Principles and guidance for wake vortex encounter risk assessment as used in the Paris CDG Wake Independent Departure and Arrival Operations (WIDAO) Safety Case

12 October 2010

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The European Organisation for the Safety of Air Navigation

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1. Introduction

1.2 Purpose

• This material has been developed to provide the principles on how to perform quantified WVE risk assessments, following the EUROCONTROL Safety Assessment Methodology SAM*E* framework and the experience gained from the “wake independent departure and arrival operations” (WIDAO) project at Paris CDG.

• It is intended to assist European Air Navigation Service Providers (ANSPs), Airport Operators, Regulators and other Stakeholders, who consider to perform a safety analysis of change to required WT separation provisions at a specific airport.

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1. Introduction

1.3 Aim and objectives

The objectives are:

- to describe an approach for WVE safety risk assessment and quantification;
- to overview the possible supporting tools and techniques

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1. Introduction

1.5 Applicable regulations and standards

The following European regulatory requirements are applicable for developing safety risk assessment of ATM changes:

- For European Union (EU) Member States, risk assessment and mitigation of changes to the ATM system must be conducted in accordance with European Commission regulation EC. 2096/2005 “Common Requirements”
- For EUROCONTROL Member States, risk assessment and mitigation in ATM must be conducted in accordance with EUROCONTROL safety regulatory requirements “ESARR 4”

The following International Standards are applicable:

- ICAO Standards and Recommended Practices for Air Traffic Services “Annex 11”, and for Aerodromes Design and Operations “Annex 14”
- ICAO Procedures for Air Navigation Services, Air Traffic Management, Doc 4444

For local implementation, national regulatory requirements may apply in addition.

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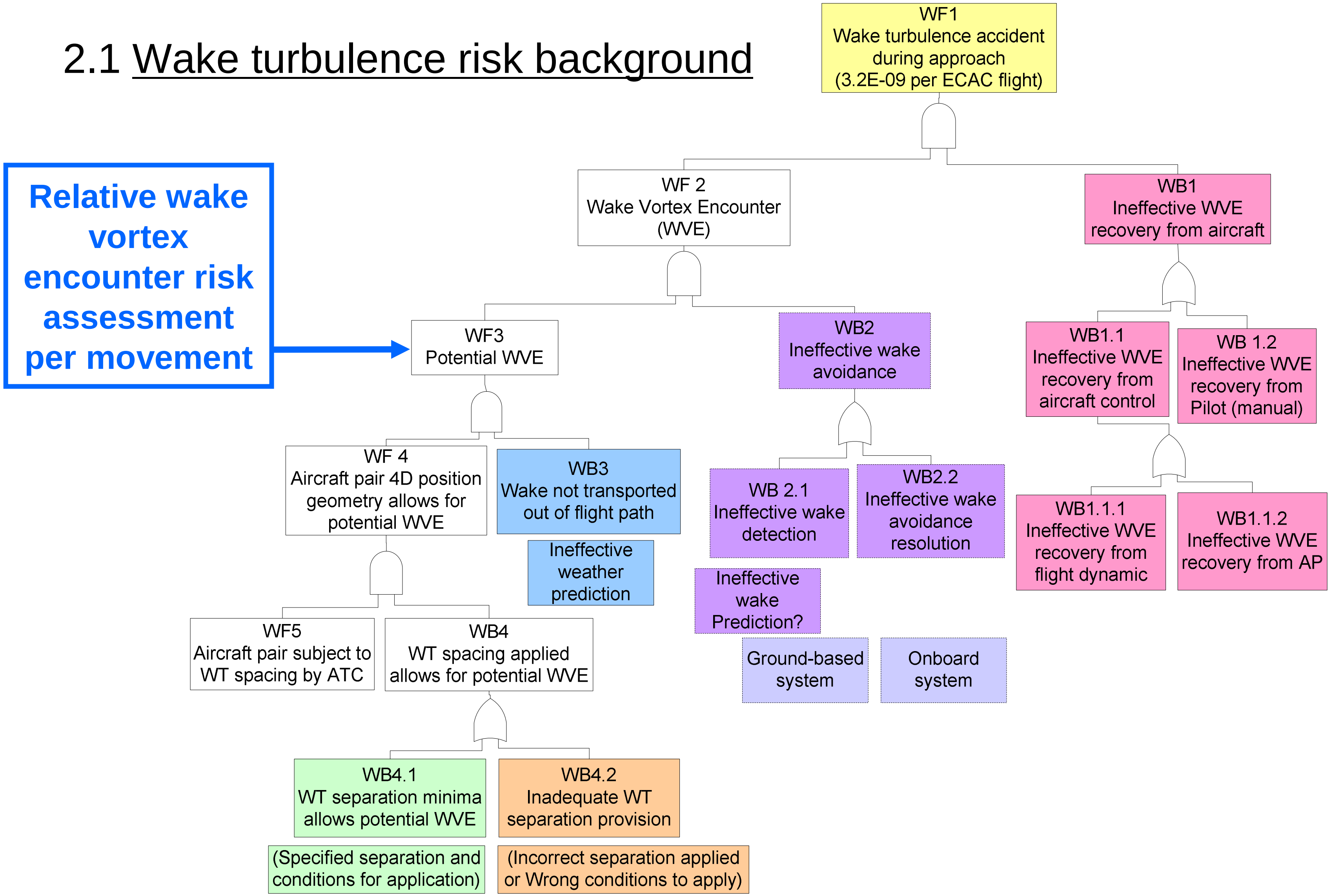
2. Wake vortex encounter risk assessment

2.1 Wake turbulence risk background



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2. Wake vortex encounter risk assessment

2.2 WIDAO CDG project background

- CDG airport operates four runways organised in two CSPR pairs.
- External RWY from each pair is used for landing and an internal RWY for take-off
- For environmental reasons, the external RWY are shorter than the internal RWY
- The consequence of this is an offset of 600m in West operations between the two runway thresholds and of 900m in East operations (Figure 1)

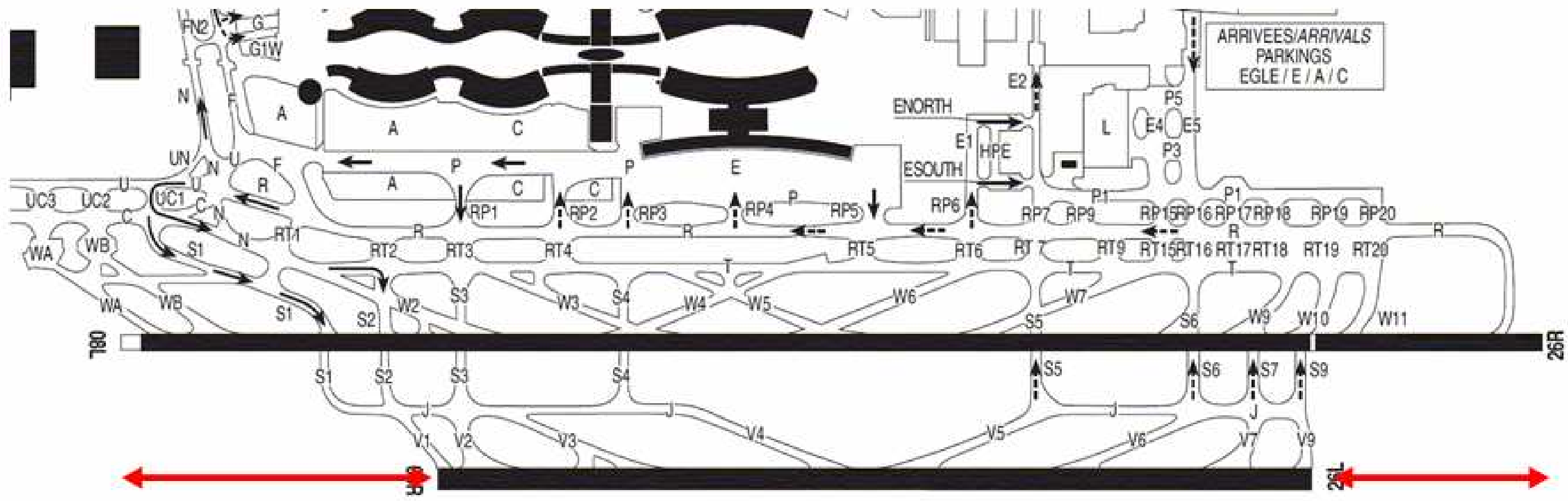

Figure 1 : Example of runway threshold offset at Paris CDG

2. Wake vortex encounter risk assessment

2.2 WIDAO CDG project background

• Constrains on departing aircraft are applied for preventing an encounter with a wake generated on the CSPR

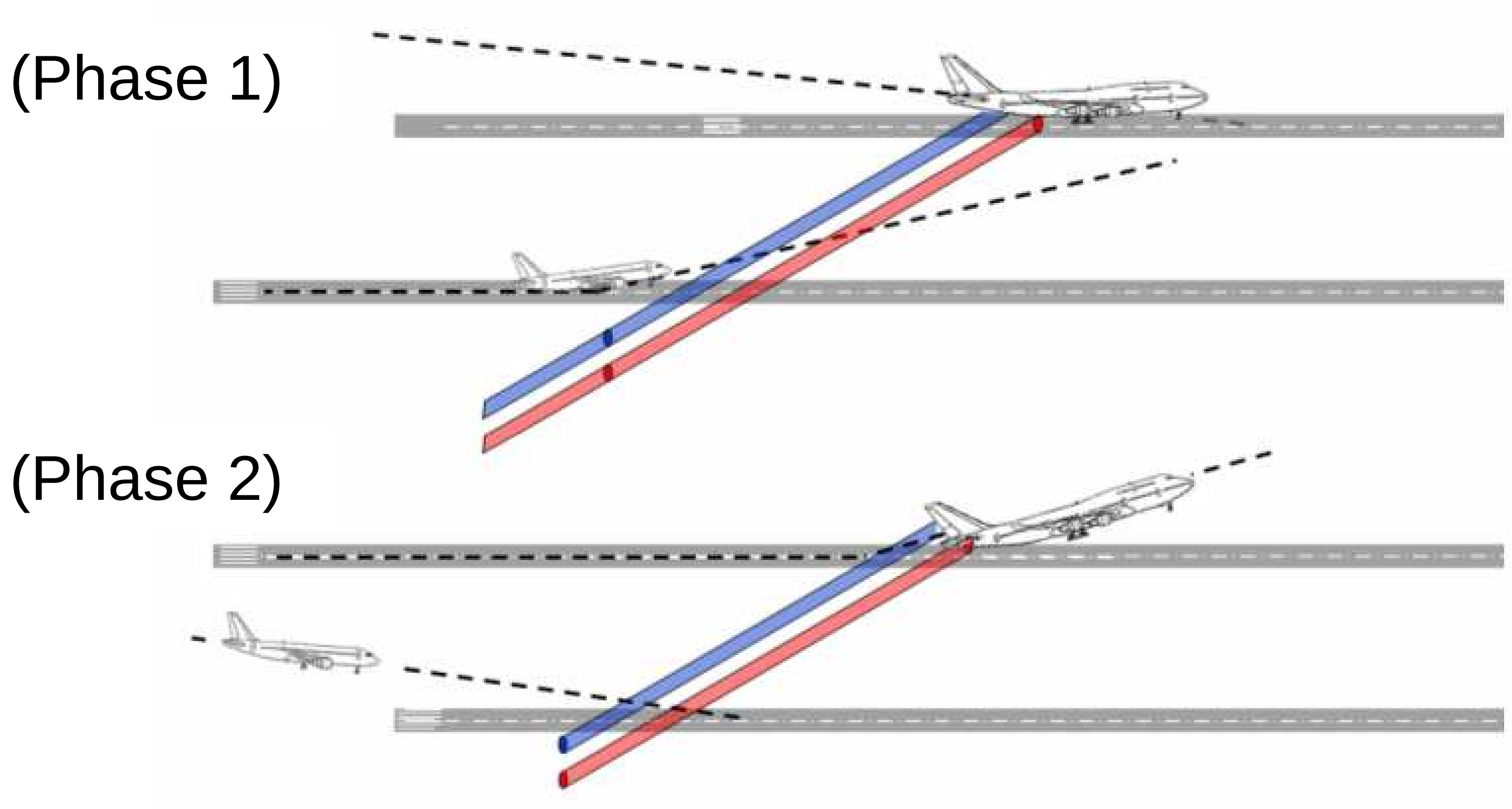

Figure 2 : Wake turbulence hazard on CSPR

2. Wake vortex encounter risk assessment

2.2 WIDAO CDG project background

• LIDAR campaign conducted between May and December 2007 for supporting WIDAO phase 1. (10,000 Medium tracks and 4,000 Heavy tracks)

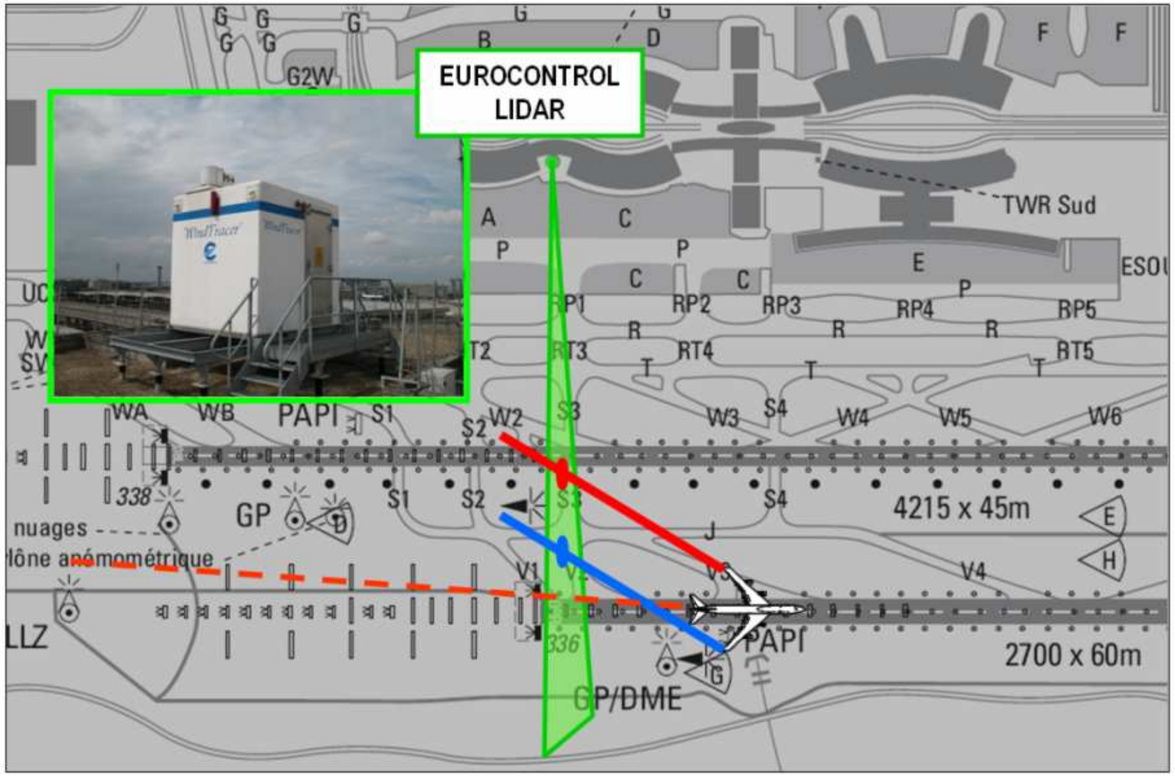

Figure 3 : - EUROCONTROL LIDAR data collection

2. Wake vortex encounter risk assessment

2.2 WIDAO CDG project background

• 8.74 million WAKE 4D simulation runs conducted in September 2009 for supporting WIDAO phase 2

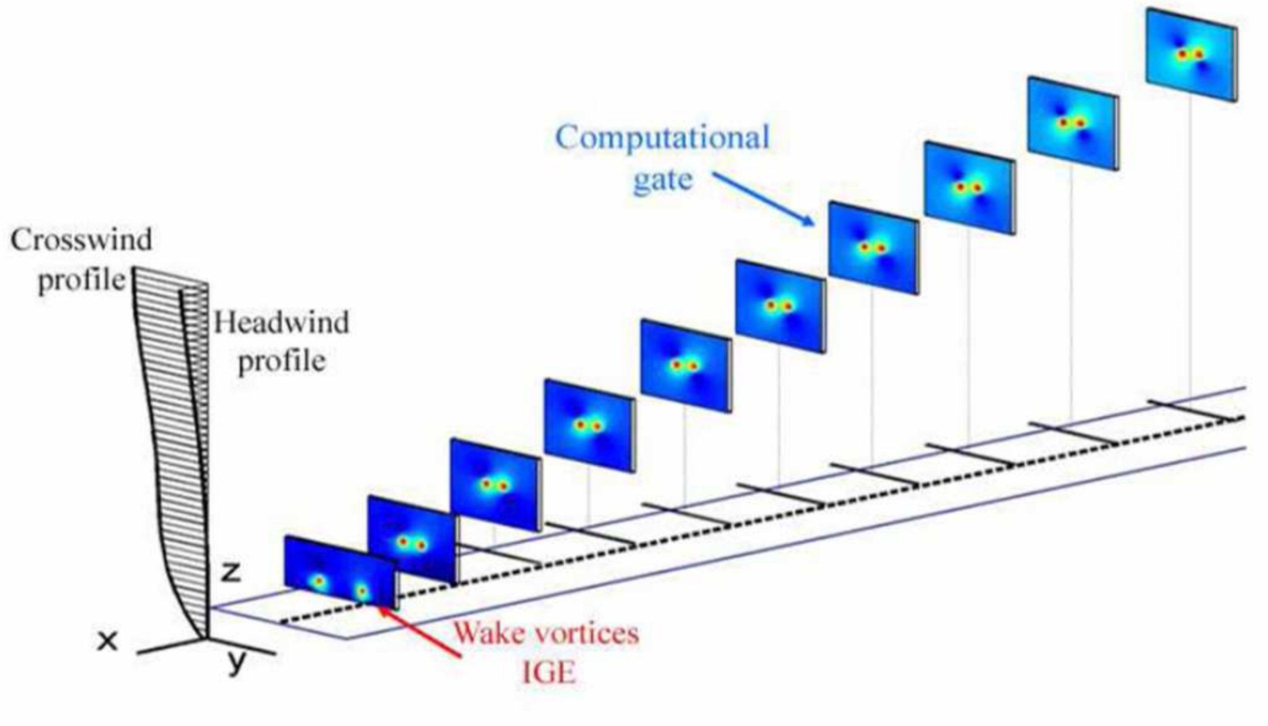

Figure 4 : - Example of a WAKE 4D simulation run

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2. Wake vortex encounter risk assessment

2.4 Safety strategy

The key accident risk type to be assessed when changing WT separation provision is obviously WT.

Any reduction in the separation between aircraft is likely to increase the risk of WVE.

The safety strategy must ensure that an acceptable level of safety is maintained.

Acceptable WVE risk can be determined using one of two criteria:

- Absolute. An absolute risk assessment requires that all wake encounters have strength below an absolute value threshold. This approach is not yet considered feasible as there is no agreed definition of acceptable severity or frequency of wake turbulence effects on aircraft in flight due to the complexity of factors influencing the outcome;
- Relative. A relative safety assessment is performed by comparing the WVE risk anticipated from implementation of the proposed change to WT separation provision to the WVE risk observed for a chosen baseline operation which is considered tolerably safe today.

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2. Wake vortex encounter risk assessment

2.5 Wake vortex encounter scenarios

A hazardous WVE scenario occurs whenever the geometry and timing for a WVE exists between two aircraft. Subsequently, the probability of encountering a wake vortex, given the correct geometry and timing, is dependent on wake vortex decay and transport which are influenced by wind speed and direction

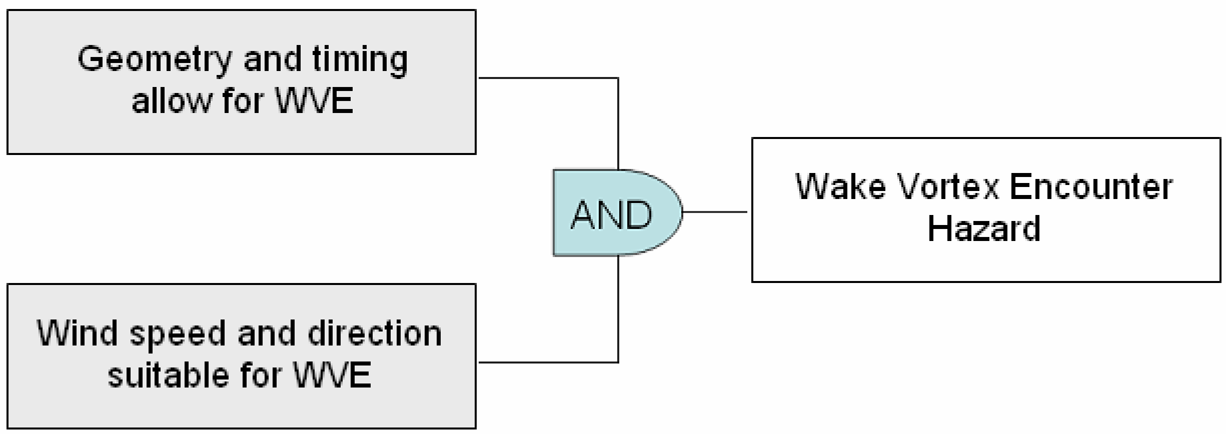

Figure 5: Logic tree leading to a WVE hazard

Outline

2. Wake vortex encounter risk assessment

2.6 Safety objectives for WVE

Safety objectives for WVE can be defined by the maximum acceptable frequency of a WVE of a given severity as characterised by the baseline scenario

In WIDAO this was expressed the following respectively for Phase 1 and 2:

- The frequency per movement of WVE (of a given severity) by a Medium on departure following WV generated by Heavy landing and transported from the adjacent CSPR in WIDAO must not be higher than the frequency per movement of WVE (of same severity) by a Medium landing at ICAO in-trail separation minima, as applied for Paris-CDG arrivals.

- The frequency per movement of WVE (of a given severity) by a Medium on normal/missed approach WV generated by Heavy departure and transported from the adjacent CSPR in WIDAO must not be higher than the frequency per movement of WVE (of same severity) by a Medium landing at ICAO in-trail separation minima, as applied for Paris-CDG arrivals on RWY 08R

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2. Wake vortex encounter risk assessment

2.7 Definition of a tolerably safe baseline

A tolerably safe baseline can be selected from on-going ATC operations of WT separation provision and for which evidence of satisfactory level of safety are available.

For example, the risk of WVE can be assessed relative to the risk of an in-trail WVE at ICAO WVE separation minima which are widely recognised as being tolerably safe

To show that the selected baseline is tolerably safe

- by analyzing wake vortex encounter reports
- by crossing RADAR and LIDAR data for detecting WVE and analyzing corresponding flight data

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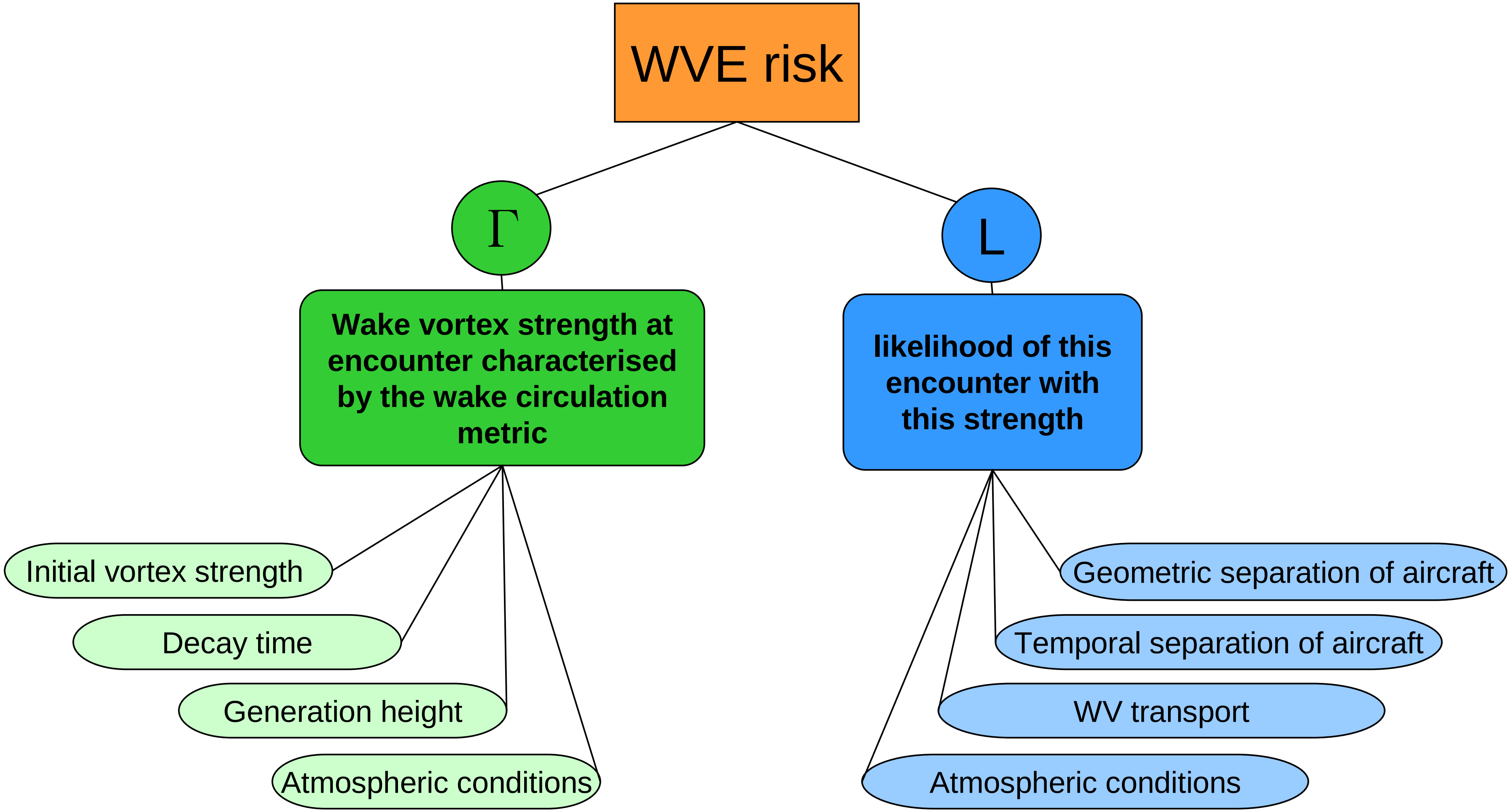
2. Wake vortex encounter risk assessment

2.8 WVE risk quantification



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2. Wake vortex encounter risk assessment

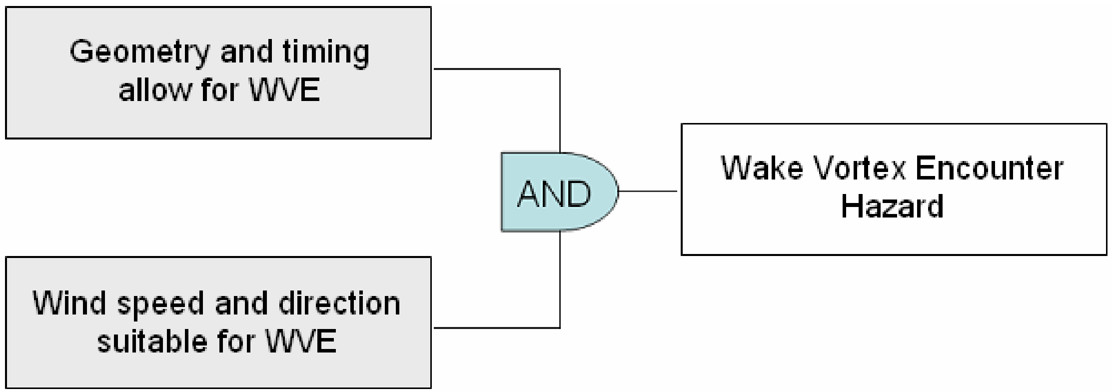
2.9 WVE risk characterisation for the baseline

The characterisation of the safety objective amounts to assessing the WVE risk associated with the selected baseline.

If this requires to make some assumptions, these assumptions have too ensure an underestimation of the WVE risk. The baseline being used as safety objective, this approach will ensure to be conservative in the assessment of the new concept against this baseline.

2. Wake vortex encounter risk assessment

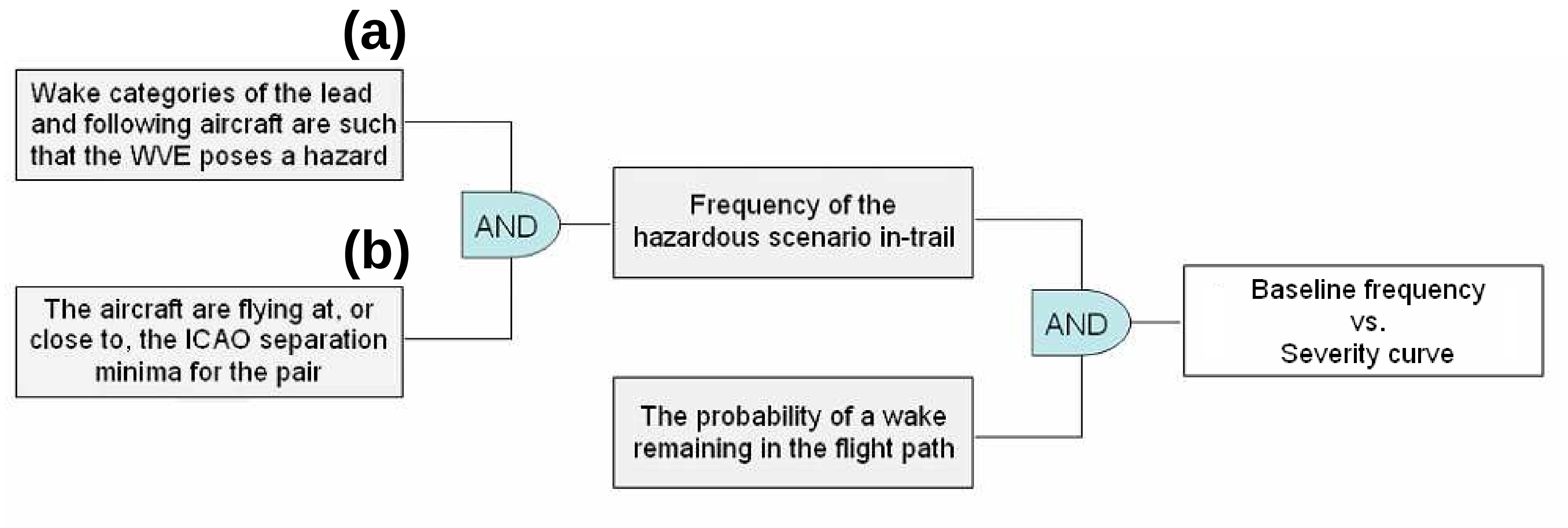
2.9 WVE risk characterisation for the baseline



Logic tree leading to WVE hazard

2. Wake vortex encounter risk assessment

2.9 WVE risk characterisation for the baseline

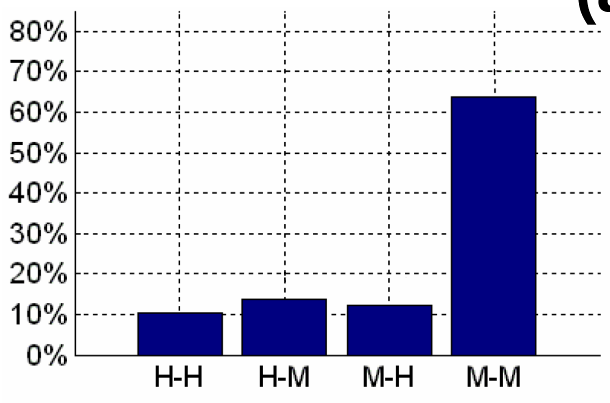


Logic tree leading to WVE hazard in-trail

2. Wake vortex encounter risk assessment

2.9 WVE risk characterisation for the baseline

(a)



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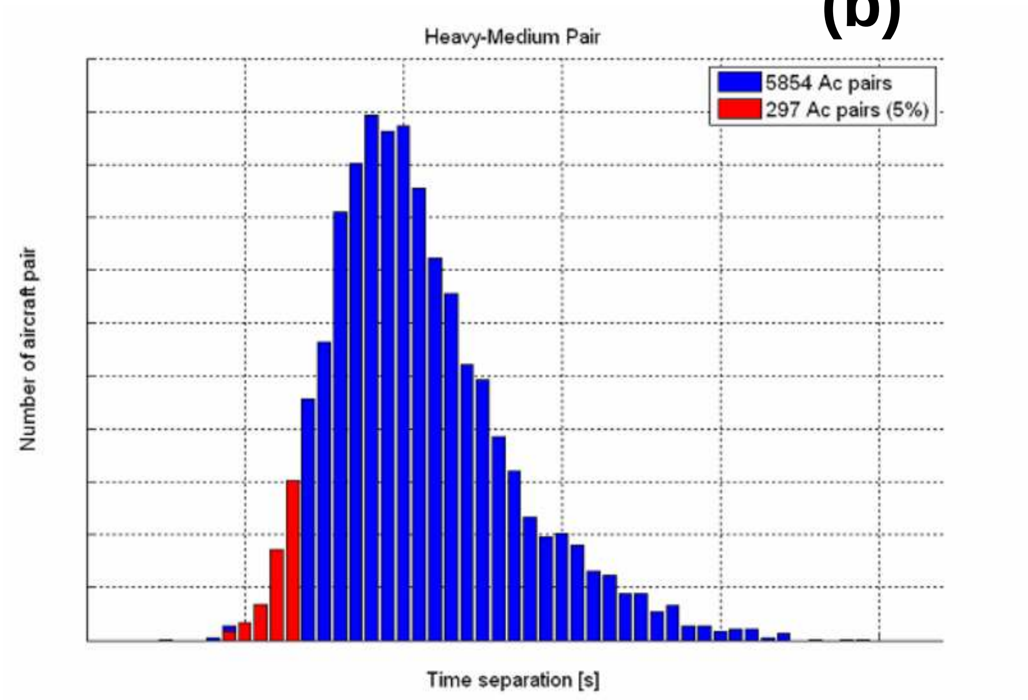
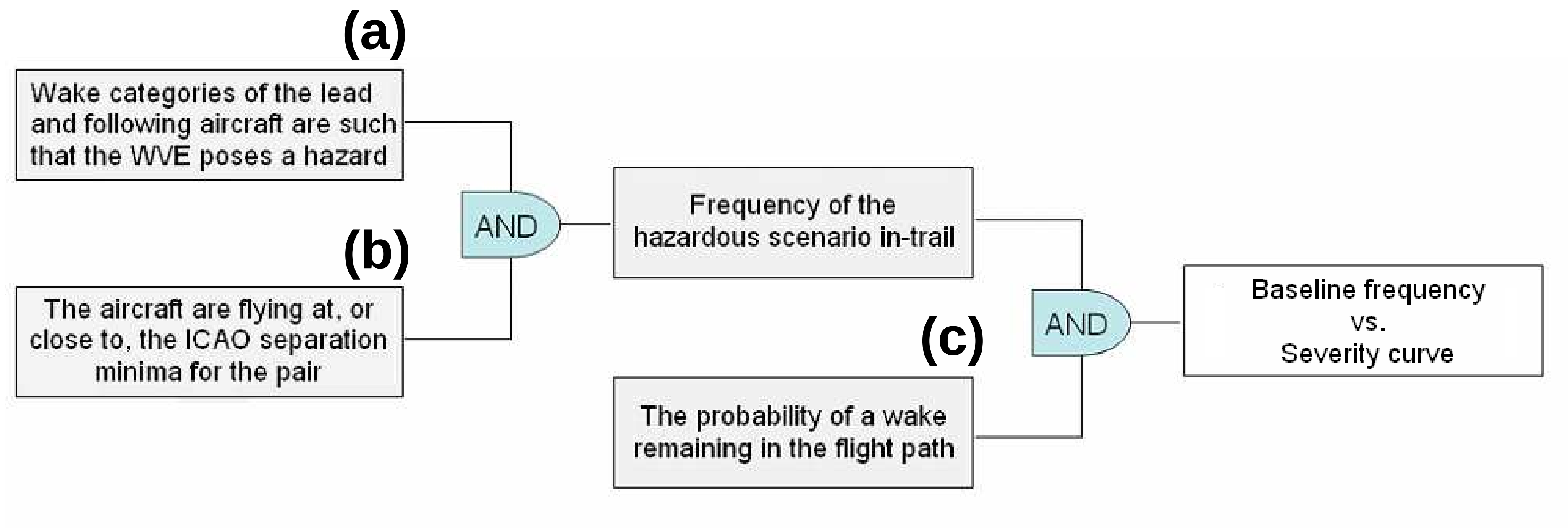


Figure 6: Example of acceptably safe minimum time separation ranges

2. Wake vortex encounter risk assessment

2.9 WVE risk characterisation for the baseline



Logic tree leading to WVE hazard in-trail

2.9 WVE risk characterisation for the baseline

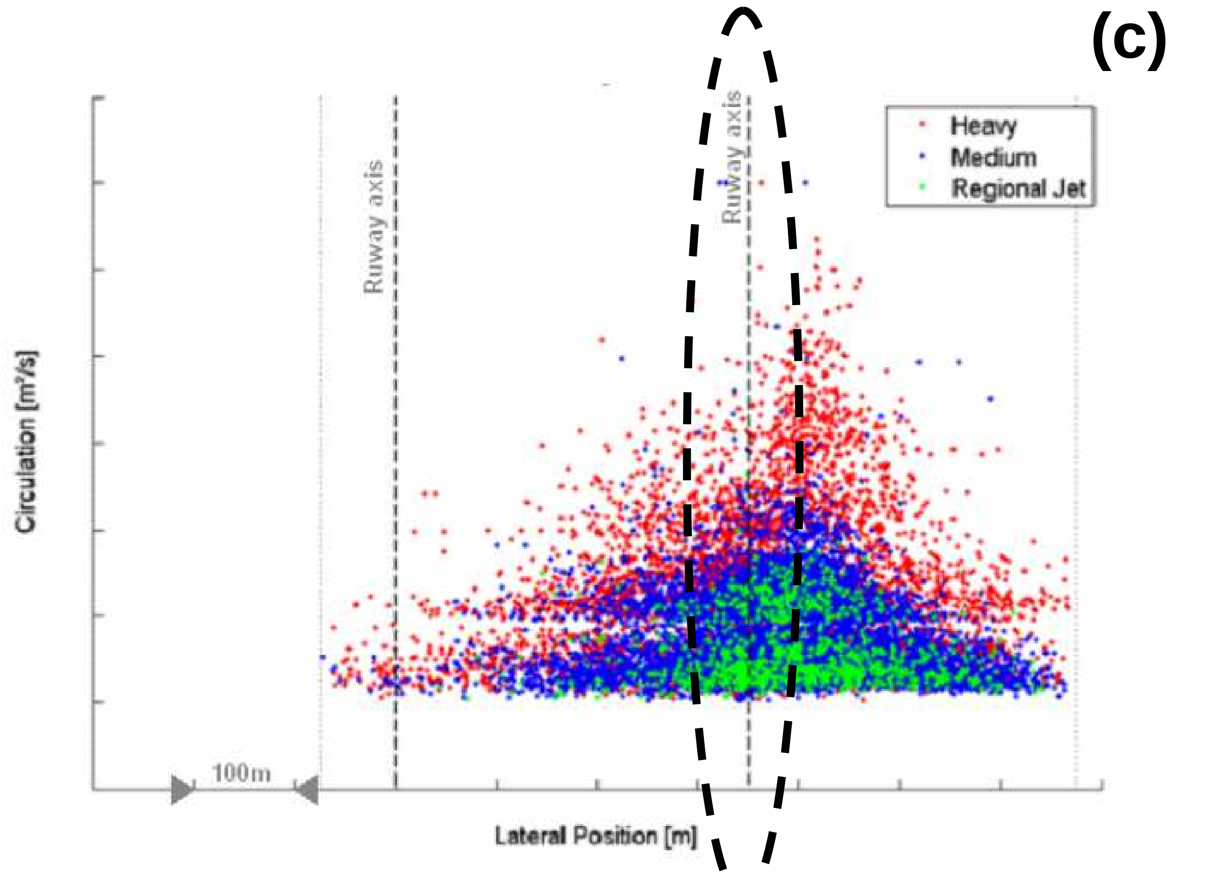
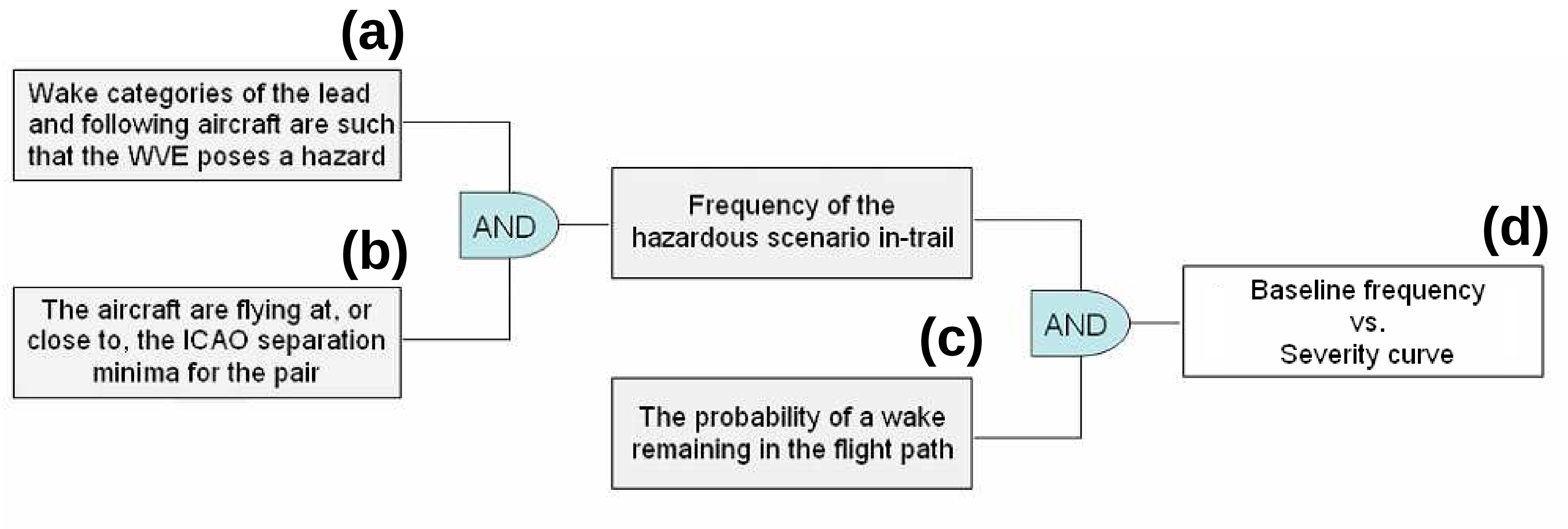


Figure 7: Example LIDAR Dataset

2.9 WVE risk characterisation for the baseline



Logic tree leading to WVE hazard in-trail

2. Wake vortex encounter risk assessment

2.9 WVE risk characterisation for the baseline

(d)

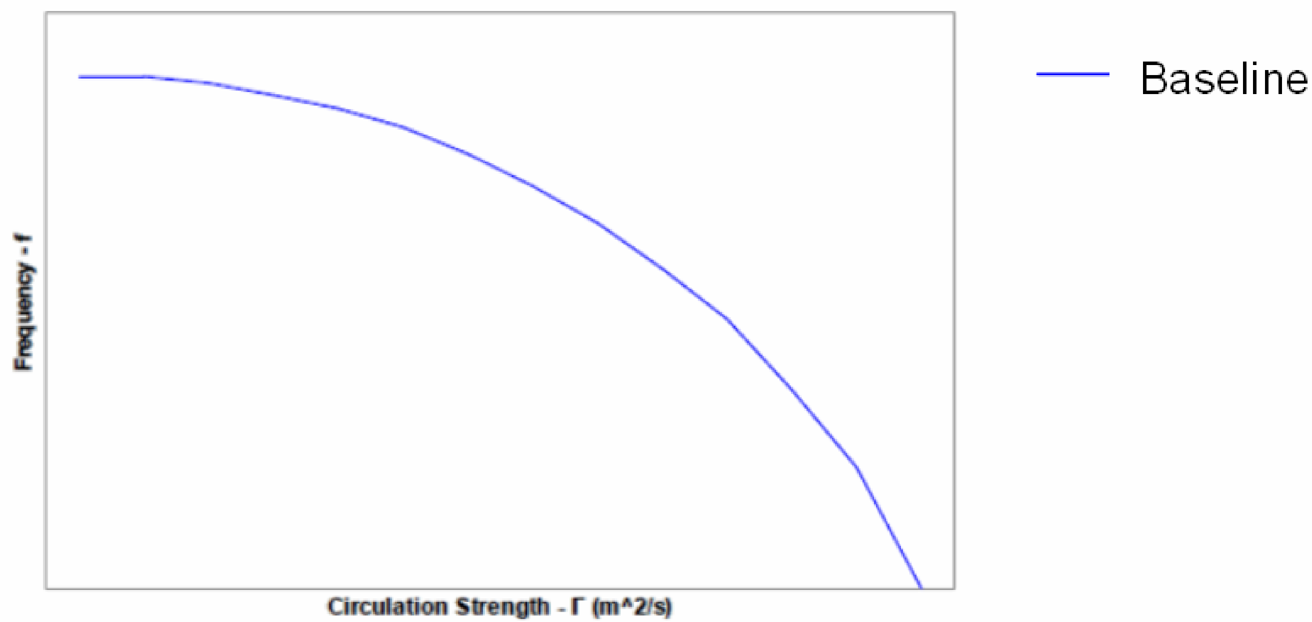


Figure 8: Schematic Example of Log Vortex Frequency (f) vs. Circulation Strength (Γ) Baseline Plot (Log-Linear plot)

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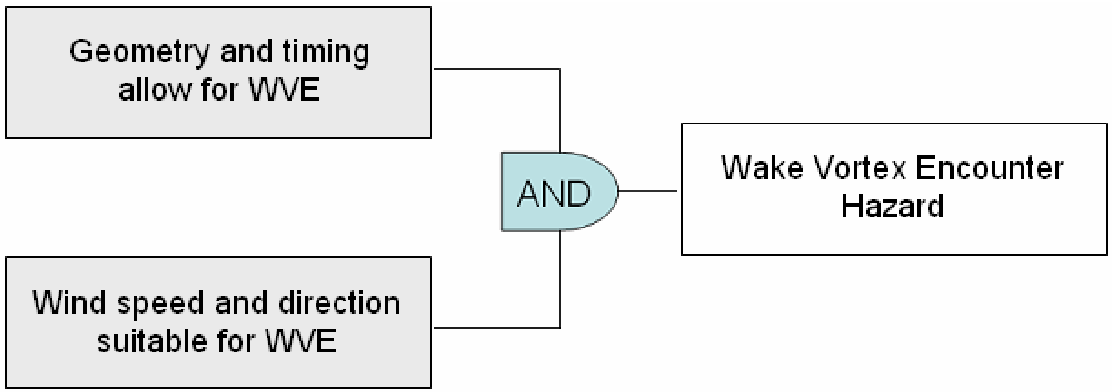

Logic tree leading to WVE hazard

2. Wake vortex encounter risk assessment

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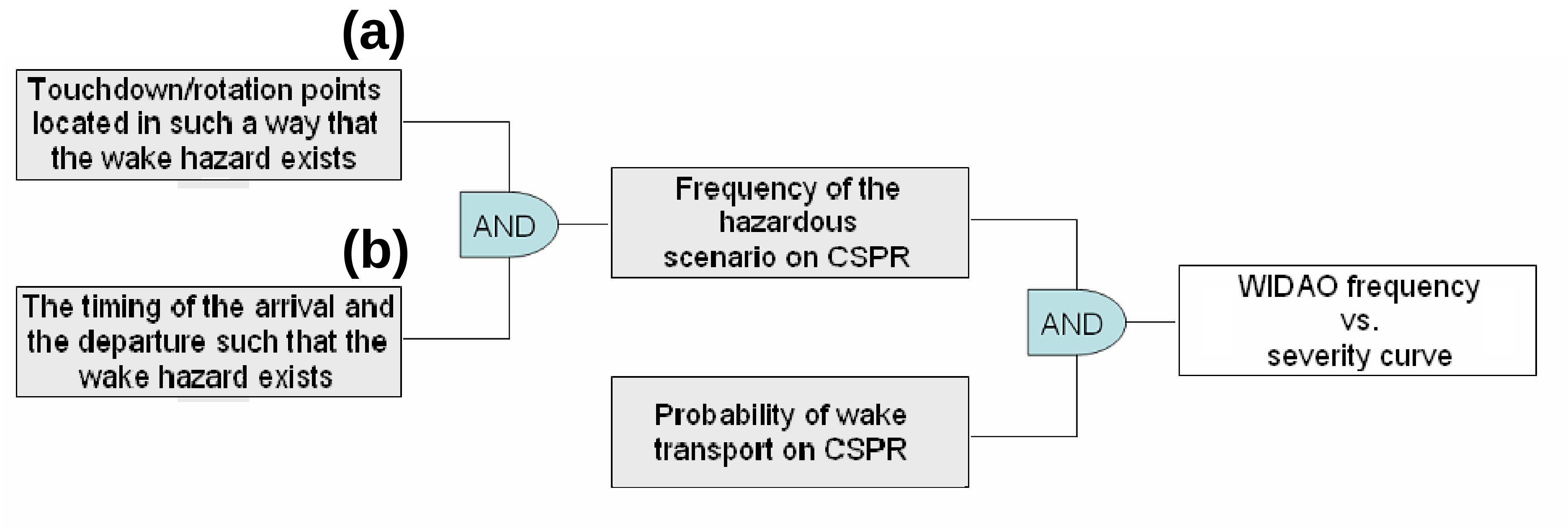
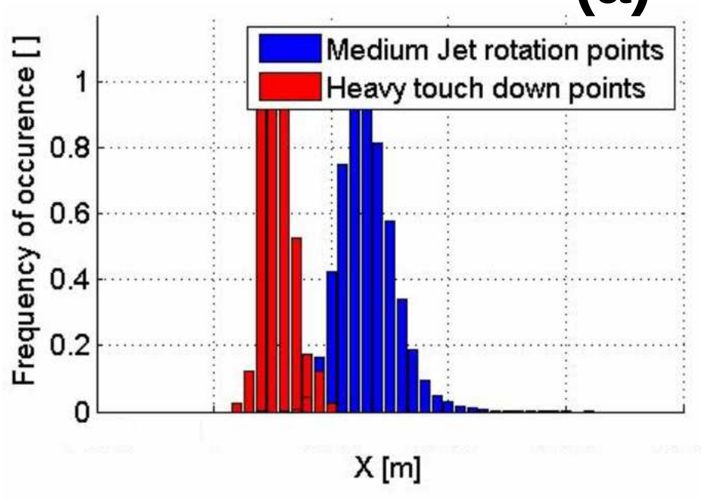


2. Wake vortex encounter risk assessment

2.10 Safety objectives are satisfied for reference scenario in normal conditions

(a)



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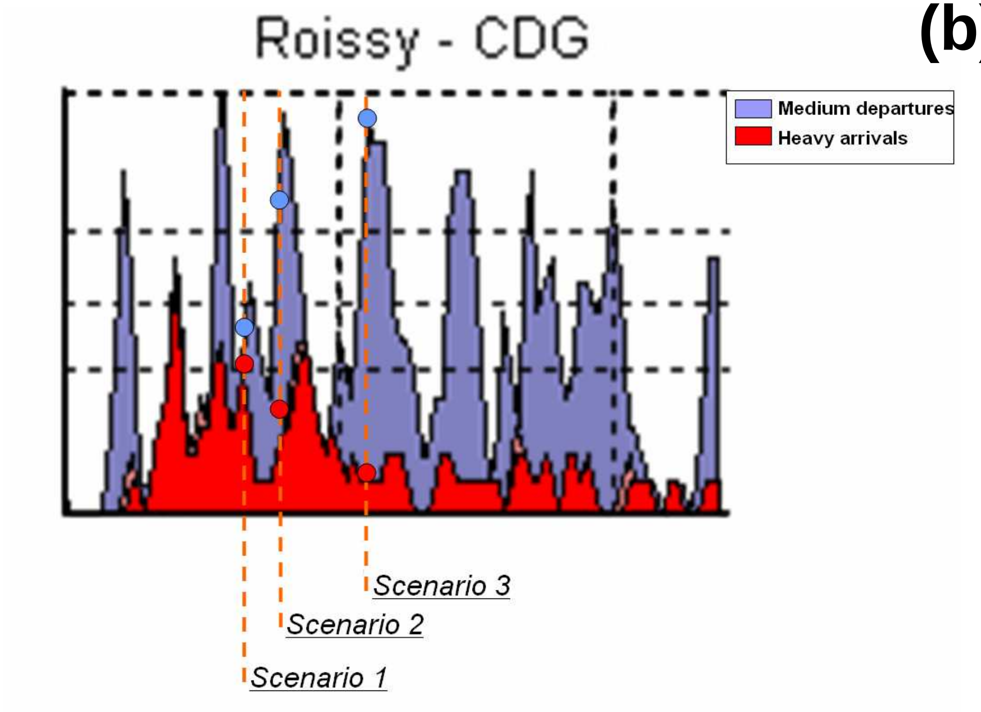

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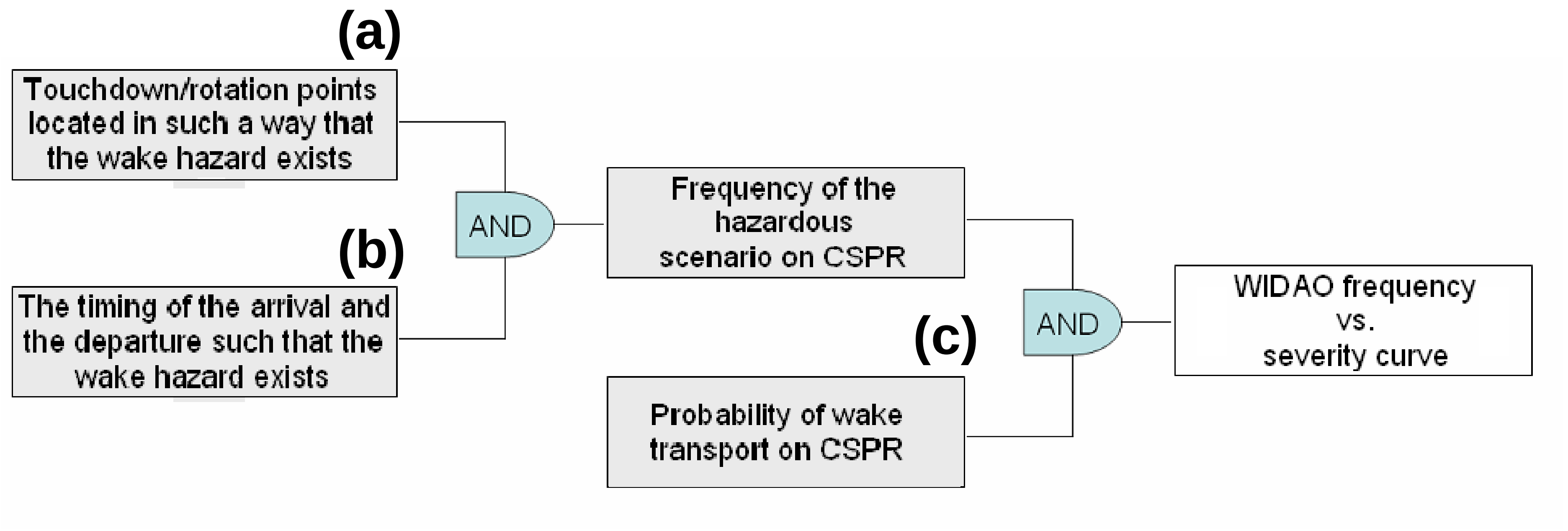
2.10 Safety objectives are satisfied for reference scenario in normal conditions



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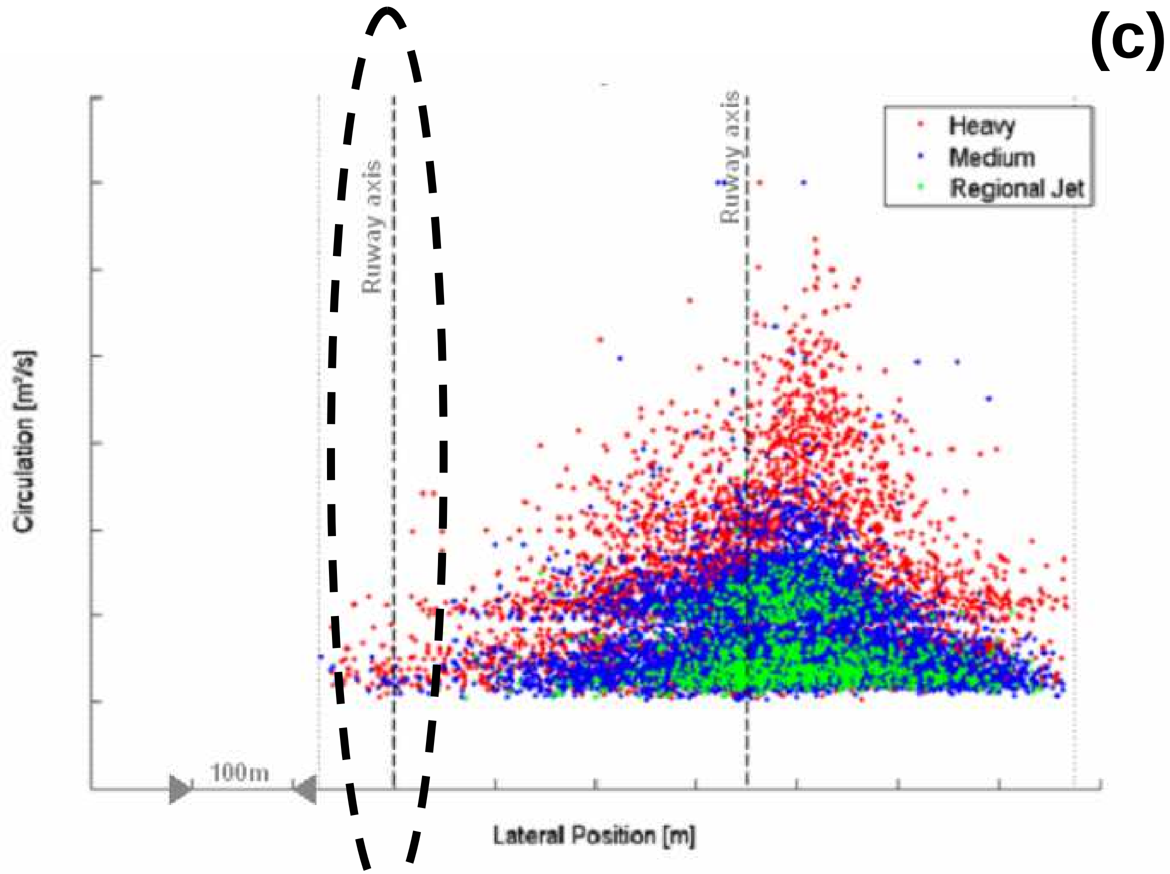

Figure 7: Example LIDAR Dataset

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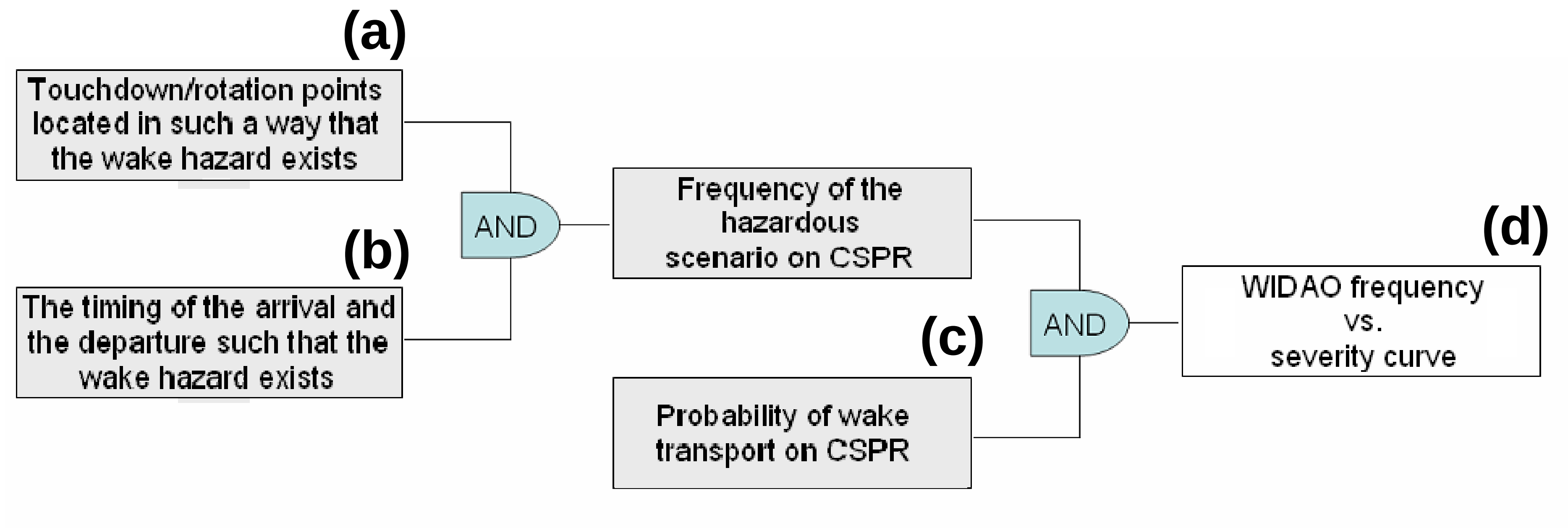

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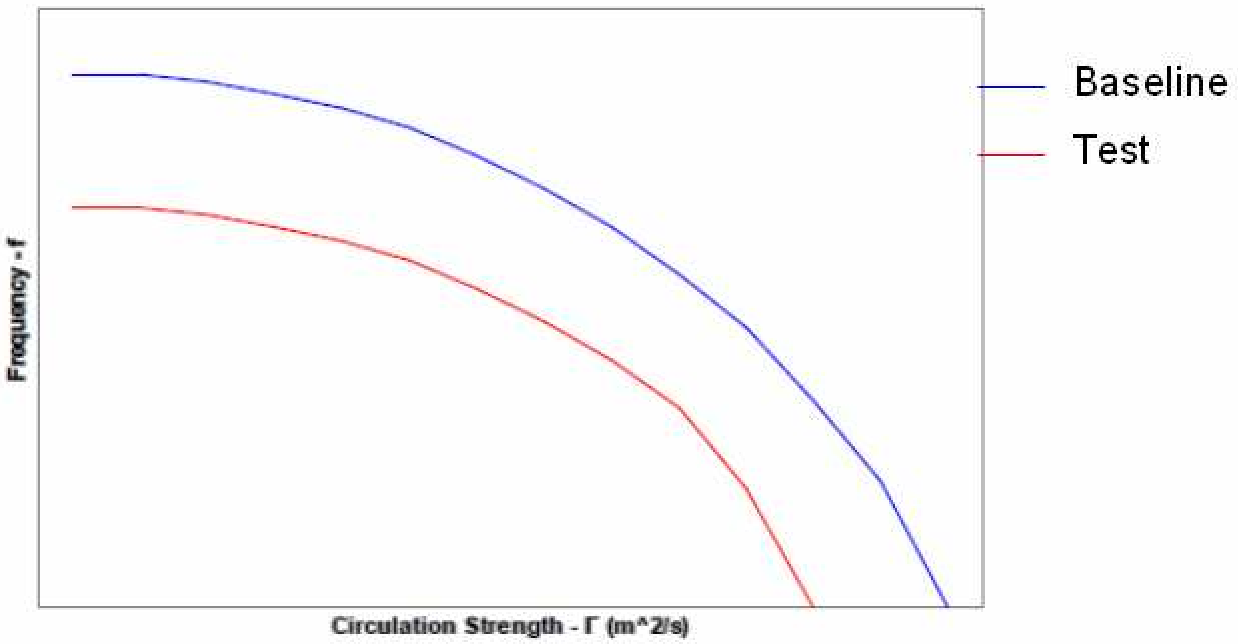

Figure 9: Schematic Example of Comparison of In-Trail Plot with CSPR Transport Plot (Log-Linear plot)

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   3.2 Wake vortex simulation
   3.3 Operational data collection
   3.4 Meteorological data collection
4. **Assumptions and Limitations**
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   4.2 Limitations
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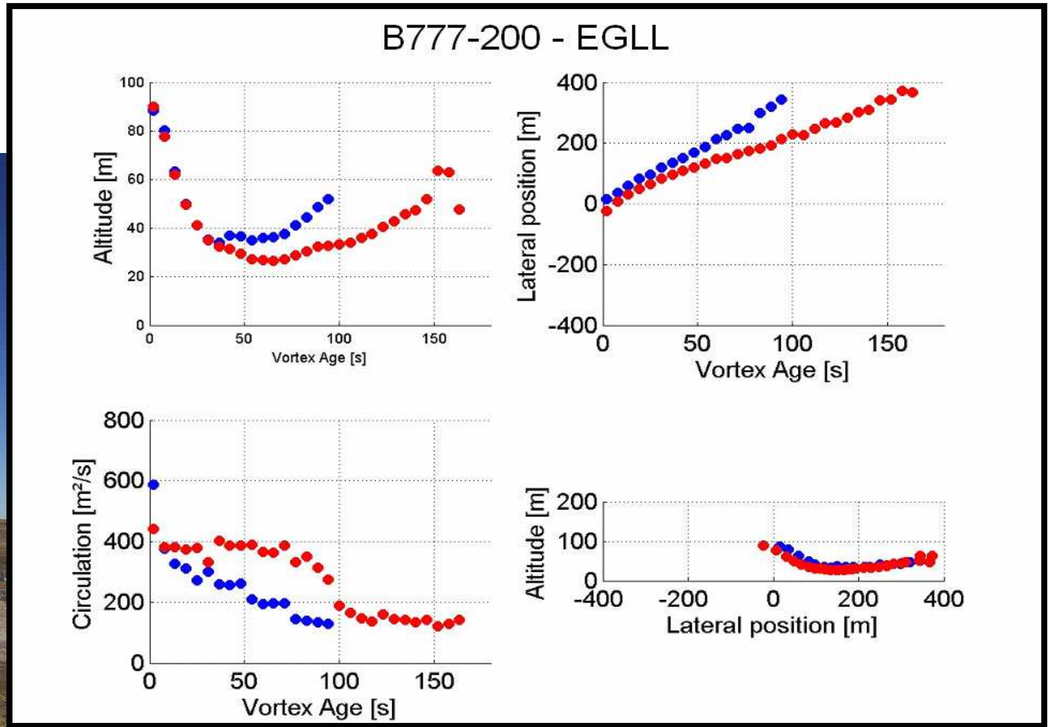
3. Wake Related Tools

3.1 LIDAR

LIDAR can be used to determine the position and strength of an aircraft's wake vortex by detecting the scattered laser light from particulate objects (such as soot and water droplets) observed in the wake vortex.



3. Wake Related Tools

3.1 LIDAR

LIDAR measurements of wake vortices from aircraft in flight are the only practical approach to measurements of wake vortices from real aircraft. LIDAR has been successfully used and provided evidence for safety cases supporting:

- the design of the A380 wake vortex separation – ICAO State Letter TEC/OPS/SEP – 08-0294.SLG;
- the National Rule Change (NRC) 1.5-Nautical Mile Dependent Approaches to Parallel Runways Spaced Less Than 2,500 Feet – FAA ORDER JO 7110.308;
- the Simultaneous Offset Instrument Approach (SOIA) – FAA ORDER 8260.49A;

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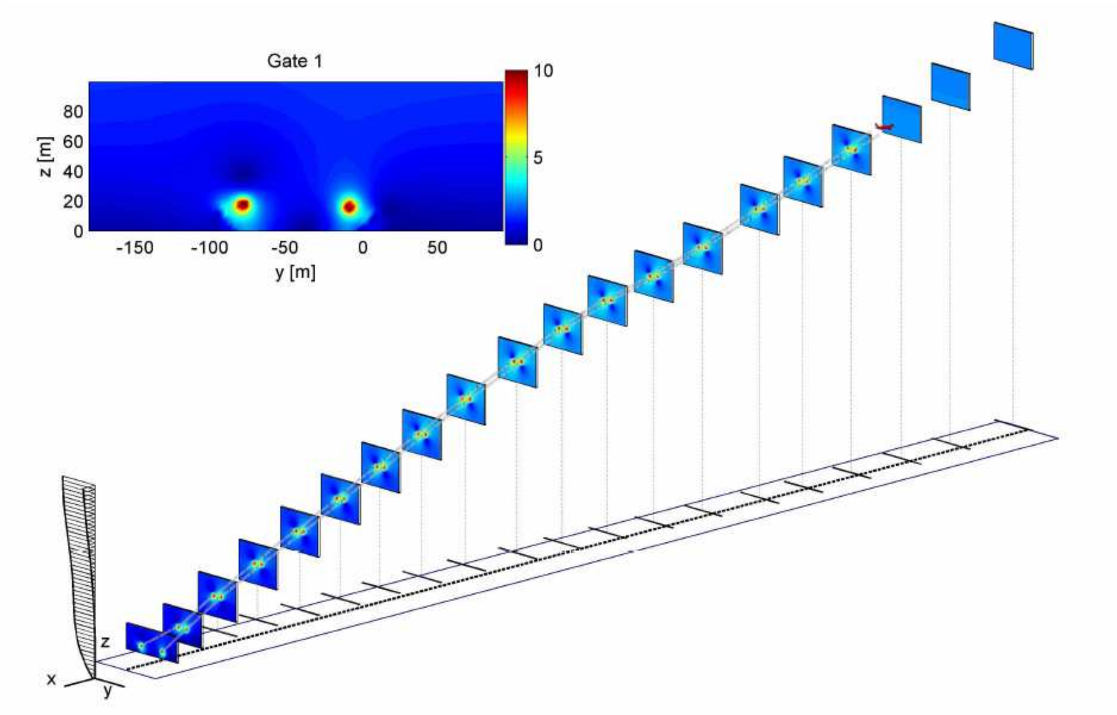
3. Wake Related Tools

3.2 Wake vortex simulation

The models used in the Wake4D tools have been calibrated and validated against various LIDAR databases and are now considered as state-of-the-art for wake vortex modelling



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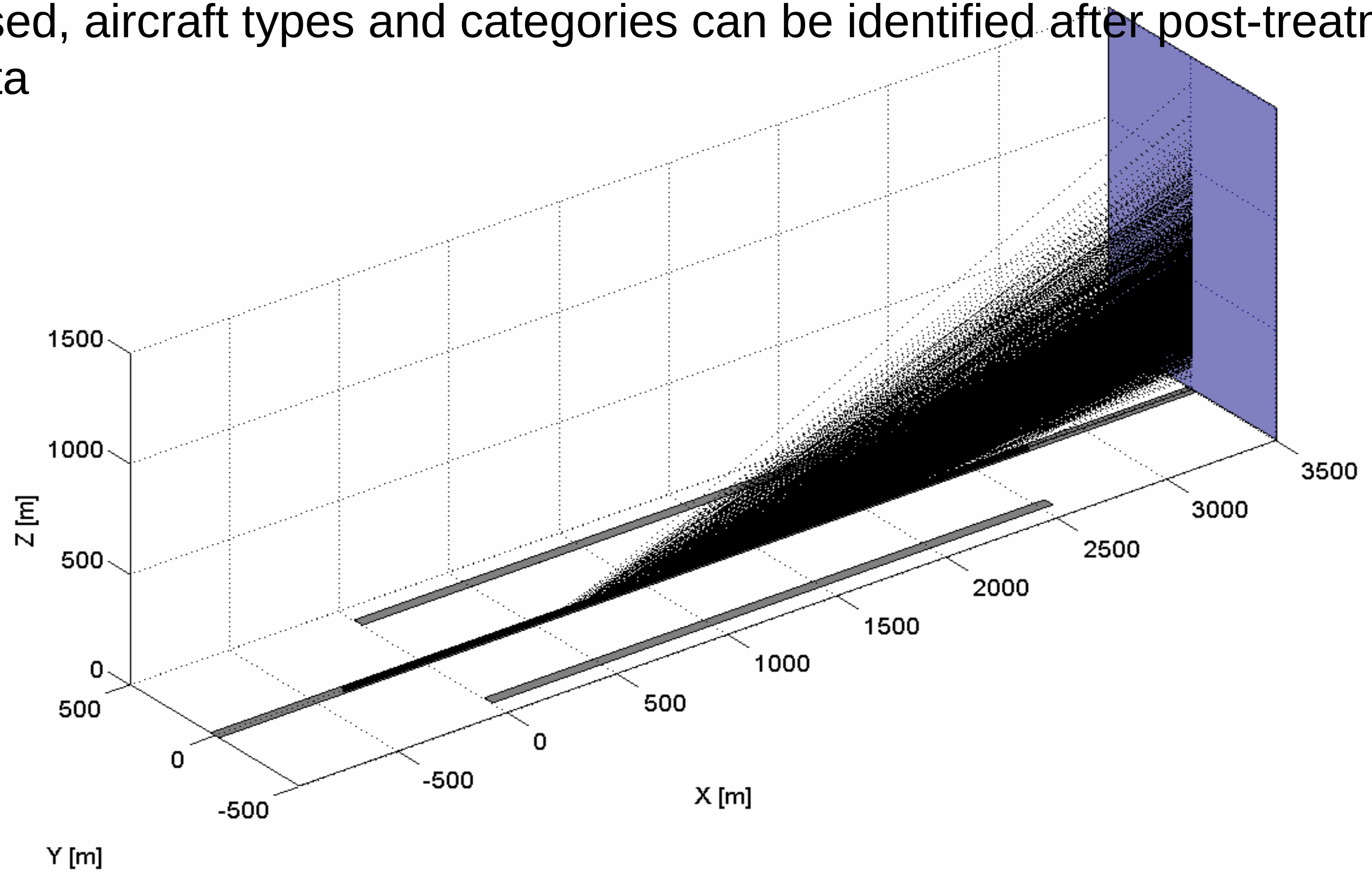
3. Wake Related Tools

3.3 Operational data collection

Primary input data can be collected using information provided by airborne and ground radar. Data such as rolling distances, approach separation, go-around, climb angles, runway entry used, aircraft types and categories can be identified after post-treatment of raw radar data



Outline

3.4 Meteorological data collection

When considering an airport surface MET data should be considered at each of the locations that are being safety assessed. Anemometers close to each assessment location can provide specific wind speed and direction measurements.

Additional MET data, particularly historic data, may be provided by a national meteorological organisation.

Outline

Outline

3. Wake Related Tools

3.1 LIDAR

3.2 Wake vortex simulation

3.3 Operational data collection

3.4 Meteorological data collection

4. Assumptions and Limitations

4.1 Assumptions

4.2 Limitations

5. References

Quantitative benefits resulting from WIDAO step 1 and 2

The implementation of the first phase of the project led to following benefits:

Safety:

1. Increased take off run available (TORAs) without WT constraints
2. Increased runway length available for departures before the crossing taxiways
3. No incident reported, since November 2008, in relation with the release of constraints

Environment:

4. The benefits result from increased departure throughput on the inner runways (less holding before take off- reduced congestion close to threshold…)

Capacity:

5. The number of departure peaks on runway 08L/26R, respectively equal or superior to 42 and 40 D/h, has increased in a very significant proportion
6. Thanks to the above results, the operational departure airport capacity will be increased
7. Maintaining operational departure runway capacity during special events or when works are in progress

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Quantitative benefits expected from WIDAO step 3 and 4

Safety:

8. Increased take off run available (TORAs) for H departures, without WT constraints
9. Increased runway length available for H departures before the crossing taxiways

Capacity/ Environment:

10. WIDAO step 4 will allow the building of the new "without WT constraints" taxiway, helping optimizing the design of the new taxiway network feeding runway 08L