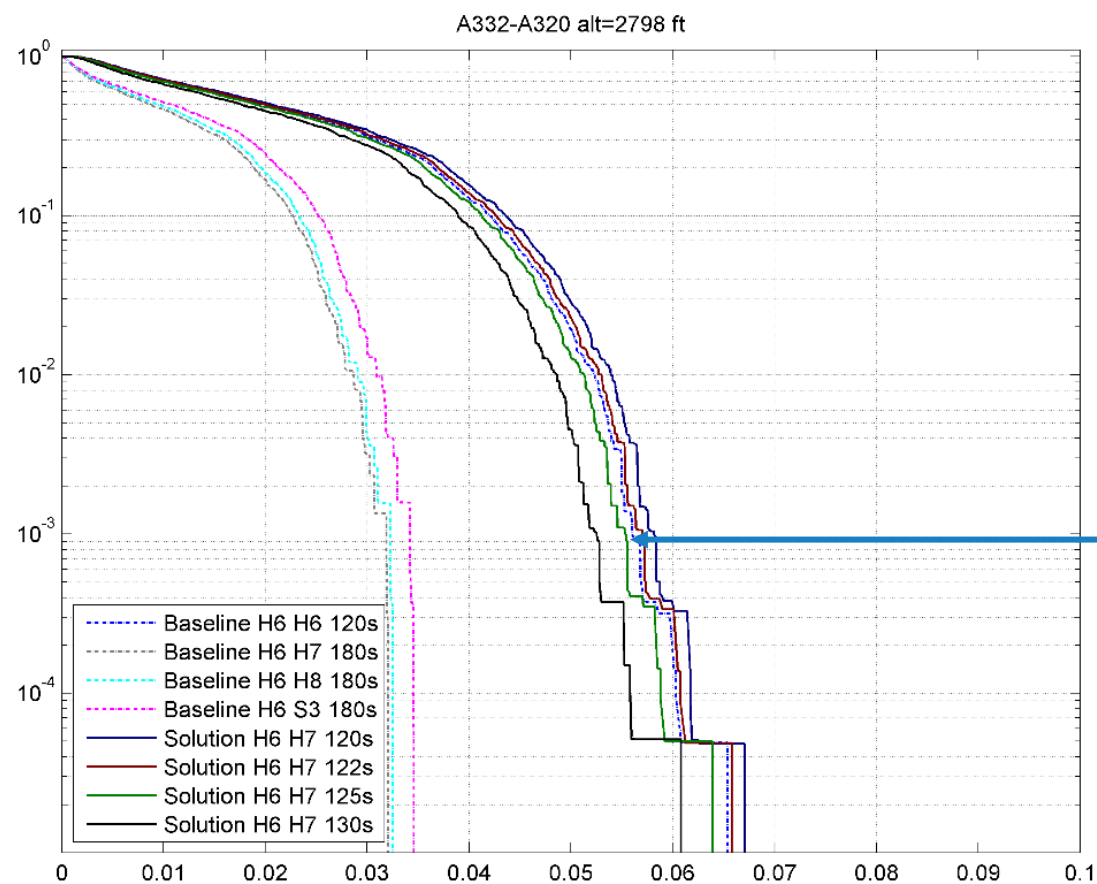
	N tracks	Fraction of tracks
Total	48669	
N no runway detected	838	1.7%
N no HP detected	1240	2.5%
N no take-off point detected	1008	2.1%
N outlier climb rate	41	0.1%
N no HW data	4540	9.3%
N rolling TO	3054	6.3%
N not on RWY 06R	27	0.1%
Remaining tracks	37921	77.9%

Trajectory modelling

- For each type and each wind range:
 - Range of Take-off Speed $[TAS_{TO,p2.5}, TAS_{TO,p97.5}]$
 - Considered mass range: from MTOW to $mass_{inf} = MTOW * \left(\frac{TAS_{TO,p2.5}}{TAS_{TO,p97.5}} \right)^2$
 - For each mass value randomly picked withing $[mass_{inf}, MTOW]$
 - Rolling distance: $R_d = R_{d,p2.5} + \frac{(R_{d,p97.5} - R_{d,p2.5})}{(MTOW - mass_{inf})} (mass - mass_{inf})$
 - Rolling Time: $R_t = R_{t,p2.5} + \frac{(R_{t,p97.5} - R_{t,p2.5})}{(MTOW - mass_{inf})} (mass - mass_{inf})$
 - TAS at take-off: $TAS_{TO} = TAS_{TO,p97.5} \sqrt{\frac{mass}{MTOW}}$
 - Climb rate taken randomly within observed p2.5 and p97.5

Example of results

A332 – A320 pair



+ 5 sec below one of the baselines

Reduced wake separation on departure for closely spaced runway entries– based on PMI case



ICAO WT Categories

	J	H	M	L
J		120 +60s	180 +60s	180 +60s
H			120 +60s	120 +60s
M				120 +60s
L				

H6-H7 and H7-H8
(**< 200m**)



	J	H	M-jets	M-Turbo	L
J		120+10	180+10	180+20	180+60
H			120+10	120+20	120+60
M					120+60
L					

H6 to H8
(**<320m**)



	J	H	M-jets	M-Turbo	L
J		120+20	180+20	180+30	180+60
H			120+20	120+30	120+60
M					120+60
L					

BRETSEP benefits & deployment perspectives

- **Significant operational benefits** through time separation reduction of up to 50s (depending on distance between entries)
 - Environmental benefits ➔ reduction of holding time
 - Increased capacity ➔ for Palma de Mallorca airport, up to 2 additional DEP/hour for Heavy-Medium pairs
 - Increased flexibility in departure traffic management through increased usage of intermediate entries during peak periods
- **Procedural** ==> No need for advanced automation support
- **Ops trial** targeted at Palma de Mallorca airport on RWY 06R for H6-H7-H8
- **Potential for many European airports** having closely spaced runway entries and traffic with applicable wake separation on departure

SUPPORTING EUROPEAN AVIATION



Thank you