Reduced Wake Vortex Separation Using Weather Information

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   - ✓ ICAO, Europe, US, Japan

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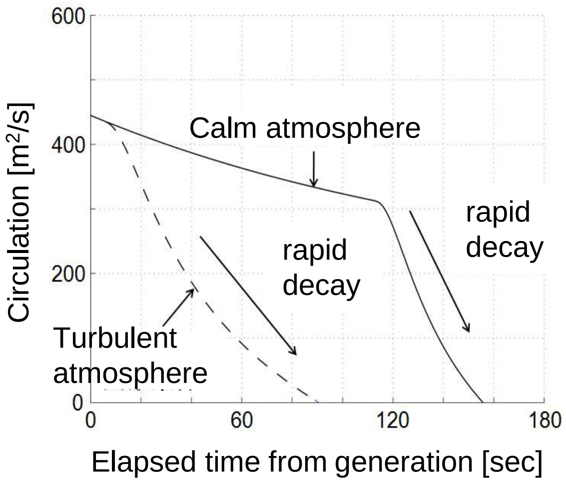
Wake Vortex Separation Minima

Quoted from “http://www.iasa-intl.com”



Wake decay process in different atmosphere conditions (prediction model calculation)

- ✓ICAO has defined STATIC wake vortex separation minima between aircraft according to their relative weights.
- ✓Current ICAO separation minima are overly conservative, assuming the worst case.
- ✓Wake vortex separation minima are a major impediment to airport capacity increase.

Current ICAO separation minima

Leader / Follower	Super	Heavy	Medium	Light
Super (A380)	MRS	6nm	7nm	8nm
Heavy ($\geqq 136_{tons}$)	MRS	4nm	5nm	6nm
Medium ($\geqq 7_{tons}$)	MRS	MRS	MRS	5nm
Light ($<7_{tons}$)	MRS	MRS	MRS	MRS

MRS：Minimum Radar Separation

- ✓Wake vortex life changes largely by weather condition.
- ✓DYNAMIC separation minima according to weather conditions can be an effective solution for airport capacity increase.

Background: International status (1/3)

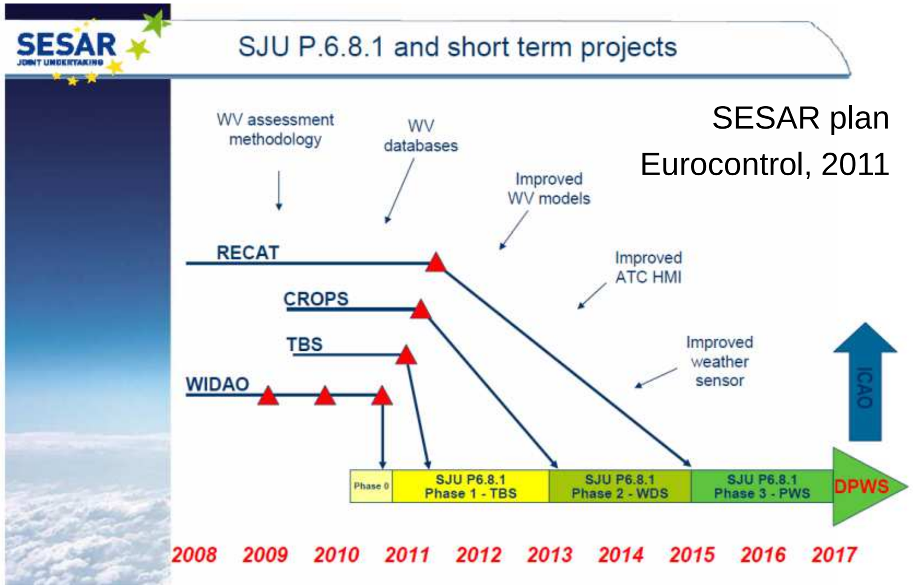
Europe

Wake Independent Departure & Arrival Operation (WIDAO)
Reduce separations at closely spaced parallel runways (CSPRs) using crosswinds.

Time Based Separation (TBS)
Change separation from distance based to time based. Separation will be reduced at strong head wind condition. (2012 or later)

Crosswind Operations (CROPS)
Reduce separation at single runway using crosswind. (2013 or later)

Dynamic Pair Wise Separation (DPWS)
Dynamic separation according to aircraft pair (leader/follower) and weather conditions. (2017 or later)



SESAR plan
Eurocontrol, 2011

CSPRs: Closely Spaced Parallel Runways
WIDAO: Wake Independent Departure & Arrival Operation
TBS: Time-Based Separation
CROPS: Crosswind Operations
CREDOS: Crosswind-Reduced Separations for Departure Operations
DPWS: Dynamic Pair Wise Separation
SESAR: Single European Sky ATM Research

Background: International status (2/3)

US

RECAT: Wake Turbulence Re-categorization

Phase 1: Re-categorize wake vortex category from 4 to 6. The operation has started from Nov. 2012.

Phase 2: Pair wise separation. Specialized separation for each pair of leader/follower (2015 or later).

Phase 3: Dynamic pair wise separation (2020 or later).

Separation Reduction at Closely Spaced Parallel Runways (CSPRs)

Dependent Staggered Approaches to CSPRs: In operation. (FAA Order 7110.308)

Wake Turbulence Mitigation for Departures (WTMD): Demonstration is ongoing since 2011.

Wake Turbulence Mitigation for Arrivals (WTMA): Plan to start from 2015.

} Reduce separations using crosswind

larger ← Follower → smaller

larger ↑ Leader ↓ smaller

Proposed Separation Matrix

Leader \ Follower	A	B	C	D	E	F
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

(green) Separation was increased for some or all aircraft pairs

(cyan) Separation was decreased for some or all aircraft pairs

(white) Separation remained the same for some or all aircraft pairs

MRS Minimum Radar Separation (3NM, or 2.5 NM when existing requirements are met) 14

RECAT Phase I

FAA, 2012

Background: International status (3/3)

ICAO

Wake turbulence study group (WTSG)

Wake Turbulence Study Group (WTSG) was established in 2009 to revise wake vortex separation minima. Japan will participate in WTSG from this March.

Japan

The Civil Aviation Bureau of Japan (JCAB) has compiled the long-term vision of future air traffic systems in Japan named CARATS (Collaborative Actions for Renovation of Air Traffic Systems) in 2010.

- Wake vortex separation reduction plan in CARATS
  1. RECAT introduction: phase 1(2015), phase2,3(2018).
  2. Dynamic separation taking actual wind data or forecast into account.
  3. Apply actual wake turbulence data or forecast from departure or arrival aircraft.

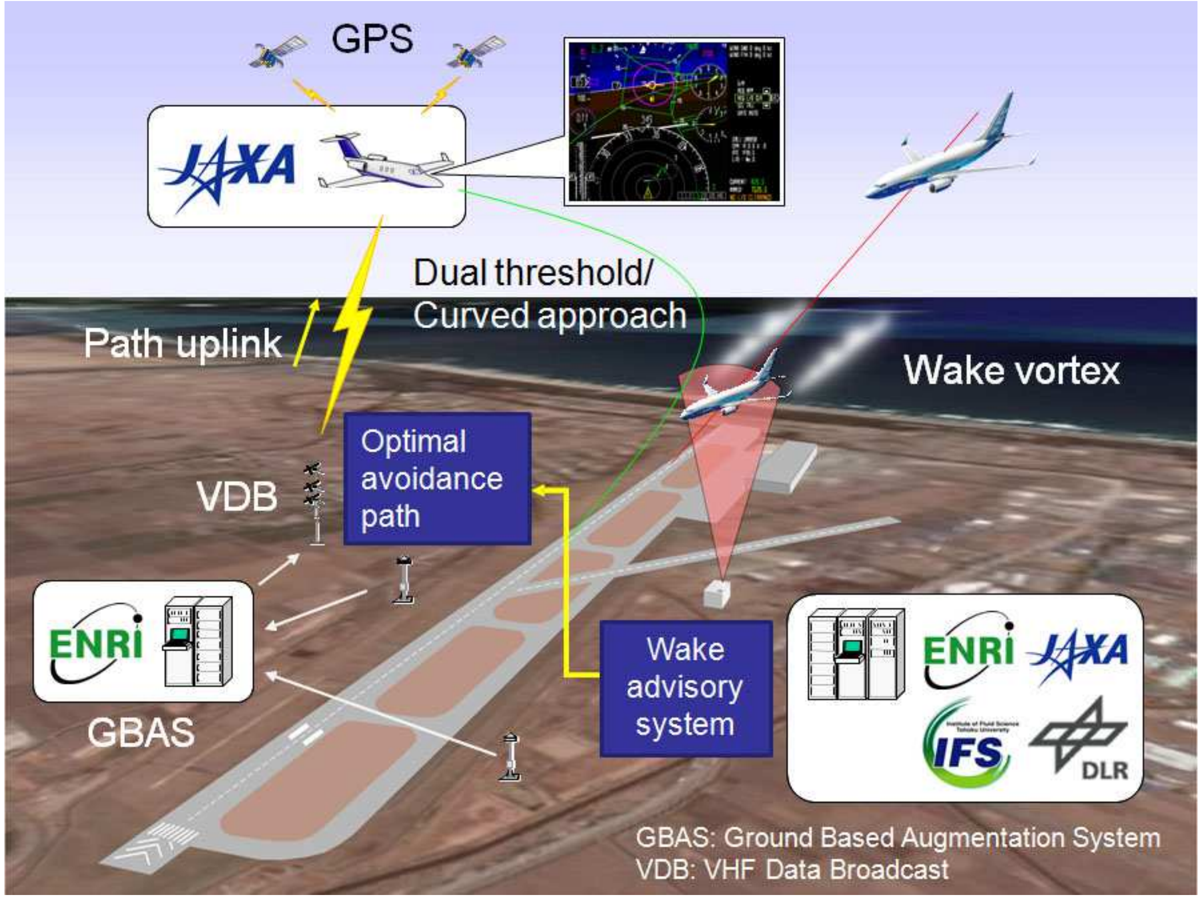
CARATS
Collaborative Actions for Renovation of Air Traffic Systems

JAXA's Objectives

Establish the following technologies to realize dynamic wake vortex separation:

✓Wake advisory system: predict wake vortex behavior and calculate WVE risks.

✓Traffic pattern optimization: optimize take-off/landing sequences and flight paths (using GBAS-based flexible paths).



ENRI: Electronic Navigation Research Institute

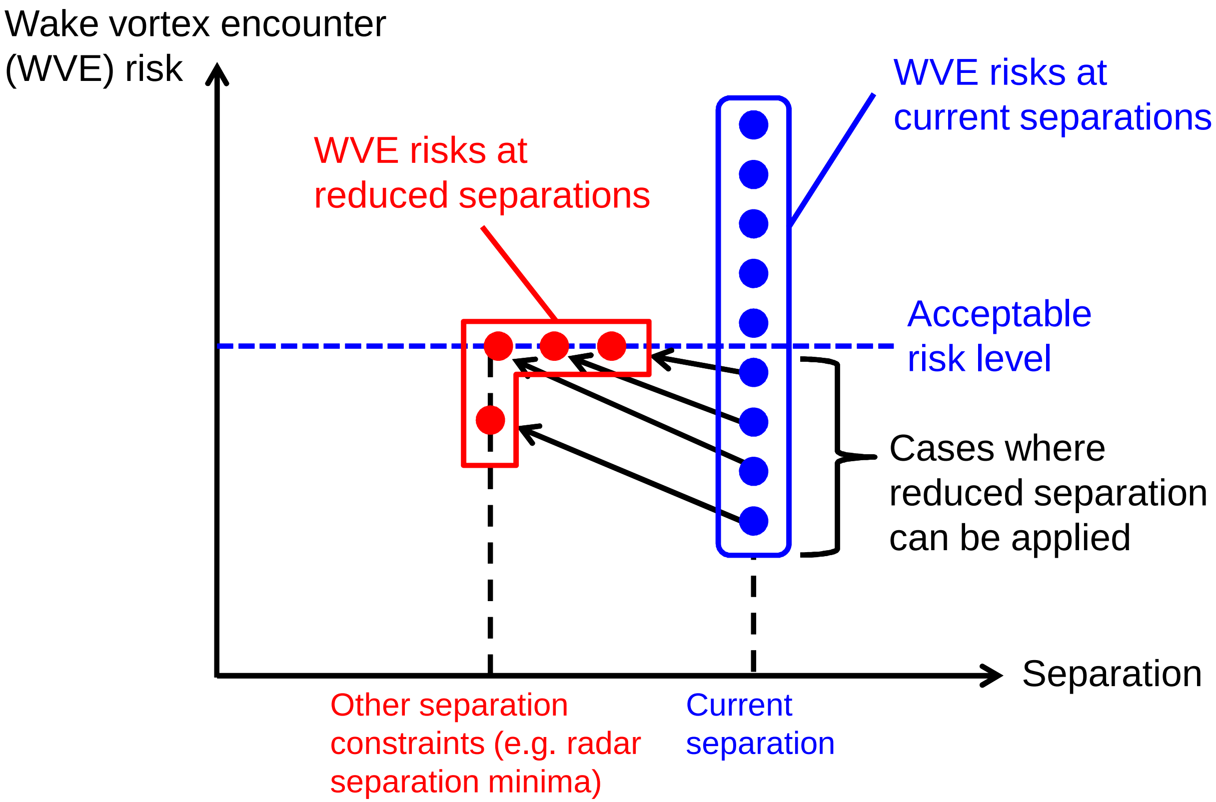
IFS: Institute of Fluid Science, Tohoku Univ.

JAXA seeks a cooperative R&D with DLR (still in discussion)

Concept of Dynamic Separation

1. Define acceptable WVE risk level within current WVE risks.
   (Assumption: Current separations are practically safe)

2. Reduce separations until the expected risk level at the reduced separation reaches the acceptable risk level, or the separation becomes limited by other constraints.

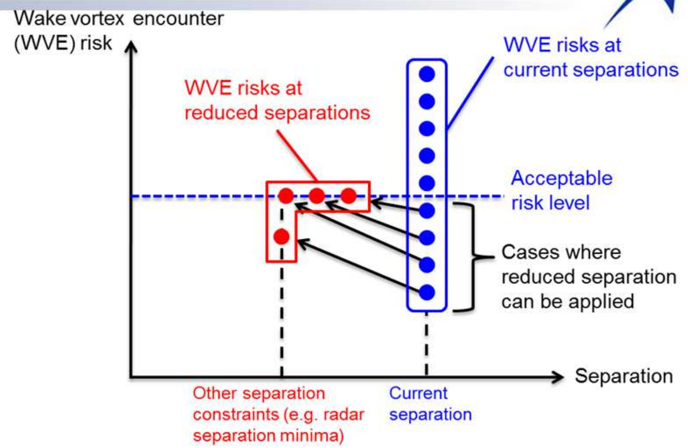


WVE Risk Calculation

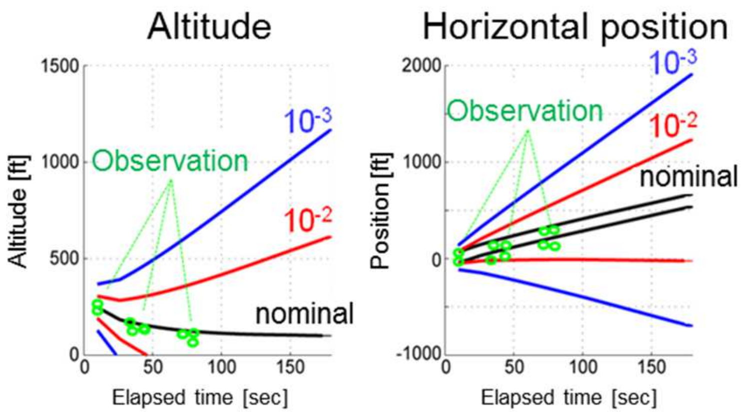
We need to calculate WVE risks at various weather conditions to realize dynamic separation.

To calculate WVE risk, we need probabilistic models that give probability density distributions (PDDs) of aircraft position and wake intensity/position.

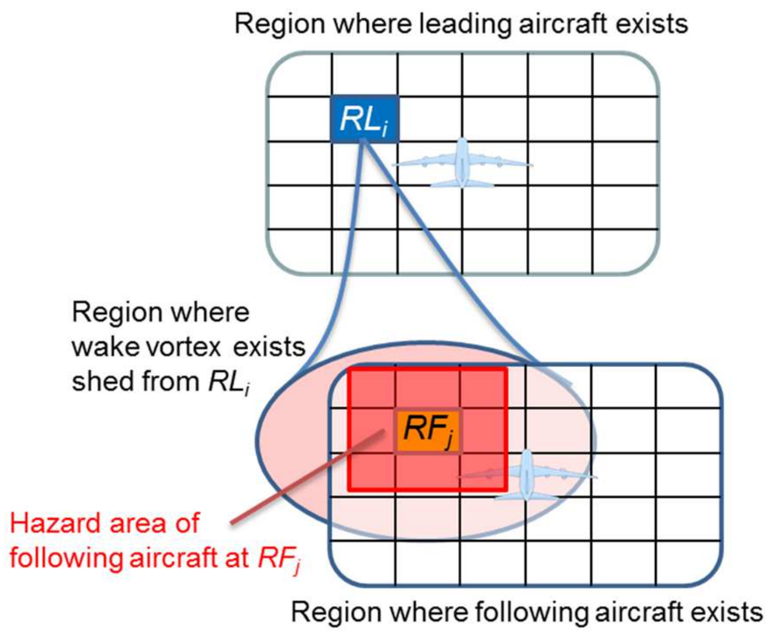
- ✓ Aircraft trajectory model
  Create JAXA original model based on actual radar track data of target airport and collision risk model (CRM) of ILS approach.
- ✓ Wake vortex prediction model
  Employ P2P/S2P model developed by DLR.



Concept of dynamic separation



Example of wake vortex prediction

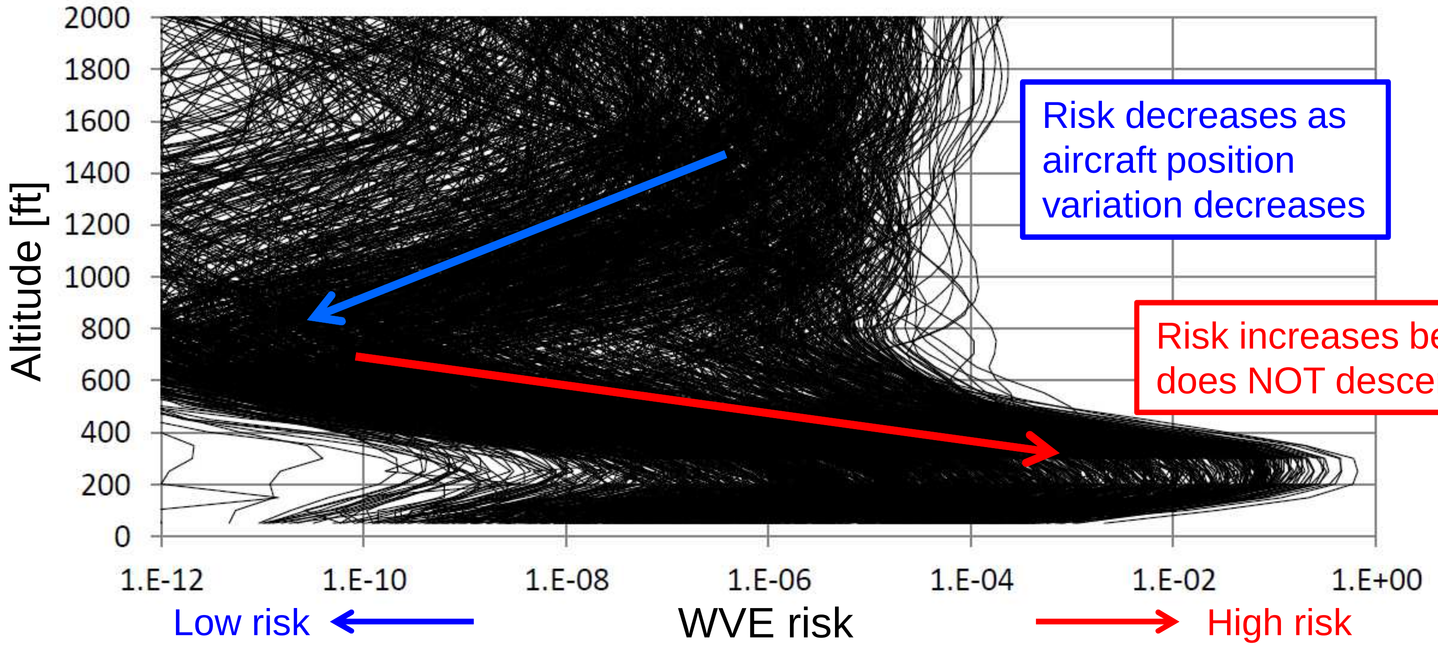


WVE risk calculation methods

Example of WVE Risk Calculation

✓WVE risks vary largely by surrounding weather conditions.
⇒ We can reduce separation at favorable weather conditions.

✓WVE risks increase at high altitude (>1500ft) and low altitude (<400ft).
⇒ GBAS-based curved approach and dual thresholds may be useful to decrease WVE risks.



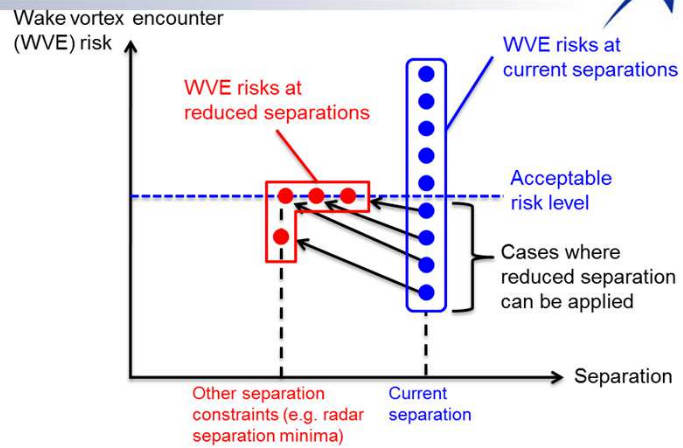
WVE risks in successive landings on RWY22 of Tokyo International airport
（about 1000 different weather conditions）

WVE risk：Risk of roll moment excitement over 5 [deg/s^2]

How to Evaluate WVE Risk Considering Risk Calculation Errors

■ Concept

Reduce separations until the expected WVE risk at the reduced separation reaches the acceptable risk level.



Concept of dynamic separation

■ Problem

WVE risks at reduced separations can be higher than current WVE risks if the following calculation errors occur:

- ✓ Underestimate WVE risks at reduced separations
- ✓ Overestimate acceptable risk level (= WVE risks at current separations)

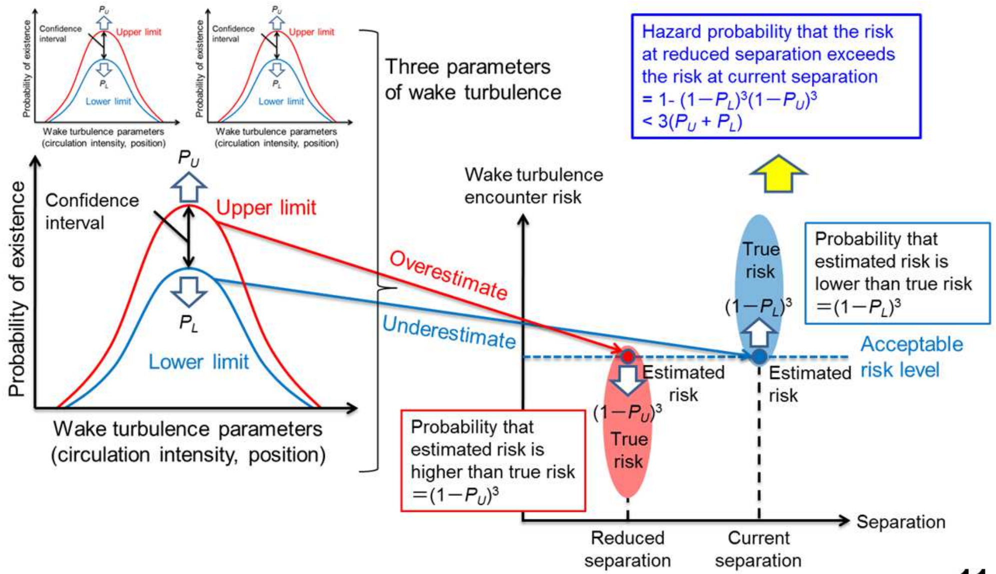
■ Solution

Control hazard probability that WVE risks at reduced separations exceed the risk at current separations as follows:

Step1: quantify WVE risk calculation errors by PDD confidence intervals.

Step2:

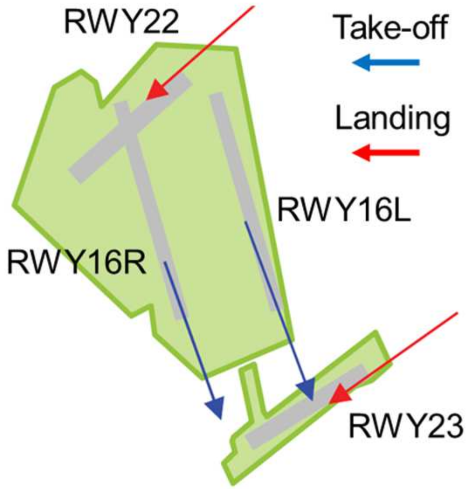
- ✓ Overestimate WVE risks at reduced separations by using upper limit of PDD confidence interval.
- ✓ Underestimate acceptable risk level by using lower limit of PDD confidence interval.



Expected Capacity Gain (1/2)

- Target airport and operation

Runway operations for southerly winds at Tokyo International airport is chosen because wake vortex separations limit the airport capacity.



Situation	Wake vortex separation without	with
Successive landings on RWY22	115 sec.	120 sec.
Successive take-offs from RWY16L/R	95 sec.	120 sec.
Take-off from RWY16L and landing on RWY23	47 sec.	102 sec.

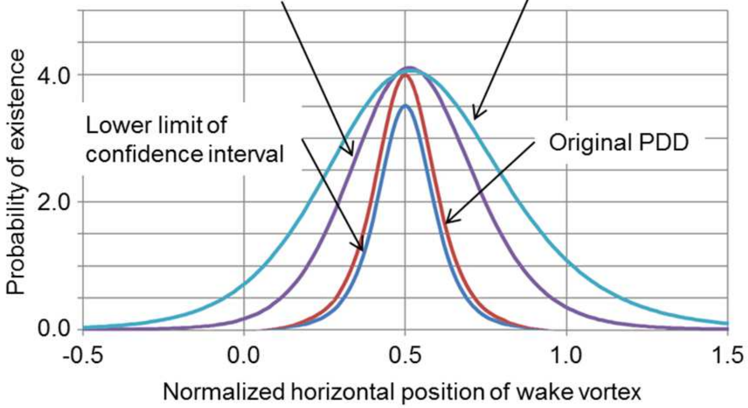
- Simulation conditions

✓ Only aircraft operations below 2000ft are considered. Cruise-phase and airport surface operation are not considered.

✓ Approximately 1000 weather conditions where southerly winds prevailed are chosen.

✓ Two different accuracy levels of available weather information are considered. The poor accuracy of weather information leads to the poor performance of wake prediction.

Item	Errors (1σ) case 1 (current)	case 2 (ideal)
EDR [$m^{2/3}/s$]	0.05	0.025
Brunt–Väisälä freq. [1/s]	0.005	0.0025
Wind [m/s]	3.0	1.5



Expected Capacity Gain (2/2)

- Major factors affecting capacity gain

✓ Acceptable risk level

Higher acceptable risk level brings larger separation reduction.

✓ Weather information accuracy

Fine accuracy of available weather information increases separation reduction. To improve weather information accuracy is a good tool to reduce separation.

Simulated separation reductions
(Averaged over approximately 1000 different weather conditions)

Situation	Weather information accuracy	Acceptable risk level (cumulative risk level at current separations)		
		50%	70%	90%
Successive landings on RWY22	Current	0 sec.	0 sec.	2 sec.
	Ideal	0 sec.	1 sec.	3 sec.
Successive take-offs from RWY16L/R	Current	3 sec.	5 sec.	10 sec.
	Ideal	4 sec.	7 sec.	13 sec.
Take-off from RWY16L and landing on RWY23	Current	0 sec.	1 sec.	7 sec.
	Ideal	1 sec.	7 sec.	16 sec.

- Expected capacity gain

We obtained **the 4.5% capacity gain** with the following assumptions:

✓ Employ 90% cumulative risk level as acceptable risk level and ideal accuracy level of weather information.

✓ Airport operating conditions at the most congested time period (8–9 AM) of the target airport. The ratio of heavy to medium category aircraft was almost one to one.

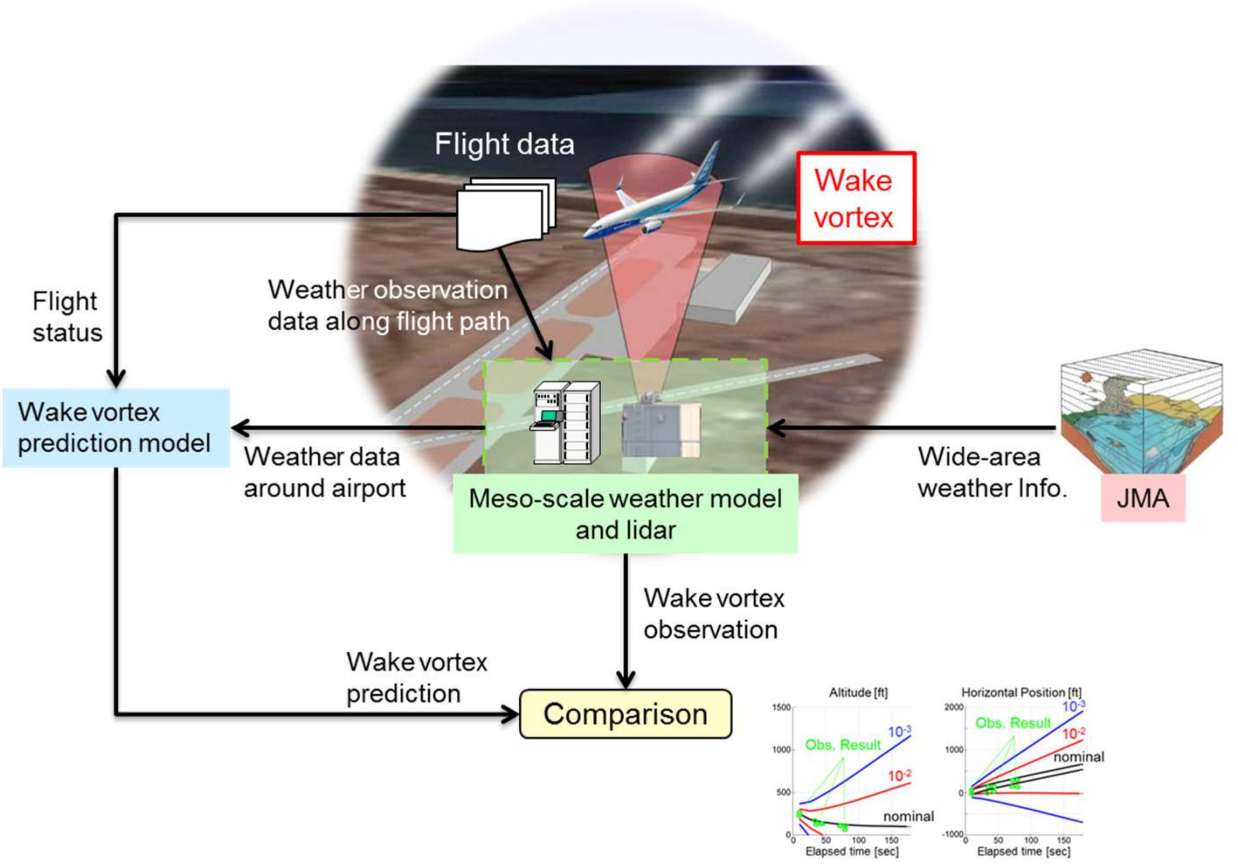
In addition, **the capacity gain increased up to 14.5% when we optimized the take-off/landing sequences.**

Conclusions

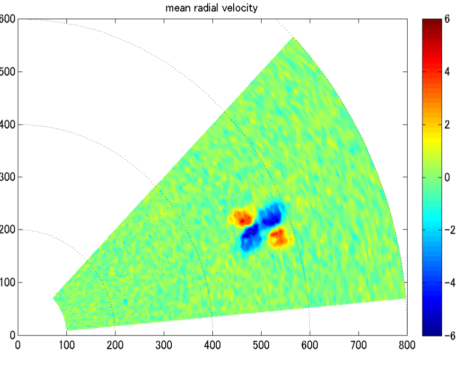
- ✓ Global activities to reduce wake vortex separation is ongoing. Dynamic wake vortex separation will be employed in about 2020.
- ✓ Japan also plans to reduce wake vortex separations.
- ✓ To realize dynamic wake vortex separations, JAXA has conducted various research activities to establish wake advisory system and traffic pattern optimization.

Future Plan: Wake Vortex Observation

- ✓ Collect wake behavior data for 2 weeks on each season (total 2 months) in FY2013 at New Tokyo international (Narita) airport to improve probabilistic wake vortex prediction.
- ✓ Plan to use a LIDAR as a wake vortex sensor and to obtain aircraft / weather data along flight paths from aircraft flight data (purchase from airlines).



Leosphere WindCube200S-AT



RECAT Phase I

Proposed Separation Matrix

		Follower					
		A	**B**	**C**	**D**	**E**	**F**
Leader	**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