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SESAR Solution PJ.02-01-06 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report

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PJ.02-W2 AART

AIRPORT, AIRSIDE AND RUNWAY THROUGHPUT

This Safety Assessment Report (SAR) is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 874477 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document specifies the results of the safety assessments carried out in SESAR 2020 Wave 1 by SESAR Solution PJ.02-01 (Wake Turbulence Separation Optimisation) by EUROCONTROL, with an emphasis on Wave 2 PJ.02.01.06 Static Pairwise Separation for Departures (S-PWS-D) concept.

This Safety Assessment Report (SAR) is contributing to the Operational Service and Environment Definition (OSED), Safety and Performance Requirements (SPR), Interoperability (INTEROP) Requirements, Technical Specifications (TS), and Interface Requirement Specifications (IRS).

The current version includes contributions from EUROCONTROL, NATS and ENAIRE.

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1 Executive Summary

This document contains the Specimen Safety Assessment for a typical application of the SESAR Solution 02-01 (Wake Turbulence Separation Optimisation) in capacity constrained Very Large and Large sized airport operations. The report presents the assurance that the Safety Requirements for the V1-V3 phases are complete, correct and realistic, thereby providing all material to adequately inform the SESAR Solution PJ.02-01 development and validation.

This Safety Assessment Report (SAR) is contributing to the Operational Service and Environment Definition (OSED), Safety and Performance Requirements (SPR), Interoperability (INTEROP) Requirements, Technical Specifications (TS), and Interface Requirement Specifications (IRS).

This report is a continuation of the PJ.02.01 SAR [27], adding mainly the developments from SESAR 2020 Wave 2 done by EUROCONTROL for the PJ.02.01.06 S-PWS-D concept.

2 Introduction

This Safety Assessment Report (SAR) is based on the PJ.02.01 SAR [27] and the CREDOS Preliminary Safety Case [19] and it is addressing the developments brought in SESAR 2020 Wave 2 to the following PJ.02.01 operational improvement step:

- AO-0323: Wake Turbulence Separations (for departures) based on Static Aircraft Characteristics (PWS-D)

Other relevant operational improvement steps for the Departures solution are:

- AO-0304: Weather Dependent Reduction of WT separation for Departures (WDS-D)
- AO-0329: Optimised Separation Delivery for Departures (OSD)

2.1 Background

The Wake Turbulence Separations for Departures, based on Static Aircraft Characteristics, aims to utilise the more efficient wake separations developed by the RECAT-EU-PWS activities (under the re-categorisation programme) under approval by EASA, in SESAR 1 (Project P06.08.01) and in SESAR 2020 (PJ.02-01 SAR [27]). RECAT-EU TB departure separations are currently employed at London Heathrow whilst all other UK airports continue to use the UK specific wake turbulence separations. Barcelona continues to operate using standard ICAO wake categories.

The Weather Dependent Reductions of Wake Turbulence Separations for Departures is based on the Crosswind Reduced Separation for Departures concept developed by the CREDOS Project in the European Commission 6th Framework Programme (EC 6th FP) from 2006 to 2010 [12]. This was further developed and validated in Project P06.08.01 from SESAR 1 which included the wind speed related "Total Wind" criteria concept [13].

The Optimised Separation Delivery for Departures and the associated controller tool support is based on the controller tool support developed in the CREDOS Project [14], taking into account the operational practitioner feedback at the end of the CREDOS Project.

[…]

2.2 General Approach to Safety Assessment

This safety assessment is conducted as per the SESAR Safety Reference Material (SRM) which itself is based on a twofold approach:

- a success approach which is concerned with the safety of the Solution operations in the absence of failure within the end-to-end Solution functional system, encompassing both Normal operation and Abnormal conditions,
- a conventional failure approach which is concerned with the safety of the Solution operations in the event of failures within the end-to-end Solution functional system.

These two approaches are applied to the derivation of safety properties at each of the successive lifecycle stages of the Solution development:

Safety Specification at the Service Level

This is defined as what the new WT separation modes and ATC tools have to achieve at the Air Traffic Management (ATM) Service level in order to satisfy the requirements of the airspace users - i.e. it takes a "black-box" view of the new method of operations and includes what is "shared" between the users (aircraft) and the Air Traffic Service (ATS) Providers.

From a safety perspective, the user requirements are expressed in the form of SAfety Criteria (SAC) and the Specification is expressed in the form of Safety Objectives (functionality & performance and integrity/reliability properties), which are derived during the V1 and V2 phases of the development lifecycle. The purpose is to check the completeness of the OSED and identify possible additional validation objectives to be revealed by the safety analysis in view of their inclusion in the Validation plans.

Safe Design at Design Level

This describes what the operations with the new WT separation modes and ATC tools are actually like internally and includes all those system properties that are not directly required by the users but are implicitly necessary in order to fulfil the specification and thereby satisfy the User requirements. Design is essentially an internal, or "white-box", view of the operations supported by the new WT separation modes and ATC tools. This is more generally called the Design-level Model for the new WT separation modes in terms of human and machine "actors" that deliver the functionality.

From a safety perspective, the Design is expressed in the form of Safety Requirements (sub-divided into functionality & performance and integrity/reliability properties), which are derived during the V2 (initial design safety requirements) and V3 (detailed design safety requirements) phases of the development lifecycle. The purpose here is to feed the SESAR Solution PJ.02-01 SPR-INTEROP/OSED Part I with a complete and correct set of safety requirements. Furthermore, where relevant, the requirements inform the validation exercises with respect to the inclusion of related additional validation objectives for which validation feedback is required.

[…]

2.3 Scope of the Safety Assessment

This Safety Assessment Report (SAR) is limited to the scope of SESAR Solution PJ.02-01, concentrating mainly on the Wave 2 sub-concept PJ.02.01.06 S-PWS-D. SESAR Solution PJ.02-01 is addressing the Static Pair Wise Separation (PWS), Optimised Separation Delivery (OSD) and Weather Dependent Separation (WDS) concepts for Departures.

This safety assessment defines the set of Safety Criteria (SAC), Safety Objectives (SOs) and Safety Requirements (SRs) for all the SESAR Solution PJ.02-01 departures concept solutions.

Meanwhile, whilst outlining the strategy employed by SESAR Solution PJ.02-01 for demonstrating the compliance with all SACs, this safety assessment focuses on the design of ATC supporting tools (separation indicators displayed to ATCOs) and working methods/procedures required for the separation delivery with the new WT separation modes, i.e. the correct application of the new WT separation minima for the departures concepts solutions.

This safety assessment does not support the Separation design i.e. the definition of new WT separation minima which, if correctly applied in operation, guarantee safe operations on the initial departure path for the departures concepts solutions. However, the relevant pieces of safety evidence (mainly in terms of wake turbulence encounter risk assessment) have been produced by P06.08.01 in SESAR 1 and are referenced and summarized within the SAC demonstration strategy. This evidence has been used by the RECAT-EU-PWS Safety Case submitted to EASA for approval [20].

This safety assessment covers the design and validation activities, encompassing Safety specification at the Service Level and Design Level. […]

2.4 Layout of the Document

Section 1 presents the executive summary of the document

Section 2 provides the background of the S-PWS-D concept, the general approach to safety assessment in SESAR and the scope of this safety assessment

Section 3 provides the operational concept overview and the scope of the change, summarises the solution operational environment and key properties together with the stakeholder's expectations and derives the Safety Criteria

Section 4 addresses the safety specification at Service level, through the definition of SOs

Section 5 addresses the safe design of the solution, through the derivation of SRDs and link to validation results

Appendix A presents the consolidated list of Safety Objectives

Appendix B presents the consolidated list of Safety Requirements with traceability to the Safety Objectives

Appendix C presents the list of Assumptions, Issues, Recommendations and Assessment Limitations

Appendix D outlines the Accident Incident Models (AIM) relevant for SESAR Solution 02-01.

Appendix E presents the Hazard Identification table in outcome of the HAZID workshop conducted within P6.8.1 TBS Phase 2 (this continues to be relevant for the arrival separation delivery concepts addressed in this SAR).

Appendix F presents the results of the PJ.02.01 arrivals and departures SAF & HP workshop which took place on the 30th of October 2018 in the frame of SESAR 2020

Appendix G presents the Risk Classification Schemes for the relevant accident-incident types

Appendix H presents the EATMA models for the arrivals and departures concepts

[…]

3 Setting the Scene of the safety assessment

3.1 Operational concept overview

The following provides the key principles of each departures concept:

- **PWS-D** involves departure wake turbulence separation according to a wake turbulence scheme based upon aircraft type pairs, rather than grouping aircraft types into wake categories.
- **WDS-D** is the conditional reduction or suspension of wake separation minima for departure operations, applicable under pre-defined wind conditions, on the basis that under those wind conditions the wake turbulence generated by the lead aircraft is either wind transported out of the path of the follower aircraft on the initial departure path or has decayed sufficiently to be acceptable to be encountered by the follower aircraft.

The application of the departure wake turbulence separation rules involved by PWS-D and WDS-D concepts requires (although there are some exceptions) an ATC tool to present the support for aiding the delivery of the required minimum separation on the CWP:

- **OSD** is the ATC support tool to enable consistent and efficient delivery of the required separation or spacing between departure pairs on the initial departure path.

Further details regarding the concepts can be found in the SPR-INTEROP/OSED Part I [22] Section 3.2.4.2.

3.2 Scope of the change

Additionally to the PJ.02-01 design and validation work done for the departures concept, the main change brought by the Wave 2 PJ.02.01.06 S-PWS-D concept is the following validation activity:

- Wake Impact Severity Assessment (WISA) Departures flight simulation campaign led by EUROCONTROL.

The above-mentioned validation activity focuses on assessing pilots' perception on the severity of various wake turbulence encounters corresponding to different S-PWS separation minima on both initial departure and final approach paths. The main aim of this activity is to ultimately contribute with further evidence to the PWS safety case for Departures.

Additionally, Wave 2 proposes to include the following new/additional a/c types in the TB-S-PWS for departures matrix: B748, A35K, B789, B38M, A20N, A21N, BCS1, BCS3 and E195.

A SAF and HP screening was done and no impact was identified on this operational safety assessment by the Wave 2 developments. The Safety Assessment done in Wave 1 is still fully applicable. The change brought by PJ.02.01.06 S-PWS-D contributes with further evidence to the design SAC (SAC#D7), derived within PJ.02.01 and shown in section 3.5 of this document. The results from the flight simulation campaign is recorded in section 6 of this document.

3.3 Solution Operational Environment and Key Properties

This section describes the key properties of the Operational Environment that are relevant to the SESAR Solution PJ.02-01 safety assessment (information summarized from SPR-INTEROP/OSED Part I Section 3.2[22]) relevant for the Departures Concepts Solutions.

[…]

3.3.1.1 Airspace Structure and Boundaries for the Departures Concepts Solutions

The airspace associated with the departures' solution for the NATS thread is that associated with EGLL[1]. A diagram showing the runway layout is illustrated below.

The NATS thread focusses on the required Standard Instrument Departures (SID) as published for EGLL and the associated RECAT-EU departure wake separation requirements.

The ENAIRE thread focusses on Barcelona Airport and the associated SIDs as published for that operation.

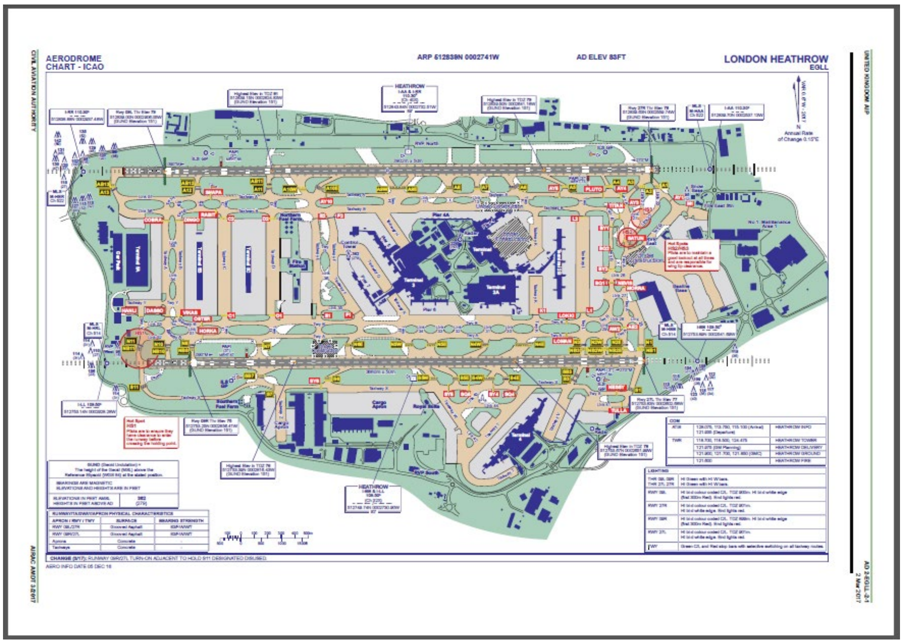

Figure 1: London Heathrow Airport

[1] London Heathrow Airport

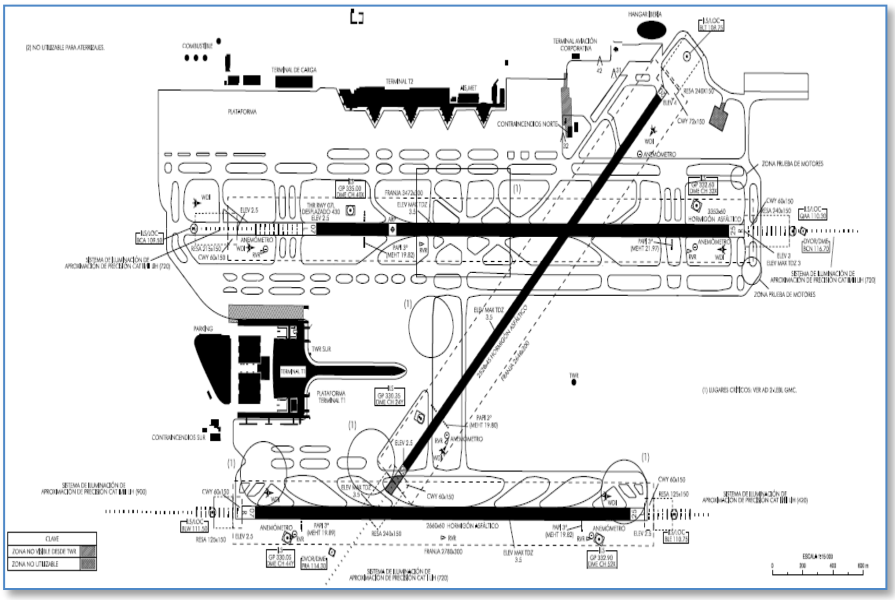

Figure 2: Barcelona Airport

3.3.1.2 Types of Airspace – ICAO Classification for the Departures Concepts Solutions

Controlled airspace associated with the reference airports.

3.3.1.3 Airspace Users – Flight Rules for the Departures Concepts Solutions

Instrument Flight Rules associated with IFR departure procedures at the reference airports.

3.3.1.4 Traffic Levels and complexity for the Departures Concepts Solutions

- In Reference Scenario: level of traffic in peak hours as per the current RWY throughput at the Very Large and Large airports.
- With Solution Scenarios: level of traffic in peak hours as per the increased RWY throughput enabled by the Solutions.

3.3.1.5 Aircraft ATM capabilities for the Departures Concepts Solutions

The Aircraft ATM capabilities are as per the Reference Scenario IFR/VFR/SVFR[2] operations at the respectively Very Large and Large airports. No additional aircraft capabilities (other than those already needed to enable IFR departures from the reference airports) were identified during V3.

3.3.1.6 Terrain Features – Obstacles for the Departures Concepts Solutions

There is a requirement to consider terrain features and obstacles that may impact the wind field when developing and validating the WDS-D concepts. Local topography, such as hangar buildings, terminal

[2]Traffic samples used during V3 validation exercises were IFR only

buildings and high ground in the vicinity of the aerodrome may impact both surface winds, and winds aloft, from where departure aircraft become airborne and along the straight-out initial common departure path.

3.3.1.7 CNS Aids for the Departures Concepts Solutions

No anticipated change from Reference Scenarios for current operations. These include:

- Air-Ground Voice Communication System
- Ground-Ground Voice Communications System
- RNAV / GNSS Navigation Services
- Primary & Secondary Radar Surveillance System for the TMA and SIDs including the straight-out initial common departure path
    - Elementary Mode-S Surveillance (ELS) or Mode A/C
    - Enhanced Mode S Surveillance (EHS) (for UK Airports)
- Surveillance System for Surface Movement (e.g. Advanced Surface Movement Guidance and Control System (A-SMGCS)) including some coverage of the straight-out initial common departure path

3.3.1.8 Separation Minima for the Departures Concepts Solutions

3.3.1.8.1 Summary

In Reference Scenarios:

- The ICAO radar separation standards for departures include MRS which prevents aircraft collision, and WT separation which is intended to protect aircraft from adverse Wake Turbulence Encounters (WTEs).
- The WT separation (based on WT categories) is determined by either time, or distance, to be applied at take-off (procedural time-based separation using metric minutes, or distance-based procedure which requires access to an Air Traffic Monitor). This involves the use of a WT category scheme for departures (providing both distance-based WT separation minima, and time-based separation minima) e.g. ICAO, the UK 5 category scheme and more recently the European Aviation Safety Agency (EASA) approved RECAT-EU 6 category scheme.
- For departing aircraft wake category pairs with no defined WT separation, then either Reduced Separation in the Vicinity of the Aerodrome (RSVA), 3NM MRS or 1000 feet vertical is applied.
- Where the common path of a lead and follower aircraft extends beyond the initial departure track, there may be a need to apply SID spacing requirements of 1 minute, 2 minutes and sometimes 3 minutes (some SID route combinations require an additional 1 minute when the lead aircraft type is in a slower speed group than the follower aircraft type with either none, one or two intervening speed groups, depending on the SID route combination). In addition, for a complex TMA with several aerodromes, there may be a need to impose a minimum departure interval (MDI) or an average departure interval (ADI) to reduce the number of aircraft following a SID route. SID route spacing, MDI and ADI are defined as distance-based constraints at aerodromes that apply distance-based separation and spacing constraints for departures.

With Solution Scenarios:

- With PWS-D, ATCOs will apply separations based on each aircraft type pair instead of the standard separations scheme where aircraft types are grouped into wake categories. Additionally, a refined wake category scheme of 20 categories (RECAT-EU 6-CAT plus a further breakdown to an additional 14 refined categories) has been defined for aircraft types not covered by the aircraft type pairwise matrix. The RECAT-EU-PWS Safety Case has defined the DB PWS-D 96x96 aircraft type pairwise matrix and the DB 20-CAT matrix for departures and also a TB 7-CAT (9-CAT) matrix for departures. There is an intention to define the TB PWS-D 96x96 aircraft type pairwise matrix and the TB 20-CAT matrix for departures, but this is currently deferred to SESAR 2020 Wave 2.
- With WDS-D, WT separations will be reduced due to weather conditions[3] (crosswind) favourable for the concepts. With the crosswind concept there is still a need to provide for sufficient time for the upwind vortex generated by the lead aircraft type to be crosswind transported clear of the downwind wing of the follower aircraft type considering the relative lateral navigation performance of the lead and follower aircraft along the straight-out common initial departure path.

3.3.1.8.2 Reference Scenario WTC Schemes for the Departures Concepts Solutions

For departures, the WT separations are defined in both distance and time to be applied at take-off. Most aerodromes in Europe apply the time separation minima.

The departure WT separations normally apply as soon as the follower aircraft becomes airborne (main wheels lift off the ground).

Such WT separation schemes (including ICAO, RECAT-EU 6 category and UK 5 category) are based on Wake Turbulence Categories (WTC) and are applied in all wind conditions.

ICAO DB and TB Schemes for Departures

Full details of the ICAO separation requirements can be found in the OSED Part 1 Section 3.2.4.2.1 and ICAO Document 4444 Chapter 5 Section 5.8

RECAT-EU DB and TB Schemes for Departures

The RECAT-EU 6 category scheme aims to provide a more efficient WT scheme by re-grouping aircraft based upon MTOW and wingspan and is the result of an optimization of the ICAO wake turbulence separation classes. See the OSED Part 1 Section 3.2.4.1.1 for more details.

For departures the RECAT-EU WT separations are defined in both time and distance. Full details of the RECAT-EU separation requirements can be found in the OSED Part 1 Section 3.2.4.2

3.3.1.8.3 Solution Scenario WT Separation Schemes for the Departures Concepts Solutions

When applying time separation minima, the criteria are applied by measuring successive airborne times (the time the main wheels lift from the ground after rotation). To deliver the airborne time separation criteria, local procedures are employed. These include determining the take-off clearance time for the follower aircraft from the recorded “start of take-off roll time” of the lead aircraft or

[3] The Total Wind (Tw) concept has not been developed or validated as part of PJ.02.01

determining the take-off clearance time of the follower aircraft from the recorded “airborne time” of the lead aircraft.

To achieve time separation when applying the recorded “start of take-off roll time” of the lead aircraft, take-off clearance may be issued to the follower aircraft once the required time separation has elapsed after the lead aircraft recorded “start of take-off roll time”. The recorded “start of take-off roll-time” is the time the aircraft is recorded as commenced rolling beyond the line-up and wait position.

The alternative to the above is to apply airborne times. This requires the take-off clearance to be issued to the follower aircraft, with an allowance for the anticipated follower aircraft take-off roll time on the runway, once the required time separation minus the anticipated follower aircraft take-off roll time has elapsed, after the lead aircraft recorded “airborne time”.

When applying distance-based separation minima, once airborne, departure aircraft are subject to the wake turbulence radar separations, therefore the Tower Runway Controller may apply a distance-based clearance such that the required distance-based wake turbulence radar separation is set up when the follower aircraft becomes airborne. A distance-based clearance can be issued as long as the Tower is equipped with radar surveillance.

On handover of separation responsibilities to the TMA Departure Radar Controller there is a need to have achieved the associated radar separation minima employed in the TMA, where the minimum radar separation is 3 NM horizontal or 1,000ft vertical, and where distance-based wake separation minima apply.

Issue 1

The wind used for the WDS-D concept needs to be locally defined with the corresponding wake separation reductions taking into account the following:

1) the local track length of the straight-out common initial departure path for each departure runway,

2) the relative lateral navigational performance of the aircraft fleet using the aerodrome for the departure wake pairs for which reduced wake separation is to be applied,

3) the local characteristics of the wind profiles over the straight-out common initial departure path for each departure runway particularly the local characterisation of changeable wind conditions impacting the risk of an unacceptably wake turbulence encounter with the employment of a reduced wake turbulence separation.

It is not established that this is required, or even feasible, over the forecast time horizon of a few minutes of the concept and with the associated performance and confidence in the forecast. An alternative approach is to adopt conservative crosswind criteria that employ sufficiently protective contingency to accommodate any potential changes to the crosswind conditions over the few minutes time horizon from committing to applying a reduced wake separation to the follower aircraft being clear of the wake turbulence encounter risk. This may be combined with some sort of discrimination between stable atmospheric conditions and unstable atmospheric conditions based on active monitoring of the atmospheric conditions through a possible combination of dynamic measurement and forecast services, and only applying the reduced wake separations in stable atmospheric conditions. **These are the research issues that still need to be addressed.**

3.3.1.8.4 Summary of WT Separation Modes covered by this Safety Assessment for the Departures Concepts Solutions

The following **WT separation modes** of operation based on combinations of the new WT separation are covered in this safety assessment[4]:

Id.	WT separation scheme& associated operation	Concepts involved
RECAT-EU	TB RECAT-EU WT scheme with OSD tool support	TB, OSD
RECAT-EU PWS	TB PWS WT scheme with OSD tool support	TB PWS-D and OSD
RECAT-EU WDS	TB WDS-D & RECAT-EU WT schemes with WDS-D & Enhanced OSD tool support	TB WDS-D and OSD
RECAT-EU PWS WDS	TB WDS-D & PWS-D WT schemes with WDS-D & Enhanced OSD tool support	TB WDS-D, TB- PWS-D and OSD

Table 1 Summary of WT Separation Modes

3.4 Airspace Users Requirements

Airspace users shall be provided with safe wake separation standards on departure. This includes from the point of nose-wheel rotation, along the common departure flight path until the aircraft makes the first turn onto the prescribed SID[5]

Pilots shall be aware of the wake separation standards in force at the time of departure.

[…]

3.5 Safety Criteria

3.5.1 Relevant Pre-existing Hazards for the Departures Concepts Solutions[6]

It has been concluded that the safety-relevant impact of the change brought in by the Departures Concepts Solutions is limited to the Initial Common Departure Path up to the first turn. The relevant

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[4] In addition to those mentioned in Table 13, ECTL has also conduced some activities on distance-based separation modes

[5] There may be a need to extend this to beyond the first SID turn for aircraft employing the same SID path after the first turn; particularly for departure pairs where the route separation constraints (e.g. SID separation) does not ensure that the distance-based wake separation to be applied by the TMA Departure Radar Controller is set up when applying the PWS-D wake time separation as the follower aircraft rotates and becomes airborne. This may be a significant risk when the follower aircraft has a faster airspeed profile than the lead aircraft over the straight-out initial common departure path and the first SID turn results in a significant headwind aloft adversely impacting the ground speed of the lead aircraft of the wake pair

[6] The pre-existing hazards in this section have been agreed (with ECTL) and amended from those mentioned in the original SAP.

pre-existing hazards, together with the corresponding ATM-related accident types and AIMs are presented in the following table for the Departures Concepts Solutions.

Pre-existing Hazards [Hp]	ATM-related accident type & AIM model
Hp#D1 "Adverse Wake Encounter on Initial Common Departure Path"	Wake Turbulence-induced Accident (WTA) on Initial Common Departure Path - associated AIM model Appendix D
Hp#D2 "Situation in which the intended 4-dimensional (4D) trajectories of two or more airborne aircraft are in conflict- Initial Common Departure Path"	Mid-Air Collision (MAC) on the Initial Common Departure Path - no AIM model available (will be partially supported by the simplified WTA model on Initial Common Departure path above)[7] [8]
Hp#D3 "The preceding landing/departing aircraft is not clear of the runway-in-use"	Relevant for single RWY in mixed mode Runway Collision (RC) & associated AIM model Appendix D

Table 2: Pre-existing hazards relevant for PJ.02.01 Departures Concepts Solutions

3.5.2 SAfety Criteria for the Departures Concepts Solutions

This section defines the SAC applicable to the operational scenarios for the Departures Concepts Solutions.

The following (amended) SAC[9] apply to all departure concepts[10]:

SAC Ref	SAC	Haz	Associated Hazard
SAC#D1	There shall be no increase of imminent wake infringement on departure induced by ATC (or the crew of the 1st aircraft), when the 2nd aircraft **is not yet** airborne, in the wake turbulence scheme under consideration, compared to current operations' wake turbulence scheme (e.g. ICAO, RECAT-EU or UK 5-Cat) Precursor: WE8.a.1, WE8.a.2 leading to WE8.a	Hp#D1	Wake Turbulence-induced Accident (WTA) on Initial Common Departure Path (associated AIM model Appendix D)
SAC#D2	There shall be no increase of imminent wake infringement on departure induced by ATC (or the crew of the 1st or 2nd aircraft), when the 2nd aircraft **is** airborne, in the wake turbulence scheme under consideration, compared to current operations' wake turbulence scheme (e.g. ICAO, RECAT-EU or UK 5-Cat) Precursor: WE8.b.1 and WE8.b.2 leading to WE8.b	Hp#D1	Wake Turbulence-induced Accident (WTA) on Initial Common Departure Path (associated AIM model Appendix D)

[7] Prior to any local implementation, ANSPs should investigate the possibility of MAC with other traffic operating in the vicinity of the aerodrome (e.g. airspace infringers and rotary traffic). Note: Also, for Wave 2 consideration.

[8] See footnote 12

[9] SACs amended following revision of the Departure Wake AIM

[10] D-TB-WDS-Tw, D-TB-WDS-Xw, D-PWS-EU

SAC#D3	There shall be no increase in imminent infringement of separation (non-wake) on departure induced by ATC	Hp#D2	Situation in which the intended 4-dimensional (4D) trajectories of two or more airborne aircraft are in conflict- Initial Common Departure Path”
SAC#D5	There shall be no increase of ATC tactical conflicts	Hp#D2	Situation in which the intended 4-dimensional (4D) trajectories of two or more airborne aircraft are in conflict- Initial Common Departure Path
SAC#D7	The probability of wake turbulence encounter of a given severity for a given traffic pair spaced at the wake turbulence minima under consideration on the initial common departure path, shall not increase compared to the same aircraft pair spaced at the current operations’ wake turbulence scheme (e.g. ICAO, RECAT-EU or UK 5-Cat) in reasonable worst-case conditions. Pre-cursor: WE6S	Hp#D1	Wake Turbulence-induced Accident (WTA) on Initial Common Departure Path (associated AIM model Appendix D)

Table 3: Safety Criteria for the Departures Concepts

[...]

4 Safety specification at ATS service level

4.1 Overview of activities performed

This section addresses the following activities:

- derivation of Safety Objectives in view of mitigating the relevant risks inherent to aviation in normal conditions of operation– section 4.2
- assessment of the adequacy of the ATS operational services provided by the Solution under abnormal conditions of the Operational Environment & derivation of necessary SOs – section 4.3
- assessment of the adequacy of the ATS operational services provided by the Solution in the case of internal failures and mitigation of the Solution functional system-generated hazards through derivation of SOs – section 4.4

[…]

4.2 Mitigation of Risks Inherent to Aviation – Normal conditions

4.2.1 Operational Services to Address the Pre-existing Hazards for the Departures Concepts Solutions[11]

The concept under assessment is applicable to the Tower (Aerodrome) Air (departures runway) Controller and may impact on the TMA Departures Radar Controller responsible for the safe separation of aircraft after take-off.

ID	Air Navigation Service Objective	Pre-existing Hazard
ACT	Determination and activation of the separation mode (in case of conditional application of the WDS-D Modes) [12]	**Hp#D1** “Adverse wake encounter on Initial Departure”
SPD	Maintain aircraft separation on the Runway Protected Area (RPA)	**Hp#D3** “The preceding landing or departing aircraft is not clear of the runway-in-use”
TO	Manage take-off, accounting for required spacing/separation behind previous departure(s)	**Hp#D1** “Adverse wake encounter on Initial Departure” **Hp#D2** “Situation in which the intended 4-dimensional (4D) trajectories of two or more airborne aircraft are in conflict- Initial Departure”

[11] SPD= **S**eparate **D**eparture; ACT = Activation/Transition phase; TO = Take-off

[12] The Automatic choice (Wind, aircraft pair) is out of scope and for future development.

SPD	Maintain spacing/separation between aircraft on the Initial Common Departure path up to transfer to APP ATC	**Hp#D1** "Adverse wake encounter on Initial Departure" **Hp#D2** "Situation in which the intended 4-dimensional (4D) trajectories of two or more airborne aircraft are in conflict- Initial Departure"

Table 4: Relevant ATM/ANS services and Pre-existing Hazards for the PJ.02-01 Departures Concepts Solutions

4.2.2 Derivation of Safety Objectives (Functionality & Performance – success approach) for Normal Operations

The following Safety Objectives are formulated to meet the SAC in normal operating conditions

Ref	Phase of Flight / Operational Service	Related AIM Barrier or Precursor	Achieved by / Safety Objective
ACT	Activation/De-activation of the separation mode (WDS-D)	WE8 and B3	SO#D01: Ensure delivery of consistent and accurate S-PWS, or WDS wake turbulence separation delivery on the common initial departure path.
			SO#D02: Ensure the application of WDS minima only when the predefined wind parameter(s) are met.
			SO#D03: Ensure no reduction in SID spacing between successive departures when applying WDS or S-PWS
			SO#D04: Ensure the application of WDS-D only when pre-defined SID/Route combinations are met
			SO#D05: Ensure the basis of WDS-D are continued to be fulfilled along the initial common departure path
SPD	Maintain aircraft separation on the Runway Protected Area (RPA)	RP3C and B3	SO#D06: Ensure that the runway is free from obstruction before issuing a line-up or take-off clearance
TO	Manage take-off accounting for required spacing/separation behind previous departure(s)	WE8 and B3	SO#D07: Issue take-off instructions, such as to establish the applicable wake separation minima on the common initial departure path
			SO#D08: Provide correct wake turbulence spacing delivery, from the moment the following aircraft rotates/begins its take-off roll as applicable, until it is transferred to the next sector

		MF7.1 and B7	SO#D09: Ensure the application of the greatest applicable departure separation constraint. i.e. wake, SID or MRS separation requirement(s). [13]
			SO#D10: Not to negatively affect the ability of Crew/Aircraft, to be able to follow ATC instructions
SPD	Monitor spacing/separation between aircraft on the Initial Common Departure path up to transfer to APP ATC	WE7 MF6.1.2.2	SO#D11: Not to increase the possibility of wake encounter on departure due to lateral deviation from the common initial departure path. (Only applicable to WDS-D Xw)

Table 5: Objectives under Normal Conditions

[…]

4.3 Mitigation of Risks Inherent to Aviation - Abnormal conditions

4.3.1 Identification of Abnormal Conditions

NATS conducted V2 Real-time Simulation exercises during 2017. The objective of the exercises, from a safety perspective, was to identify if there was likely to be any impact on the SESAR pre-existing hazards particularly:

- Hp#D1 "Adverse wake encounter on Initial Departure"; and/or
- Hp#D2 "Situation in which the intended 4D trajectories of two or more airborne aircraft are in conflict- Initial Departure"

A concept of introducing an NBAT[14] supported by a count-down timer was trialled. The purpose of the countdown timer is to support the Tower Runway Controller to consistently deliver the required wake separation time as defined by the wake separation rules being employed. It is the purpose of the wake separation rules to ensure that there is an acceptable risk (rather than to prevent) of an adverse wake encounter on initial departure.

[13] The ATCO issuing the clearance is ultimately responsible for determining the departure separation interval based on SID and wake or any other factor that may determine when an aircraft may be released for departure,

[14] Not Before Airborne Time. this is the earliest airborne time to satisfy the required wake separation time to the preceding departure aircraft and is applicable to "airborne time" to "airborne time" wake separation procedures. In the case of "start of roll-time" wake separation procedures the equivalent is the NBTOT (Not Before Take-Off Time), the earliest time to issue the take-off clearance to satisfy the required wake separation time.

Real Time simulations conducted by NATS in Q1 2019 identified that the above pre-existing hazards are still applicable. Two abnormal scenarios were experienced during the RTS as follows:

No	Abnormal Scenario	Description
ABN01	Go Around	This scenario had an aircraft on final approach with others at the holding points awaiting departure clearance. The aircraft on final went around therefore requiring the Tower departure controller to delay the pending departures
ABN02	Aborted Take-off	This scenario had an aircraft cleared for take-off begin its take-off roll and then stop on the runway. This required the departure controller to delay subsequent departures until such time that the runway had been vacated.

Table 6: Abnormal events experienced during RTS5

Additional events identified but not experienced as part of RTS5 are as follows:

No	Abnormal Scenario	Description
ABN03	Runway Obstructed	This scenario includes unexpected runway incursion or, landing aircraft ahead does not vacate in a timely manner or other aircraft emergency and/or FOD.
ABN04	Wet Runway	Braking action is reduced, or aquaplane occurs
ABN05	Strong Cross-wind	Effect on landing aircraft might be such that a go-around occurs or an aircraft aborts take-off. Important also for consideration in WDS operations in the event that aircraft are unable to maintain track after departure.
ABN06	Delay in take-off or line up	Crew advise that they are not ready to accept take-off or line-up instruction necessitating a change in departure sequence order.

Table 7: Other Abnormal/Non-nominal events

[…]

4.3.2 Safety Requirements at ATS Service level (SRS) for Abnormal conditions of operation

ID	Description	Abnormal Scenario	Ref. SAC
SO#D12	Ensure wake turbulence separation between departing aircraft and an aircraft executing a go-around/missed approach	1 & 5	SAC#D1
SO#D13	Maintained lateral/vertical separation between departing aircraft and an aircraft executing a go-around/missed approach	1	SAC#D3
SO#D14[15]	In the event of an aborted take-off, ensure the runway is unobstructed before any subsequent departures are permitted	2	SAC#D5

[15] See Table 17

SO#D15	Provision of wake vortex warning(s) when crosswind transport is not assured due to divergence of either the preceding, or follower, aircraft from the straight-out initial common departure path.	1	N/A
SO#D16	Maintain the ability of ATCOs to tactically rearrange the departure sequence	6	SAC#D3

Table 8 Safety Objectives for Abnormal Conditions (Departures)

4.4 Mitigation of System-generated Risks (failure conditions)

This section provides the list of operational hazards, effects and where possible, any associated severity. [16]

[…]

4.4.1 Operational Hazards Identification and Analysis

A number of real-time simulation exercises were conducted at NATS during 2017 and 2019. This did not address either theoretical or actual modelling of wake transportation but looked at the development of a prototype OSD tool and associated ConOps. The objective of the V2 and V3 exercises was to establish if an ATCO could safely ensure departure wake separation requirements under both PWS-D wake time separations (96x96 pairwise matrix and 20x20 20-CAT matrix) and during periods where WDS-S Xw were in operation. Details of the results from RTS5 are available under the Analysis of safety section and summarised in section 6 of this document.

In addition, workshops were conducted at EUROCONTROL's Experimental Centre, Bretigny on the 30th October 2018 and EGLL ATC on the 29th March 2019. The workshops were facilitated by EUROCONTROL and NATS and attended respectively by representatives from ECTL, Paris CDG, Austrocontrol and NATS. The final discussion resulted in the identification of three hazards which are illustrated below:

Note: Refer to Section 5.5.1.1.1 for detailed Bow-tie analysis.

ID	Hazard Description	High Level Cause(s)	Operational Effects	Mitigations protecting against propagation of effects	Severity *(most probable effect)*

[16] It is important to note that at the time of writing this section, the Wake AIM relevant to departures is not yet mature.

	ATCO issues premature take-off clearance regarding wake separation		Adverse wake encounter by following aircraft	ATCO shall, where possible, instruct aircraft to stop take-off roll Equipment and training shall be provided, to enable ATCOs to be robust in providing the required, accurate, wake separation between successive departures	SC3B
	ATCO issues a premature take-off clearance with respect to SID separation	ATCO fails to take into account a SID constraint within the departure clearance (even though appropriate wake separation applied)	Loss of Minimum Radar Separation and/or SID separation[17]	HMI design and training to enable ATCOs to be robust in providing applicable SID separation	SC3B
	Aircraft deviates from planned trajectory	External factors such as bird strike, adverse weather, ATC intervention or unexpected speed differential	Loss of wake separation[18]	Well defined airborne procedures, HMI design and training to prevent, and/or recover from, any aircraft deviation from expected departure track	SC3B

Table 9: High level description of Departure Concept Operational Hazards

[...]

4.4.2 Safety Objectives associated to failure conditions

It is recommended:[19] that the objectives identified as a result of the CREDOS work are further analysed when addressing WDS-D-Xw implementation at local level.

Note: Further analysis should also be performed following any future development of the SESAR Safety Reference Material.

CREDOS Preliminary Safety Case

The following table shows high level system integrity objectives:

SO ref	Safety Objectives (integrity/reliability)	Associated Hazard

[17] Aircraft may be required to follow SIDs in order to provide MRS on transfer of the aircraft to the departures radar ATCO

[18] Applicable to WDS-D-Xw

[19] These objectives must be reviewed at local level

SO#D17	Provision of accurate tool-based information regarding wake separation intervals between successive departing aircraft in order to prevent an increase in the frequency of ATC issuing a premature take-off clearance regarding wake separation (Related to SC3b of the WAKE ID AIM Model)	Ho#D01
SO#D18	Provision of reliable tool-based information regarding departure intervals in order to prevent an increase in the frequency of the occurrence of a premature take-off	Hp#D1 Ho#D2

Table 10: Integrity objectives – Departures

It is important to note that the integrity of the information provided to the OSD tool must, by default, be such that tool works in accordance with the details in Table 11. This will include the following for each departure runway:

The following system requirements are derived in order to support the objectives in Table 11.

Objective	Objective Detail	Req Ref	Requirement Detail
SO#D17 and SO#D18	Provision of accurate tool-based information regarding wake separation intervals between successive departing aircraft and Provision of reliable tool-based information regarding departure intervals	SR#D07 DEP3.0018	The tool shall be provided with the intended take-off order of the departure aircraft;
		SR#D08 DEP3.0008	The Tower Runway Controller shall be trained to ensure the integrity and stability of the departure sequence information.
		SR#D09 DEP3.0003	The tool shall be provided with the Aircraft Type and RECAT-EU Wake Turbulence Category of each departure aircraft.[20]
		SR#D10 DEP3.0002	ATCOs shall be trained to ensure the integrity of the aircraft type and wake category information.
		SR#D11 DEP3.0019	The tool shall be provided with the accurate line-up position of each departure aircraft (to allow for automatically adding the 60s for intermediate position line-up).
		SR#D12 DEP3.0007	The Tower Runway Controller shall be trained to ensure the integrity of the entry taxiway line-up position information of each departure aircraft.
		SR#D13 DEP3.0020	The tool shall be provided with the SID for each departure aircraft (for WDS-D and distance-based).
		SR#D14	The Tower ATCOs shall be trained to ensure the integrity of the aircraft SID information.

[20] including subsequent updates to this information for new aircraft types;

		DEP3.0005	
		SR#D15 DEP3.0021	The tool shall be provided with the accurate airborne time of each departing aircraft (for airborne time procedures).
		SR#D16 DEP3.0009	The Tower Runway Controller shall be trained to ensure the consistency of the airborne time information.
		SR#D17 DEP3.0022	The tool shall be provided with accurate and reliable wind measurements at the rotation positions on the runway surface and aloft along the common straight-out initial departure path (for WDS-D).
		SR#D18 DEP3.0023	The tool shall take into account staleness criteria with respect to the wind information and the timely suspension of applying associated reduced wake separations (for WDS-D)
		SR#D19 DEP3.0024	The software assurance level of the tool shall be such that ATCOs may justifiably be reliant on the wake separation information provided by the tool facilitating the provision of the wake turbulence separation between each successive departure.
		SR#D20 DEP3.0025	In the case of wake separation time procedures, the wake separation time shall be accurately displayed with respect to indicating the applicable wake separation time interval between each successive departure.
		SR#D21 DEP3.0026	In the case of wake separation distance-based procedures, the wake separation distance shall be accurately displayed with respect to indicating the applicable wake separation distance between each successive departure.
		SR#D22 DEP3.0016	The OSD Tool shall be configured with the accurate roll time and rotation position of each aircraft type for each departure runway and line-up position (to determine the DDI-D position for distance-based separation procedures).
		SR#D23 DEP0.0006	Time until next departure shall be calculated to correctly and accurately represent the WDS (departure) or standard wake separation (according to the wake separation in use) for all departure pairs, in all normal ranges of weather and operating conditions
		SR#D24 DEP3.0027	The tool shall be provided with the accurate start of take-off roll time of each departing aircraft (for start of take-off roll time procedures).

		SR#D25 DEP3.0011	The Tower Runway Controller shall be trained to ensure the integrity and consistency of the start of take-off roll time information.
		SR#D26 DEP3.0015	The OSD Tool shall be configured with the accurate airspeed and climb profiles of each aircraft type over the SID routes from each departure runway out to the maximum wake separation distance from the rotation positions of the follower aircraft types (to determine the DDI-D position for distance-based separation procedures)
		SR#D27 DEP3.0028	The tool shall be provided with accurate and reliable wind measurements along the SID route of each departure runway out to the maximum wake separation distance from the rotation positions of the follower aircraft types (to determine the DDI-D position for distance-based separation procedures).
		SR#D28 DEP3.0029	The tool shall take into account staleness criteria with respect to determining the DDI-D position for distance-based separation procedures

Table 11: System Integrity Requirements – Departures

Safety Requirements (integrity/reliability) for the Departures Concepts Solutions[21]

It is recommended that the following requirements realised as a result of the work carried out in CREDOS are further investigated.[22] They are not to be used specifically for PJ.02.01 but only referred to by ANSPs for assistance when producing local tool integrity requirements.

Name & OSED Part 1 Ref	Text
WDS-D Xw concept undetected error in wind forecast DEP2.0002	For the WDS-D Xw concept the probability of an undetected error in the wind forecast, leading to an erroneous Go/No-Go indication shall be no greater than 2×10-9 per take-off.
WDS-D Xw concept undetected error in wind now-cast DEP2.0005	For the WDS-D Xw concept the probability of an undetected error in the wind now-cast, leading to an erroneous Go/No-Go indication shall be no greater than 2×10-9 per take-off.
WDS-D Xw concept advisory trigger line displayed wrongly DEP2.0013	For the WDS-D Xw concept the probability that the advisory trigger line is displayed wrongly on the radar display shall be no greater than 9×10-6 per take-off.
WDS-D Xw concept time separation displayed wrongly DEP2.1013	For the WDS-D Xw concept the probability that the advisory time separation is displayed wrongly shall be no greater than 9×10-6 per take-off.

[21] It must be noted that ATCOs will be heavily reliant on tool support to provide correct/safe Wake Turbulence spacing.

[22] These requirements are not included in the consolidated list in this report's appendices.

WDS-D Xw concept runway controller failure to see the advisory trigger line is not displayed DEP2.0019	For the WDS-D Xw concept the probability that the runway controller fails to see that the advisory trigger line is not displayed shall be no greater than 1×10-2 per take-off.
WDS-D Xw concept runway controller failure to see the time separation is not displayed DEP2.1019	For the WDS-D Xw concept the probability that the runway controller fails to see that the advisory time separation is not displayed shall be no greater than 1×10-2 per take-off.
Applying WDS-D Xw concept to an unsuitable aircraft pair DEP2.0023	For the WDS-D Xw concept the probability that the runway controller applies WDS-D Xw concept reduced wake separation to an unsuitable aircraft pair shall be no greater than 1×10-9 per take-off.
WDS-D Xw concept Flight Crew deviating from SID in nominal operations DEP2.0038	For the WDS-D Xw concept the probability of the crew deviating from the SID to avoid clouds (Cb), other traffic, or expected wake turbulence shall be no greater than 4×10-6 per take-off.
WDS-D Xw concept aircraft catches up due to speed differences DEP2.0042	For the WDS-D Xw concept the probability that an aircraft catches up on its predecessor due to speed differences shall be no greater than 3×10-5 per take-off.
WDS-D Xw concept aircraft deviates laterally on SID DEP2.0044	For the WDS-D Xw concept the probability that the aircraft deviates laterally outside the boundaries of the Wake Turbulence Separations Suspension Airspace Volume (WTSSAV) shall be no greater than 1×10-6 per take-off.
WDS-D Xw concept aircraft employs different SID to WDS-D planning DEP2.0046	For the WDS-D Xw concept the probability that the SID used by an aircraft is not the SID used in WDS-D planning shall be no greater than 4×10-6 per take-off.

Table 12: Integrity (CREDOS) Requirements

[...]

5 Safe Design of the Solution functional system

5.1 Overview of activities performed

This section addresses the following activities:

- Section 5.2 - introduction of the design model (initial or refined) of the Solution functional system
- Section 5.3 - derivation of Safety Requirements (functionality & performance) at Design level (SRD) in normal conditions of operation from the SOs (functionality & performance) of section 4.2 and supported by the analysis of the initial or refined design model above
- Section 5.4 - derivation of Safety Requirements (functionality & performance) at Design level (SRD) in abnormal conditions of operation from the SRS (functionality and performance) of section 4.3 and supported by the analysis of the operation of the initial or refined design under abnormal conditions of operation
- Section 5.5 - assessment of the adequacy of the design (initial or refined) in the case of internal failures and mitigation of the Solution operational hazards (identified at section 4.4) through derivation from SOs (integrity/ reliability) of Safety Requirements (functionality & performance) and Safety Requirements (integrity&reliability) at Design level (SRD)
- Section 5.6 - realism of the refined safe design (i.e. achievability and "testability" of the SRD)
- Section 5.7 - safety process assurance at the initial or refined design level

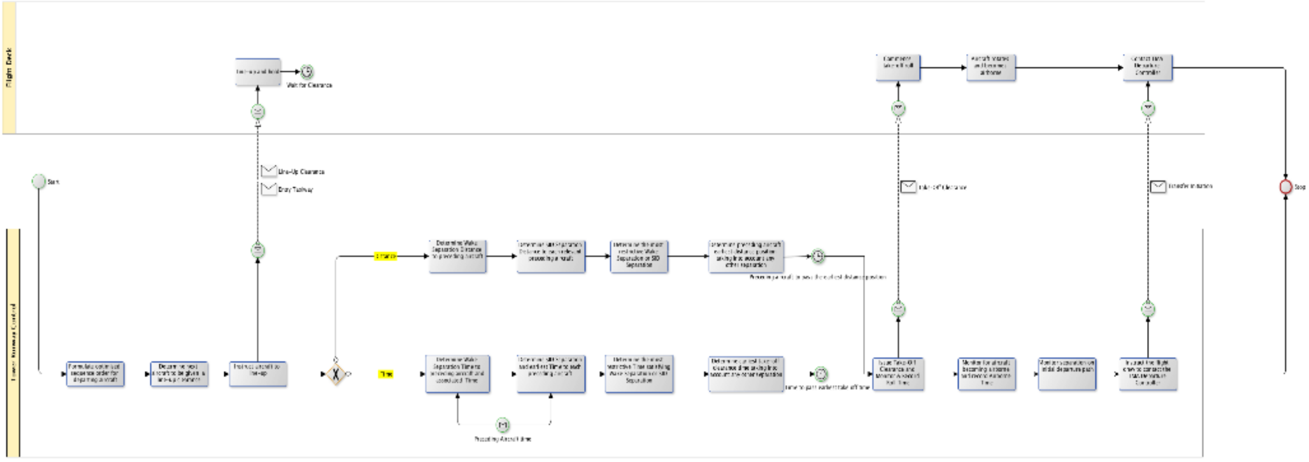
[…]

5.2 Design model of the Solution functional system

5.2.1 Description of the Design Model

5.2.1.1 Description of Functional Model for the Departures Concepts Solutions

The SPR-Level model for Departures is high-level and should not be taken as the final design for what will, eventually, be bespoke designs for individual ANSPs at different geographical locations. However, the following may be used as a basic example:



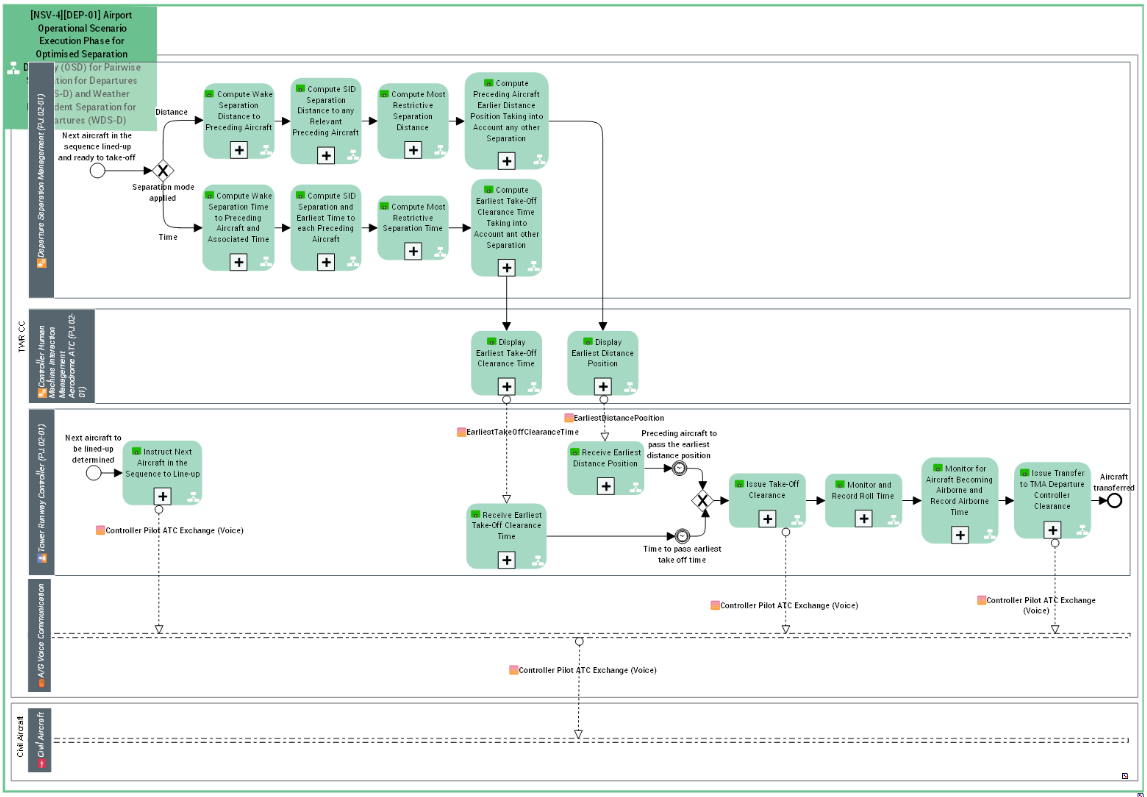
5.2.1.1.1 Safety functions

The ATCOs are responsible for issuing a safe clearance based on information given by the ORD Tool.

The OSD Tool shall provide robust safe Wake Separation information, and may provide support for other separation/spacing requirements such as the SID separation requirements. This would require the OSD Tool being configured to support the SID separation rules and so would require the development of SID separation rules that provide usable and acceptable support to the Tower Runway Controllers so that these are available to be configured into the OSD Tool.

5.2.2 The Departures Concepts Solutions SPR-level Model

5.2.2.1 Description of SPR-level Model for the Departures Concepts Solutions



5.2.2.1.1 Human Actors in the Model

Refer to Table 9 in the OSED Part 1

5.2.2.1.2 Equipment

Equipment / Tool	Current relevant function	Specific/additional function
Wind sensors (Surface and winds aloft)	Provides touch-down and stop-end wind direction and velocity to the Tower Departures ATCO	To include wind direction and wind speed at rotation point and provide information to the OSD tool to enable the calculation of WDS-D time intervals[23]
	Not in current use	Measurement of wind conditions aloft along the straight out initial common departure path to the first SID turn for WDS-D-Xw concept
	Not in current use	For application of wake distance separation there is also a need to and (as another separate new row) the wind conditions aloft services across all the departure runway-in-use SID routes out to the maximum distance separation from the initial airborne position of the departure aircraft that are required to be supported by the OSD Tool
Ground Surveillance	Provides information on the actual geographic position of aircraft on the airfield	No change from current operations
OSD Tool (Countdown Timer/NBAT)	Not in current use	Provides required time intervals for wake turbulence separation purposes
Flight plan information including aircraft type and wake category	Informs and enables ATCO to decide on sequencing of departures with regards to required SID and Wake spacing requirements	No change except that in WDS mode ATCOs must be cognisant of the relevance of upwind v downwind departures for wake purposes.

Table 13 - Machine-based elements in the Model – Specific to WDS-D

5.2.2.1.3 Aircraft Elements

No change expected

5.2.2.1.4 Ground Elements

[23] This is to enable to determine whether the WDS-D Xw concept minimum crosswind speed criteria are satisfied for the pre-determined WDS-D reduced time separation (of 90s).
There is the possibility that this may be further refined to have additional pre-defined crosswind speed criteria to enable the WDS-D reduced to 80s, 70s and 60s.
Note it is not just the runway surface crosswind speed criteria that need to be satisfies; there is also a need to satisfy the wind conditions aloft minimum crosswind speed criteria along the straight-out initial common departure path.

Additional elements required to provide more detailed Wind information, including surface wind and wind aloft.

5.2.2.1.5 External Entities

No Change expected

5.3 Deriving Safety Requirements at Design level for Normal conditions of operation

5.3.1 Safety Requirements at Design level (SRD) – Normal conditions of operation

Safety Objectives	Req Ref & Part 1 Ref	Safety Requirements
SO#D01: Ensure delivery of consistent and accurate wake turbulence separation delivery on the common initial departure path (for WDS-D in the context of PWS-D).	SR#D29 DEP0.0008	The Tower Runway Controller (ATC Departure Controller) shall be provided with a tool[24] that provides accurate and robust information on the required wake turbulence separation interval between each successive departing aircraft (when applying WDS-D in the context of PWS-D)
	SR#D30 DEP0.0025	ATCOs shall be provided with appropriate training in the operation of the OSD Tool (when applying WDS-D in the context of PWS-D)
	SR#D31 DEP0.0026	ATCOs shall be trained to recognise the importance of inputting consistent and accurate take-off time information (when applying WDS-D in the context of PWS-D)
	SR#D32 DEP0.0009	The Tower Runway Controller should be supported through automatically determining when aircraft become airborne.
	SR#D33 DEP0.1009	he Tower Runway Controller shall be supported through automatically determining when aircraft start their take-off roll.
	SR#D34 DEP0.0004	In the case of wake separation time application, the Tower Runway Controller shall be presented with a means to monitor the remaining time to satisfy the wake separation.
	SR#D35 DEP0.0002	The Tower Runway Controller shall be able to check the delivery conformance to the required wake separation distance on the HMI (when applying WDS-D in the context of PWS-D)

[24] Tool refers to the OSD Tool in Requirement SR#D01

	SR#D36 DEP0.0020	The Tower Runway Controller shall be able to visualise the planned route of each aircraft when applying distance-based separation (when applying WDS-D in the context of PWS-D)
	SR#D37 DEP0.1002	The Tower Runway Controller shall be able to check the delivery conformance to the required wake separation time on the HMI (when applying WDS-D in the context of PWS-D)
	SR#D38 DEP2.0078	WDS-D Xw concept wake separation rules shall be provided to the Enhanced OSD tool.
SO#D02: Ensure the application of WDS minima only when the predefined wind parameter(s) are met	SR#D39 DEP2.0085	Tower controllers shall only apply WDS-D reduced wake separation when the pre-defined weather parameters are met
	SR#D40 DEP2.0086	The WDS-D Tool shall inform Tower ATC when the defined weather parameters are met
	SR#D41 DEP2.0087	The WDS-D Tool shall support procedures for authorising the application of the WDS-D reduced wake separations[25]
	SR#D42 DEP2.0088	The WDS-D Tool shall support automatic de-authorisation of the application of the WDS-D reduced wake separation when the wind conditions change such that the pre-defined weather parameters are no longer met
	SR#D43 DEP2.0022	The Tower Runway Controller shall be informed of when WDS-D Xw concept reduced wake separation is being applied.
	SR#D44 DEP2.0037	The responsibility to authorise the application of WDS-D Xw concept reduced wake separations for a significant period of time or on a case by case basis shall be clearly defined as part of Tower ATC operational procedures.
	SR#D45 DEP2.0067	The WDS-D Xw concept wind threshold shall be based on locally considering specificities of local traffic aircraft performance in the local weather conditions over the local straight-out common initial departure paths.
	SR#D46 DEP2.0070	The Tower Runway Controller shall have the possibility to invoke the transition from applying WDS-D Xw concept wake separation reductions to applying standard wake separations.

[25] Local procedures for authorising go/no-go for WDS-D

	SR#D47 DEP2.0076	The WDS-D Xw concept shall apply weather dependent wake turbulence separation rules for departures, over the straight-out initial common departure path until aircraft diverge on to wake independent paths after the first SID turn, defined as minimum crosswind condition with an associated time separation minimum and associated SID pair constraints to be defined locally.
SO#D03: Ensure no reduction in SID route spacing or any other non-wake constraints between successive departures when applying WDS or S-PWS	SR#D48 DEP0.0027	If the OSD tool only displays the wake separation to be applied, the ATCOs shall be trained to recognise and consistently apply SID route spacing and any other larger non-wake constraints when applying WDS-D or S-PWS-D[26]
	SR#D49 DEP0.0018	SID information shall be provided to the Tower Runway Controller.
SO#D04: Ensure the application of WDS-D only when pre-defined SID/Route combinations are met	SR#D50 DEP2.0089	ATCOs shall only apply WDS-D Xw reduced wake separation when the follower aircraft departure SID is upwind of all applicable preceding aircraft departure SIDs (e.g. this may be also to the second preceding departure aircraft in the case of an A380 – Light – Light departure sequence).
	See SR#D49 DEP0.0018	SID information shall be provided to the Tower Runway Controller.
SO#D05: Ensure the basis of WDS-D are continued to be fulfilled along the initial common departure path	SR#D51 DEP2.0090	ATCOs shall monitor the conformance of the flight path of the departing aircraft along the initial common departure path (when WDS-D Xw reduced separation is being applied)
	SR#D52 DEP2.0041	When a WDS-D Xw concept reduced wake separation is applied, the Runway Controller shall monitor the aircraft during the initial climb phase.
	SR#D53 DEP2.0045	The Runway Controller shall have a delegated responsibility for issuing radar vectoring instructions to aircraft subject to WDS-D Xw concept reduced wake separation up to the agreed flight level for the handover to the TMA Departure Controller.

[26] This requirement is of particular importance when the tool is only providing wake separation information

	SR#D54 DEP2.0048	The Tower Runway Controller shall be alerted, through audio and / or visual signal, when an aircraft deviates from its planned SID trajectory when applying a WDS-D Xw concept reduced wake separation.
	See SR#D45 DEP2.0067	The WDS-D Xw concept wind threshold shall be based on locally considering specificities of local traffic aircraft performance in the local weather conditions over the local straight-out common initial departure paths.
SO#D06: Ensure that the runway is free from obstruction before issuing a take-off clearance	SR#D55 DEP0.3020	If used in mixed mode or partially segregated operations, the OSD tool shall not display the departure separation to be applied to the preceding departure aircraft when the immediately preceding aircraft in the sequence is an arrival aircraft, unless the Tower Runway Controller gives the departure aircraft a line-up clearance behind the arrival aircraft
SO#D07: Issue take-off instructions, such as to establish the applicable wake separation minima on the common initial departure path (for PWS-D or RECAT-EU with OSD alone)	SR#D56[27] DEP0.0028	ATCOs shall ensure that the runway entry point information on the electronic flight progress strip reflects the corresponding runway entry point issued to the departing aircraft
	SR#D57 DEP0.0008	The Tower Runway Controller (ATC Departure Controller) shall be provided with a tool[28] that provides accurate and robust information on the required wake turbulence separation interval between each successive departing aircraft (for PWS-D or RECAT-EU with OSD alone)
	SR#D58 DEP0.0025	ATCOs shall be provided with appropriate training in the operation of the OSD Tool (for PWS-D or RECAT-EU with OSD alone)
	SR#D59 DEP0.0026	ATCOs shall be trained to recognise the importance of inputting consistent and accurate take-off time information (for PWS-D or RECAT-EU with OSD alone)
	See SR#D32 DEP0.0009	The Tower Runway Controller should be supported through automatically determining when aircraft become airborne.
	See SR#D33 DEP0.1009	The Tower Runway Controller shall be supported through automatically determining when aircraft start their take-off roll.

[27] This is on the basis that this is the source of runway entry point information provided to the OSD Tool

[28] Tool refers to the OSD Tool in Requirement SR#D01

	See SR#D34 DEP0.0004	In the case of wake separation time application, the Tower Runway Controller shall be presented with a means to monitor the remaining time to satisfy the wake separation.
	SR#D60 DEP0.0002	The Tower Runway Controller shall be able to check the delivery conformance to the required wake separation distance on the HMI (for PWS-D or RECAT-EU with OSD alone)
	SR#D61 DEP0.0020	The Tower Runway Controller shall be able to visualise the planned route of each aircraft when applying distance-based separation ((for PWS-D or RECAT-EU with OSD alone)
	SR#D62 DEP0.1002	The Tower Runway Controller shall be able to check the delivery conformance to the required wake separation time on the HMI (for PWS-D or RECAT-EU with OSD alone)
SO#D08: Provide correct wake turbulence spacing delivery, from the moment the following aircraft rotates/begins its take-off roll as applicable, until it is transferred to the next sector	SR#D63 DEP0.0031	The Tower Runway Controller shall apply the applicable time or distance separation until separation responsibility is transferred to the TMA Departure Radar Controller[29]
	SR#D64 DEP0.3021	If the OSD tool takes into account aircraft performance, it shall integrate the adequate buffers to accommodate for aircraft performance variability on the runway and airborne
	SR#D65 DEP0.3022	If the local airport departure route structure permits catch-up situations, prior to giving a take-off clearance, the TWR controller shall be warned when an a/c is outside the climb profile envelope used by the OSD tool such that the controller takes the appropriate action to manage the possible catch-up between that pair of a/c
	SR#D66 DEP0.3023	If the OSD tool calculates SID, MRS and Wake separations, it shall take into account the separation not only between the first pair of aircraft but also between the leader and other aircraft in the sequence (e.g. 1st and 3rd, etc.)
SO#D09: Ensure the application of the greatest applicable departure separation constraint. i.e. wake, SID and MRS separation requirement(s).	SR#D67 DEP0.0029	ATCOs shall apply the applicable safe departure intervals fully taking into account all of the SID route separation, MRS and wake turbulence separation requirements.
	See SR#D49 DEP0.0018	SID information shall be provided to the Tower Runway Controller.
	See SR#D48 DEP0.0027	If the OSD tool only displays the wake separation to be applied, the ATCOs shall be trained to recognise and consistently apply SID route spacing and any other larger non-wake constraints when applying WDS-D or S-PWS-D

[29] Different from current (2019) operations in that timings will vary from those used today

SO#D10: Not to negatively affect the ability of Crew/Aircraft, to be able to follow ATC instructions	SR#D68 DEP0.0030	All Flight Crew shall be briefed/trained on the optimised wake separation standards and informed of the wake separation standards being applied at each departing airport
	SR#D69 DEP2.0012	Flight Crew shall be notified about the employment of WDS-D Xw concept reduced wake separations at an aerodrome
SO#D11: Not to increase the possibility of wake encounter on departure due to lateral deviation from the common initial departure path. (Only applicable to WDS-D Xw)	See SR#D51 DEP2.0090	ATCOs shall monitor the conformance of the flight path of the departing aircraft along the initial common departure path (when WDS-D Xw reduced separation is being applied)
	See SR#D06 DEP2.0084	Flight Crew shall be provided with adequate training to enable awareness for accurate track keeping after departure

Table 14 - Safety Objectives - Departures Concept- Success Approach

5.3.2 Analysis of the functional system behaviour – Normal conditions of operation

5.3.2.1 Scenarios for Normal Operations for the Departures Concepts Solutions

Normal operational scenarios follow the same theme for all airports. As already shown, in the models above, aircraft normally call on Ground for initial taxi instructions. This is followed by sequencing for departure by the Tower Air Controller who issues take-off instructions. A thread analysis is not required due to the straightforward nature of normal departure operations.

Use cases for the departures concept can be found in the OSED [22].

[...]

5.4 Deriving Safety Requirements at Design level for Abnormal conditions of operation

Abnormal condition scenarios are as described in Table 6: Abnormal events experienced during RTS5 and Table 7.

[...]

5.4.1 Safety Requirements at Design level (SRD) for Abnormal conditions of operation

ID	Description	Req Ref & Part 1 Ref	Requirement detail

SO#D12	Ensure wake turbulence separation between departing aircraft and an aircraft executing a go-around/missed approach	SR#D70 DEP0.0032	ATCOs shall be trained to issue safe instructions to aircraft on a go-around/missed approach that will minimise the possibility of a WTE (to be developed at local level)
		SR#D71 DEP2.0091	ATCOs shall be trained to issue safe instructions to departure aircraft that will minimise the possibility of the follower departure aircraft encountering the wake generated by the preceding departure aircraft when a WDs-D Xw reduced wake separation is being applied
SO#D13	Maintained lateral/vertical separation between departing aircraft and an aircraft executing a go-around/missed approach	N/A	No additional requirement – as per current local procedures
SO#D14[30]	In the event of an aborted take-off, ensure the runway is unobstructed before any subsequent departures are permitted	N/A	No additional requirement – as per current local procedures
SO#D15	Provision of wake vortex warning(s) when crosswind transport is not assured due to divergence of either the preceding, or follower, aircraft from the straight-out initial common departure path.	See SR#D51 DEP2.0090	ATCOs shall monitor the conformance of the flight path of the departing aircraft along the initial common departure path (when WDS-D Xw reduced separation is being applied)
		SR#D72 DEP2.0092	System support shall be provided to monitor and provide a warning when there is divergence of either the preceding, or follower, aircraft from the straight-out initial common departure path when a WDS-D Xw reduced separation is being applied.
SO#D16	Maintain the ability of ATCOs to tactically rearrange the departure sequence	SR#D73 DEP0.0003	The Tower Runway Controller shall be able to amend the departure sequence plan/order used by the OSD tool as required.

[30] See Table 17

		SR#D74 DEP3.0030	The OSD Tool shall be informed of late/tactical changes to the departure sequence
		SR#D75 DEP3.0031	The OSD Tool shall ensure the correctness of the wake turbulence separation information presented to the controller when there is a late/tactical change to the departure sequence[31]

[...]

5.5 Safety Requirements at Design level addressing Internal Functional System Failures

5.5.1 Design analysis addressing internal functional system failures

The objective of this analysis consists in determining how the system architecture (encompassing people, procedures, equipment) designed for the new WT separation modes and ATC tools can be made safe in presence of internal system failures. For that purpose, the method consists in apportioning the Safety Objectives of each hazard into Safety Requirements to elements of the system driven by the analysis of the hazard causes.

5.5.1.1 Causal Analysis for the Departures Concepts Solutions

For each system-generated hazard a top-down identification of internal system failures that could cause the hazard was conducted. The hazards relating to the departures concept are as illustrated in Section 4.4.1 of this document.

5.5.1.1.1 Hazard analysis & causal analysis

The following Bow-ties were produced as a result of the hazard analysis detailed in Table 9.

[31] There is a need to ensure the removal of the stale wake separation information for the old sequence order that no longer applies and the generation and presentation of the wake separation information for the new sequence order

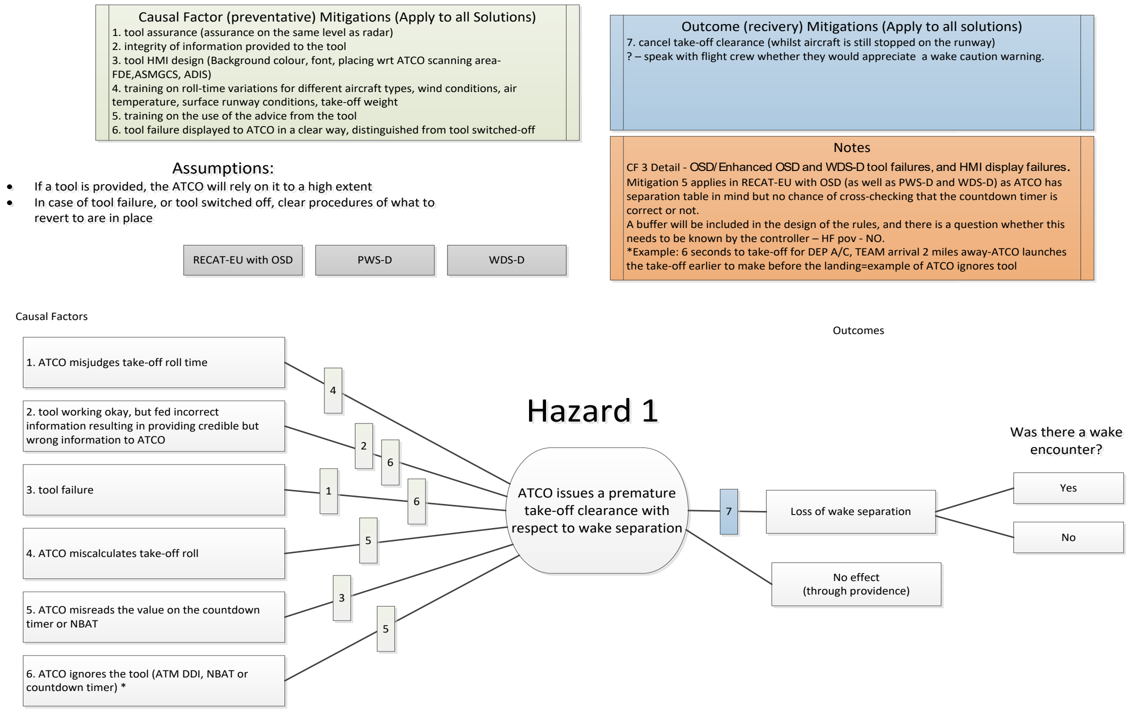


Figure 3: Bow-tie analysis Ho#D1

Hazard 2 was considered to be single sequence and, therefore, this can be referred to in Table 9.

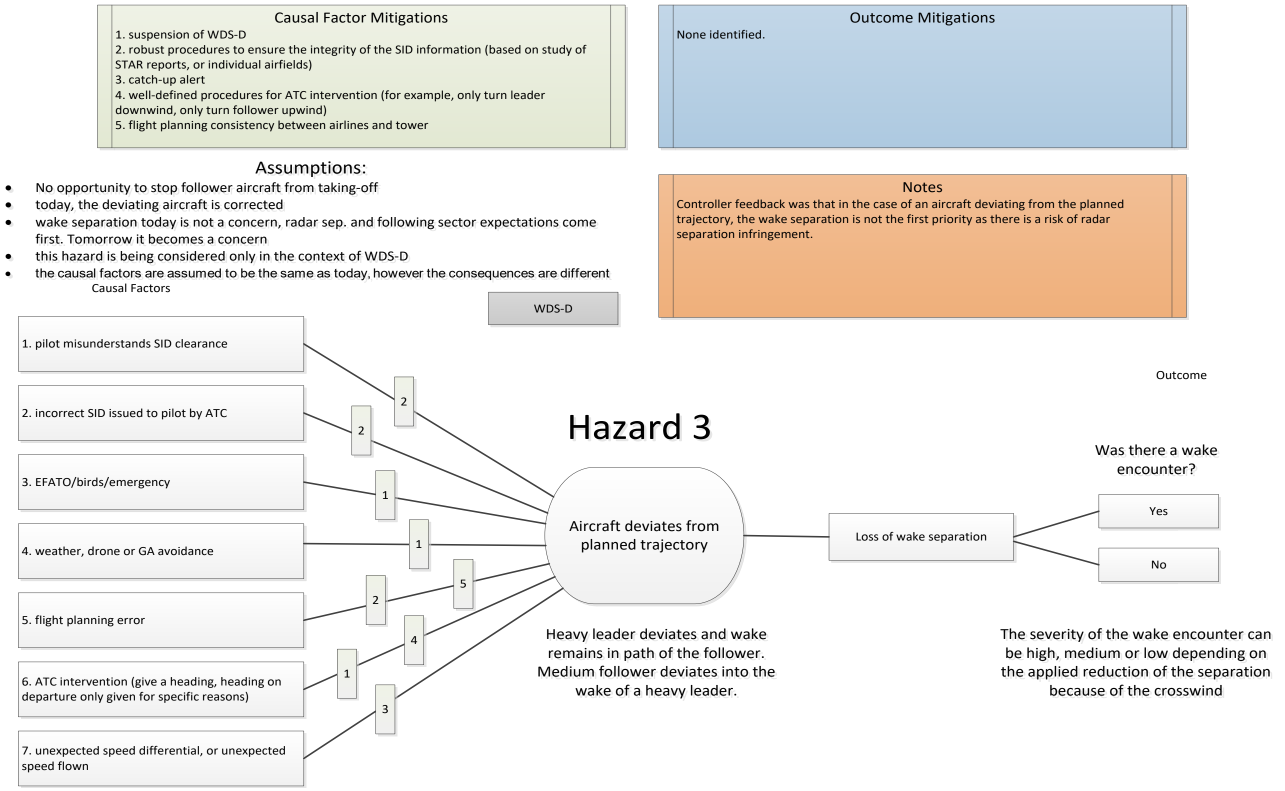


Figure 4: Bow-Tie analysis for Ho#D3

5.5.1.1.2 Safety requirements derived from the hazard analysis & causal analysis

Requirements (as a result of the hazard analysis and causal analysis):

Requirement	Details
SR#D01[32] DEP3.0017	OSD Tool assurance/integrity shall be set to a level, as appropriate for total ATCO dependence, to ensure, all applicable separations on departure (e.g. as required for the assurance of radar equipment)
SR#D02 DEP0.0021	Procedures shall be implemented such that greater departure spacing/separation requirements, e.g. SID spacing, MDIs, LVOs are not eroded by the introduction of more efficient wake turbulence separation standards.
SR#D03 DEP0.0022	ATCOs shall be alerted to the possibility of catch-up by following aircraft, that may lead to an erosion of wake separation requirements.[33]

[32] See recommended Objectives in 3.2.8.2

[33] This requirement will need to be agreed at local level in order to determine the definition of catch-up and corresponding erosion in wake turbulence separation

SR#D04 DEP0.0023	ATCOs shall, when possible, instruct aircraft to stop a premature take-off roll.[34] (in the context of an aircraft has started its take off roll and is able to safely stop subject to speed)
SR#D05 DEP0.0024	ATCOs shall be provided with sufficient training in the operation of new wake turbulence separation standards
SR#D06 DEP2.0084	Flight Crew shall be provided with adequate training to enable awareness for accurate track keeping after departure

Table 15: Safety Requirements (as a result of Dep HazId) Failure Case

5.6 Realism of the safe design

5.6.1.1 Achievability of Safety Requirements / Assumptions for the Departures Concepts Solutions

As a result of the RTS and face-to-face workshop discussions, it is believed that the requirements for the departures concept are achievable. However, no wake vortices modelling has been conducted during this phase of the solution.

5.6.1.2 "Testability" of Safety Requirements for the Departures Concepts Solutions

Most of the safety requirements are verifiable by direct means which could be by equipment and/or integrated system verification report, training certificate, published procedures, AIP information, etc. For some safety requirements, verification should rely on appropriate assurance process to be implemented.

The real-time simulations illustrated that the concept is potentially achievable. However, as mentioned above in 5.6.1.1, there will be a need to test the requirements at local level and to conduct further wake modelling in order to determine safe and accurate intervals between successive departures.

5.6.2 Validation & Verification of the Safe Design at SPR Level for the Departures Concepts Solutions

The safety assessment for the departures concept has been supported by a team of Safety, Human Performance, Technical and Operational Experts. All requirements have been agreed by these experts and are listed together in Appendix B specific to departures.

Appendix C lists assumptions, issues and recommendations specific to departures.

[34] This requirement needs further discussion. EGLL ATCOs suggest that this may not be a reasonable requirement as a take-off may only be cancelled if an aircraft is below 80kts IAS

6 SAfety Criteria achievability

This section outlines the results of the safety assurance activities in response to the validation objectives. These results encompass outcomes of the modelling, data collection and analysis dedicated to the risk of Wake Vortex Encounter (to meet **W-SAC#1**), results of the validation exercises or outcomes of the safety-dedicated workshops (making use of operational experts' judgment). Such results may confirm that the validation objectives are satisfied (thus proving that the correspondent SAC is met) or may allow to validate Safety Requirements or to derive new ones.

It is recalled that at design level, SOs have been mapped to SRDs for normal conditions (See section 5.3), for abnormal conditions (See section 5.4) and for failure aspects (See section 5.5.1). It was shown in these sections (using a combination of safety engineering techniques, safety assessment and results from validation exercises) that these Safety Requirements satisfy the Safety Objectives which in turn have been already shown to satisfy the Safety Criteria.

The information regarding the safety requirements that have been derived within the safety assessment is provided in the Appendix B (providing the consolidated list of the functionality & performance safety requirements).

The next table summarizes the results for the Safety KPA dedicated to each of the SESAR solution success criteria identified in the VALP for the relevant validation exercises. For detailed results please see the corresponding VALR [26].

Note with regard to all the success criteria about the quantification of the under-separations and go-arounds:

- Based on the data collected in the RTS and due to the limited number of scenarios and conditions that can be tested in an RTS, only a limited statistical analysis could be performed for these success criteria, as the data is insufficient to derive a significant statistical conclusion. However, these results do give an indication of trends. Thus, this quantitative data in combination with the qualitative safety data/results obtained from the RTS and other safety related activities (e.g. workshops, HAZIDs) enables us to conclude that safety is not negatively impacted.

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage	Validation results & Level of safety evidence
RTS04a – Conducted by EUROCONTROL Real Time Simulation to assess the ORD tool for arrivals plus Static Pairwise Separations for departures (S-PWS-D) with Optimised Separation Delivery (OSD) tool under mixed runway operations. The objective was to assess the impact of S-PWS-D with the OSD tool for departures on runway throughput capacity, safety and human performance in nominal conditions.	**OBJ-PJ2.02-V3-VALP-SA5** To assess the impact of static pairwise separations for Departures on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA5-001** To assess the impact of PWS-D with OSD in mixed mode runway operations on operational safety compared to current operations applying current wake vortex separation scheme for departures without OSD tool in single runway mixed mode operations under nominal conditions.	D-SAC#F2, D-SAC#F4, D-SAC#F5, D-SAC#R3	Safe working practice were observed during the simulation and the controllers reported that PWS with OSD tool did not increase the risk of human error in any way. Furthermore, two degraded mode scenarios were assessed: • **OSD tool corruption: Aircraft type/WTC was simulated.** The ATCO immediately detected that the DDI-T proposed time did not fit the wake constrained pair and applied reference ICAO separation with some margin. In post-exercise debriefing the controllers confirmed that it very probable that the ATCO is able to detect the anomalies with TB PWS 7 categories, however it could be questionable in case of further TB PWS with multiple categories (20x20 or more). • **Wrong aircraft type/WTC in FPL (not simulated but discussed):** In post exercise debriefing, the TWR controllers was asked if the controller would be able to detect the wrong aircraft type in the flight plan system. The controller pointed out that in good visibility condition, the discrepancy in aircraft type would be spotted by Ground ATCO. In low visibility conditions the wrong aircraft type could remained undetected. Considering that in low

The operational feasibility and usability of an upgraded OSD tool that takes into consideration the aircraft performance of departing aircraft was also assessed.				visibility the departure distances are not increased, this could potentially lead to a safety issue. Although the same issue exists today, with time based Pair-Wise separations the safety impact might increase due to reduced separations. Potential mitigation could be to include the aircraft type as a ground report at their first contact.
		CRT-PJ2.01-V3-VALP-SA5-002 To collect partial supporting evidence that PWS-D with OSD in mixed ode runway operations maintains the same probability of a wake vortex encounter by a following aircraft as in the current operations wake vortex separation scheme without OSD tool, through comparing against the reference scenario the percentage of under-separated aircraft (for various amplitude and location of separation infringement) and considering the increased potential for wake encounter when	D-SAC#F1, D-SAC#F2, D-SAC#F4	Post simulation data processing showed there to be issues with the aircraft performance for the departures applied in the simulation. Therefore the system performance metrics relating safety are not considered to be reliable or valid.

		under-separation is higher		
		CRT-PJ2.01-V3-VALP-SA5-003 To collect partial supporting evidence that PWS-D with OSD in single runway mixed mode operations maintains the same probability of departure-related Runway incursions* (in relation to RWY increased throughput in mixed mode operations enabled by the Concept) as in the current operations wake vortex separation scheme without OSD tool *In case of Departure-related Runway incursion either a Go-around or a Abort take-off need to be performed	D-SAC#R3	In RTS4a no impact could be found on runway conflicts in with PWS and the OSD tool No impact could be found on runway conflicts in with PWS and the OSD tool. Post simulation data processing showed there to be issues with the aircraft performance for the departures applied in the simulation. Therefore the system performance metrics relating to safety and human performance are not considered to be reliable or valid.
RTS04b - Conducted by EUROCONTROL The first aim is to assess the	**OBJ-PJ2.02-V3-VALP-SA5** To assess the impact of static pairwise separations for	**CRT-PJ2.01-V3-VALP-SA5-001** To assess the impact of PWS-D with OSD in mixed mode	D-SAC#F2, D-SAC#F4,	No unsafe controller working practices were seen to be introduced by the OSD tool alone.

operational feasibility of time based static Pair-Wise Separation (S-PWS-A - AO-0310) with Optimised Runway Delivery (ORD - AO-0328) for arriving aircraft in a closely spaced parallel runway environment; The second aim is to assess the operational feasibility of the Static PairWise Separations departure concept (S-PWS) - wake turbulence separations for departing aircraft based on static aircraft characteristics (AO-0323).under partially segregated runway departure operations. RTS4b will us conducted	Departures on operational safety compared to current wake vortex separation scheme	runway operations on operational safety compared to current operations applying current wake vortex separation scheme for departures without OSD tool in single runway mixed mode operations under nominal conditions.	D-SAC#F5, D-SAC#R3	However, due to the fact that the OSD tool was not taking into account the arrivals on RWY28Lwhich could increase the potential for human error with safety implications, PWS-D with OSD in partially segregated runway operations is considered as not acceptable. The OSD tool needs to be developed further for partially segregated and mixed mode runway operations, to indicate to TWR ATCO that the runway is in use due to an imminent arrival and no departures are allowed.
		CRT-PJ2.01-V3-VALP-SA5-002 To collect partial supporting evidence that PWS-D with OSD in mixed ode runway operations maintains the same probability of a wake vortex encounter by a following aircraft as in the current operations wake vortex separation scheme without OSD tool, through comparing against the reference scenario the percentage of under-separated aircraft (for various amplitude and location of separation infringement)	D-SAC#F1, D-SAC#F2, D-SAC#F4	Number of minor and major under-separated aircraft on the initial departure path is not higher under time based PWS-D with OSD compared to the Solution 1 scenario (TB ICAO no OSD).

using g the Paris CDG airport and approach environment.		and considering the increased potential for wake encounter when under-separation is higher		
		CRT-PJ2.01-V3-VALP-SA5-003 To collect partial supporting evidence that PWS-D with OSD in single runway mixed mode operations maintains the same probability of departure-related Runway incursions* (in relation to RWY increased throughput in mixed mode operations enabled by the Concept) as in the current operations wake vortex separation scheme without OSD tool *In case of Departure-related Runway incursion either a Go-around or a Abort take-off need to be performed	D-SAC#R3	There were no RWY incursions observed in the runs where PWS-D with the OSD tool was applied (i.e. Solution 2).

RTS5 – Conducted by NATS. Real Time Simulation validation of Static Pairwise Separations on Departure (S-PWS-D) and Weather Dependent Separations on Departure (WDS-D) and their integration with a departure Optimised Separation Delivery (OSD) tool on a single runway in segregated mode (London Heathrow). The objective was to assess the impact on departure capacity in both nominal, non-nominal and failure conditions. A Human Performance and	**OBJ-PJ2.02-V3-VALP-SA5** To assess the impact of static pairwise separations for Departures on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA5-001** To assess the impact of PWS-D with OSD in mixed mode runway operations on operational safety compared to current operations applying current wake vortex separation scheme for departures without OSD tool in single runway mixed mode operations under nominal conditions.	D-SAC#F2, D-SAC#F4, D-SAC#F5, D-SAC#R3	ATCOs provided positive feedback by either agreeing or strongly agreeing with the statement that the working procedures/practises under the PWS-D scenario are safe. No controller disagreed with the statement that the potential for human error is the same (low) as current operations in the PWS-D scenario. Some controllers highlighted the potential risk of over-relying on the tool as well as the risk of being mislead with the use of the word "NONE" on the NBAT even when a SID separation still applies. The PWS-D scenario runs show a minor change in the proportion of under-separated SID pairs compared to the matched reference scenario runs. However, there were still instances of SID under-separation during the PWS-D scenario.
		CRT-PJ2.01-V3-VALP-SA5-002 To collect partial supporting evidence that PWS-D with OSD in mixed ode runway operations maintains the same probability of a wake vortex encounter by a following aircraft as in the current operations wake vortex separation scheme without OSD tool, through comparing	D-SAC#F1, D-SAC#F2, D-SAC#F4	The PWS-D scenario runs show a reduction in the proportion of minor under-separated wake pairs compared to the matched reference scenario runs. The number of large under-separated wake pairs in the PWS-D scenario runs was comparable to the matched reference scenario runs. There were no occurrences of aborted take-offs or go-arounds in any of the matched runs. During 09R runs, no TEAM arrivals were observed to be constrained in the PWS-D scenario runs.

Safety analysis was also conducted as part of the activities.		against the reference scenario the percentage of under-separated aircraft (for various amplitude and location of separation infringement) and considering the increased potential for wake encounter when under-separation is higher		There were instances of under-separated wake pairs indicating the take-off clearance was issued such that the follower ac became airborne prior to the NBAT. The PWS-D scenario runs show negligible change in the proportion of under-separated SID pairs compared to the matched reference scenario runs. However, there were still instances of under-separated SID pairs indicating the take-off clearance was issued such that the follower ac became airborne prior to the SID separation time.
		CRT-PJ2.01-V3-VALP-SA5-003 To collect partial supporting evidence that PWS-D with OSD in single runway mixed mode operations maintains the same probability of departure-related Runway incursions* (in relation to RWY increased throughput in mixed mode operations enabled by the Concept) as in the current operations wake vortex separation scheme without OSD tool *In case of Departure-related Runway incursion	D-SAC#R3	Same as above

		either a Go-around or a Abort take-off need to be performed		
RTS06 – Conducted by CRIDA/ENAIRE to assess OI Steps AO-0310 and AO-0328 for arrivals, AO-0323 and AO-0329 for departures, which address weather dependent separations for arrivals (WDS-A) and Wake Turbulence Separations (for Departures) based on Static Aircraft Characteristics (S-PWS-D)	**OBJ-PJ2.02-V3-VALP-SA5** To assess the impact of static pairwise separations for Departures on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA5-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under static pairwise separations for departures compared to the current wake vortex separation scheme	D-SAC#F2, D-SAC#F4, D-SAC#F5, D-SAC#R3	The level of perceived safety remained practically at the same level between reference and solution scenarios. Moreover the result of the analysis of the infringements go along the same line.
WISA Departures flight simulation campaign: Conducted by EUROCONTROL. This validation activity focuses on assessing pilots'	**OBJ-PJ2.02-V3-VALP-SA5** To assess the impact of static pairwise separations for Departures on operational safety compared to current	**CRT-PJ.02-01-V3-VALP-SA5-001** There is evidence from the simulated wake encounter scenarios to show that the underlying principle of the safety case that justifies the	SAC#D7	The results of the A320 simulation exercises show that when considering the mean values, the increase of severity between the ICAO4 and PWS for all departure scenarios are overall lower than or equivalent to that for the corresponding ICAO4 and PWS arrival scenarios for the non-motion scenarios. For the motion scenarios, the increase in severity ratings between ICAO4 and S-PWS

perception on the severity of various wake turbulence encounters corresponding to different S-PWS separation minima on both initial departure and final approach paths. The main aim of this activity was to ultimately contribute with further evidence to the PWS safety case for Departures.	wake vortex separation scheme	reduction in departure separations through "equivalence" to arrival separation minima is valid, i.e. that the increase in "objective" severity for departures is perceived similarly or lower than the increase for arrivals under S-PWS and is acceptable from the cockpit perspective, i.e.: Subjective feedback from pilots regarding the severity of the wake impact encountered under S-PWS-D scheme compared to ICAO 4 category scheme, for departures versus arrivals, show that the increase in wake encounter severity between ICAO 4 and S-PWS is in the same order of magnitude for departures as for arrivals.		scenarios are not fully conclusive and as when considering the mean values, the increase of severity between the ICAO4 and PWS for the 1V departure scenarios is lower than the increase for the arrival scenarios but slightly higher for the 2V departure scenarios. . However, in all cases the departures wake encounter severity ratings are generally lower. Therefore, in summary the results from the non-motion A320 exercises meet the safety success criteria. The results of the motion based A320 exercises are inconclusive. For the AT-76 non-motion exercise runs when looking at the means the increase in wake ratings between ICAO and PWS for the 1V scenarios is greater than for the arrivals, whilst in the 2V scenario, the increase in wake ratings between ICAO and PWS is smaller compared to the arrivals. However, if considering the Q3 evolution, the increase is larger for arrival cases compared to departure cases (either considering 1 or 2 vortices). As an encounter of a vortex pair rather that a single vortex is always perceived as more severe it should be considered as worst case for wake separation design (also since this encounter geometry is realistic for wake encounter for departure). Therefore, for the worse case scenario of a vortex pair encouter on departures

				the non-motion AT-76 exercises meet the safety success criteria. For the AT76 motion scenarios the increase in wake impact severity ratings from ICAO to PWS is greater for both departure scenarios (1V and 2V) compared to arrivals. This is due to the low severity rating given for the ICAO arrivals. Hence, the severity of the ICAO arrival and departure encounters is rated almost equally by the pilots. In addition, for the departure scenarios, the encounter of a vortex pair rather that a single vortex is perceived as less severe under S-PWS which again is questionable. As a result, the results from the AT76 motion exercises are inconclusive. Furthermore, the results from all the motion based scenarios (A320 and AT76) should be interpreted with caution as it should be noted that the Level D training simulators were not capable of accurately reproducing the quick and changing roll accelerations during the wake vortex encounter, which is thought to have impacted the reliability of the findings from the motion based scenarios.

7 Acronyms and Terminology

Term	Definition
150k	150,000
ACAS	Airborne Collision Avoidance System
ATC/M/S	Air Traffic Control / Management / System
ATCO	Air Traffic Controller
A-CDM	Airport Collaborative Decision Making
A-SMGCS	Advanced Surface Movement Guidance and Control System
AIM	Accident Incident model
A/C	Aircraft
ANS	Air Navigation Services
APP	Approach
ATIS	Automatic Terminal Information Service
AISP	Aeronautical Information Service Provider
AIP	Aeronautical Information Publication
ARR	Arrival
CSPR	Closely Spaced Parallel Runway Operations
CREDOS	Crosswind Reduced Separations for Departure Operations
CWP	Controller Working Position
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. / German Aerospace Centre (formerly the German Aerospace Research Institute)
DBS	Distanced Based Separation
DEP	Departure
D-ATIS	Data link / Digital - Automatic Terminal Information Service
EARTH	The project acronym for SESAR 2020 PJ.02 incr**EA**sed **R**unway and Airport **TH**roughput
EUROCONTROL	European Organisation for the Safety of Air Navigation

ENAIRE	Spanish Air Navigation Service Provider
EASA	European Aviation Safety Agency
EC	European Commission
ELS	Elementary Mode-S Surveillance
EGGL	Heathrow Airport
EHS	Enhanced Mode-S Surveillance
FT	Feet
FMS	Flight Management System
FCF	Facilitate Capture of the Final approach
FLD	Facilitate Landing & Deceleration
FAP	Final Approach
FTD	Final Target Distance indicator
FCRW	Flight Crew
FP	Framework Programme
FA	Final Approach
GBAS	Ground Based Augmentation System
GS	Ground Speed
GWCS	Glideslope Wind Conditions Service
HP	Human Performance
HP#X	Pre-existing Hazard
HMI	Human Machine Interface
Hz#X	Hazard
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ITD	Initial Target Distance indicator
IAS	Indicated Air Speed
IM	Impact Modifier

IA	Interception of the Final Approach
INTEROP	Interoperability
IRS	Interface Requirement Specification
KTS	Knots
LiDAR	Light Detection and Ranging
MRS	Monitoring and Ranging Stations
MLS	Microwave Landing System
MODE A/C	Secondary radar reply message giving aircraft identity
MAC	Mid Air Collision
MET	Meteorology
MSAW	Minimum Safe Altitude Warning
NATS	UK Air Navigation Service Provider
NM	Nautical Miles
NOTAM	Notice to Airmen
OSED	Operational Service and Environment Definition
ORD/OSD	Optimal Runway Delivery / Optimal Separation Delivery
OFA	Operational Focus Area
PJ.02.01	Project 02.01
PANS	Procedures for Air Navigation Services
RWY	Runway
RECAT-EU	European separation standard for aircraft wake turbulence
RSVA	Reduced Separation in the Vicinity of an Aerodrome
ROT	Runway Occupancy Time
RPA	Runway Protected Area
RIMCAS	Runway Incursion Monitoring and Conflict Alert System
RC	Runway Collision
SAR	Safety Assessment Report

SPR	Safety and Performance Requirements
SESAR	Single European Sky ATM Research
S-PWS-A/D	Static Pair-Wise Separation Arrivals/Departures
SRM	Safety Reference Material
SAC	SAfety Criteria
SO	Safety Objective
SR	Safety Requirement
SAP	Safety Assessment Plan
SAF	Safety
SMI	Separation Minima Infringement
SUP	Supervisor
SURV	Surveillance
SAD	Separate Arrival Departure
SP	SeParate aircraft with other aircraft
SPT	SeParate aircraft with Terrain
SID	Standard Instrument Departure
SC	Severity Criteria
STCA	Short Term Conflict Alert
TS	Technical Specifications
TBS	Time-based Separation
TMA	Terminal Manoeuvring Area
TWR	Tower
TAS	True Air Speed
TDI	Target Distance Indicator
TAWS	Terrain Avoidance Warning System
UK6	UK Wake Turbulence Separation Category
V1-V3	Validation Maturity Level 1 to Level 3

VCS	Voice Communication System
VAPP	Final Approach Speed
WDS-A/D	Weather Dependant Separation for Arrivals / Departures
WT/E	Wake Turbulence / Encounter
WIDAO	Wake Independent Departure & Arrival Operations
WTC	Wake Turbulence Category

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Appendix A Consolidated List of Safety Objectives

Appendix A covers the following Concepts Solutions:

- Consolidated Lists of Safety Objectives for Arrivals Concepts Solution in Section A.1
- Consolidated Lists of Safety Objectives for Departures Concepts Solutions in Section A.2

A.1 Departures Concepts Solutions

A.1.1 Safety Objectives (Functionality and Performance) for the Departures Concepts Solutions

ID	Description
SO#D01	Ensure ATC application of consistent and accurate S-PWS, or WDS wake turbulence separation rules on the common initial departure path
SO#D02	Ensure the application of WDS minima only when the predefined wind parameter(s) are met.
SO#D03	Ensure no reduction in SID spacing between successive departures. When applying WDS or S-PWS
SO#D04	Ensure the maintenance of required track after departure, taking into account uncertainty in wind prediction or measurement. (Only applicable to WDS-D Xw)
SO#D05	Ensure the application of standard ATC practices to ensure that the runway is free from obstruction before issuing a take-off clearance
SO#D06	Enable sequencing at the holding point, and the issuance of aircraft to line-up & take-off instruction, such as to initially establish and the applicable wake separation minima on the common initial departure path.
SO#D07	(At a local level) Calculate and display the greatest applicable departure separation constraint. i.e. wake, SID or MRS separation requirement(s).
SO#D08	Not to reduce the capability of ATC to apply SID and/or MRS constraints
SO#D09	Not to negatively affect the ability of Crew/Aircraft, to be able to follow ATC instructions
SO#D10	Provide correct wake turbulence spacing delivery, from the time the follower rotates until it is transferred to the next sector
SO#D11	Not to increase the possibility of wake encounter on departure due to lateral deviation from the common initial departure path. (Only applicable to WDS-D Xw)
SO#D12	Ensure wake vortices separation between departing aircraft and an aircraft executing a go-around/missed approach
SO#D13	Maintain lateral/vertical separation between departing aircraft and an aircraft executing a go-around/missed approach
SO#D14	In the event of an aborted take-off, ensure the runway is unobstructed before any subsequent departures are permitted
SO#D15	Apply the required wake separation interval between succeeding departures
SO#D16	Provide (when possible) wake turbulence warning(s), when crosswind transport is not assured due to divergence of either the preceding, or follower, aircraft from their planned SID, or from the straight-out initial common departure path
SO#D17	Ensure that the frequency of occurrence of the inadequate separation management (Wake separation) of a pair of aircraft on departure shall be no more than: 1×10^{-9}

SO#D18	Ensure that the frequency of occurrence of the inadequate separation management (MRS) of a pair of aircraft on departure shall be no more than: $3x10^{-5}$
SO#D19	Ensure that the frequency of a departure clearance being issued whilst the runway remains occupied shall be no more than 1×10^{-9}

A.1.2 Consolidated List of Safety Objectives (Integrity) for the Departures Concepts Solutions

SO#D20	Provide accurate wake separation intervals between successive departing aircraft
SO#D21	Provide reliable information regarding departure intervals

Appendix B Consolidated Lists of Safety Requirements

Appendix B includes the consolidated Lists of Requirements for Departures Concepts Solutions.

Safety Requirements (Functionality and Performance) in Normal operational conditions - See Section 5.3

Safety Requirements in Abnormal Operational Conditions - See Section 5.4

Safety Requirements (functionality and performance) for mitigating the system generated hazards - See §5.5.1.1.2

Note: No Safety Requirements (Integrity&reliability) have been derived for the Departures Concept Solution (that will be performed in the industrialization phase when the architecture of the actual OSD tool will be defined).

Appendix C Assumptions, Safety Issues & Limitations

Appendix C covers the following Concepts Solutions:

- Assumptions, Safety Issues & Limitations for Arrivals Concepts Solution in Section C.1
- Assumptions, Safety Issues & Limitations for Departures Concepts Solutions in Section C.2

C.1 Departures Concepts Solutions

C.1.1 Assumptions Log for the Departures Concepts Solutions

None identified during V3

C.1.2 Safety Issues Log for the Departures Concepts Solutions

The following Safety Issues were necessarily raised during the safety assessment of the Departures Concepts Solutions:

Issue ref	Safety Issue	Status
ISSUE D01 [0]	The wind used for the WDS-D concept needs to be locally defined with the corresponding wake separation reductions taking into account the following	Open
Issue D02	Any erosion of time/distance-based wake separation needs to be further investigated in order to determine the severity of any possible wake encounter as a result of such erosion.	Open

Table 16: Safety Issues Log for the PJ.02.01 Departures Concepts Solutions

C.1.3 Recommendations Log for the Departures Concepts Solutions

None identified during V3 other than that the CREDOS safety requirements and objectives should be revisited during future phases of the departures concept

C.1.4 Operational Limitations Log for the Departures Concepts Solutions

None raised during V3 other than those associated with the hazard analyses

Appendix D Relevant Accident Incident Models (AIM)

The simplified version of the Accident Incident Models as being relevant for the PJ.02 Solution 1 are presented in the next figures.

Appendix D covers the following Concepts Solutions:

- Relevant Accident Incident Models (AIM) for Arrivals Concepts Solution in Section D.1
- Relevant Accident Incident Models (AIM) for Arrivals and Departures Concepts Solutions in Section D.2
- Relevant Accident Incident Models (AIM) for Departures Concepts Solutions in Section D.3

D.1 Relevant Accident Incident Models (AIM) for the Arrivals and Departures Concepts Solutions

TBD – simplified version not yet available.

D.2 Relevant Accident Incident Models (AIM) for the Departures Concepts Solutions

WAKE-induced risk on Initial Departure- Simplified model
[WAKE-ID v0.3 unchanged]
(Unchanged compared to v0.2 agreed with NATS on 20/07/2017, only the comments were removed)

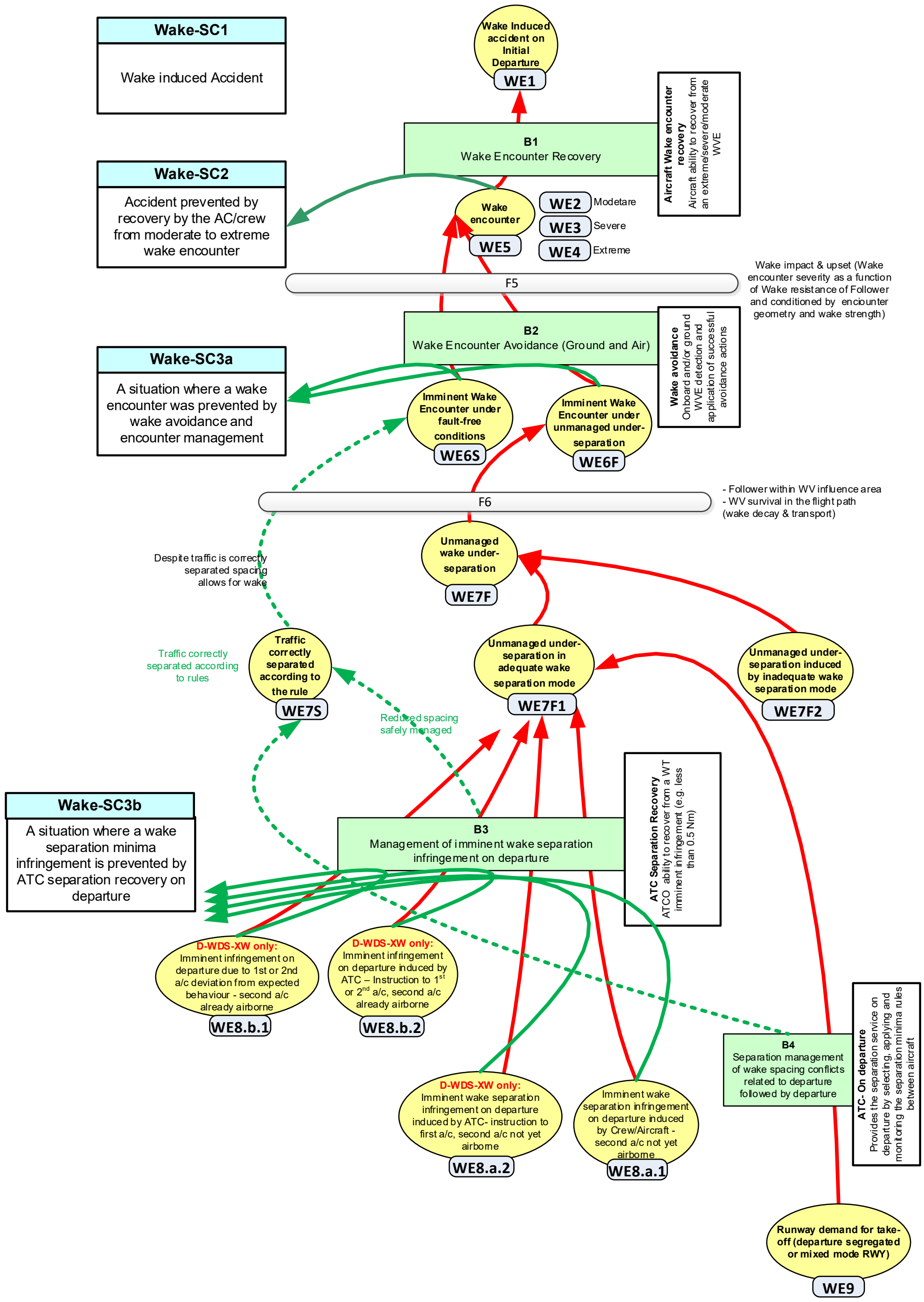


Figure 5: Simplified AIM model for WT Induced Accident on Initial Departure for the PJ.02.01 Departure Concepts Solutions

Appendix E TBS for Arrivals Hazid Table (P6.8.1 TBS Phase 2)

This HAZID table is the outcome of the SAF/HP workshop held in December 2014 within TBS Phase 2 of P6.8.1. The scope is Time-based PWS (renamed TBS within this safety assessment report) and DBS with indicators (corresponding to DBS separation mode in this report).

Note that the Safety Objectives (SO) and Operational Hazards IDs correspond to the ones used within the Time-based PWS Safety Assessment Report [8]. To allow re-use of the information in the current safety assessment, traceability to the new SOs and Operational Hazards is provided in the table following the TBS HAZID table.

Whenever applicable, the link with the Safety Requirements of the current safety assessment is provided in the column addressing the Mitigations detecting and protecting against propagation of the failure mode effects.

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
Execution Phase-Interception						
Execution Phase-Interception in Time-based PWS mode						

SO#25: In Time-based PWS operations, ATC shall sequence and instruct aircraft to intercept the final approach path such as to establish applicable separation minima rule based on Time-based PWS indicators. SO#30: The Time-based PWS indicators shall be calculated to correctly and accurately represent the Time-based PWS-equivalent distance separation minima (surveillance and wake turbulence) for all traffic pairs, in all normal range of weather and operating conditions	Time-based PWS indication for one aircraft not (timely) available on turn-on	- Separation delivery tool failure - Arrival traffic not in planned Arrivals list - Planned Arrivals list input failure into the separation supporting tool - Missing or unrecognised WV category	An aircraft on turn-on will not have Time-based PWS indications associated for spacing reference with the preceding lead aircraft. When the Controller will look after the Time-based PWS indications to support the turn-on decision for creating spacing, the spacing would look excessively large from preceding aircraft, and the Controller will probably detect the missing indication. This may create extra workload to manage this situation but is expected to be managed within safety margins. However, if not detected (e.g. case of two aircraft which are both at similar spacing from the preceding aircraft), that might lead to associating the Time-based PWS indication to a wrong aircraft (worst case: with a lighter WT category). This is addressed below as a separate failure mode: controller turns the “wrong” aircraft onto the displayed Time-based PWS indication.	➢ Following detection of the indication loss: • APP ATCO is able to handle traffic with missing Time-based PWS indication (SR1.123 and SR1.323) and applies DBS without indication for that aircraft (SR1.323) • In case of a lack of Time-based PWS indications displayed behind a lead aircraft before turn-on, a safety mitigation function (e.g. a visual warning) should be provided to facilitate a timely detection by the Controller that no indication is associated to this aircraft (SR 665, SR 666). In that case, the Controller shall revert to and apply DBS rule (SR 525, SR 668) • If an aircraft is not in the arrival list and if the situation can be handled by the controller, the Approach Controller shall provide appropriate additional spacing between the aircraft in the list to establish a correct spacing ahead and behind the aircraft not in the list so that the separation indicator can still be used as the separation/spacing reference for the follower aircraft in the arrival list. Alternatively, the Approach controller could request the inhibiting of the display of the separation indicator behind the lead aircraft in the arrival list and for both the aircraft not in the arrival list and the follower aircraft in the arrival list to be merged on to final approach. In such case controller shall observe DBS constraints without the associated support of a separation indicator (SR1.309) • In case inputs are not available to compute Time-based PWS indications, a safety mitigation function should display by default the DBS rule applicable behind the lead aircraft, with an information to the Controller that the DBS rule is displayed (This requirement has not been retained in the final version safety assessment)	**TB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier needs to be enhanced at least with APP ATCO procedure as follows: • APP ATCO is able to handle traffic with missing Time-based PWS indications (SR 525) • APP ATCO easily revert back to DBS operations without indicators (SR1.123)		
	Time-based indications for several aircraft not (timely) available on turn-on	- Separation delivery tool failure - AMAN failure - Special scenario requiring to interrupt use of Time-based PWS indication for several aircraft	If the missing indication is affecting several aircraft, it is easily detected by APP ATCO.	➢ APP ATCO easily detects problem and applies DBS (without indication) for all aircraft (SR1.123 and SR 525) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier needs to be enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR1.123)	**TB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
	Incorrect Time-based indications provided behind the lead aircraft (too small, too large)	- Separation delivery tool failure - Wind profile used for the indication computation different from the actual wind on the glide -Aircraft speed for the interception different from the speed used for the indication computation -WT category error in flight plan -A/C Type error in Flight plan - Planned Arrivals list input corruption - Arrival sequence not updated - Arrival aircraft in wrong position in the arrival sequence list	If the Time-based PWS indications are too small but error is detected during turn-on, the Controller shall revert to DBS rule without the support of the separation indication. Multiple corrupted indications might affect the ability to detect errors during the turn on because it may distract APP ATCO's attention to other corrupted indications.	➢ APP ATCO shall check that the provided Time-based PWS indications look consistent with displayed aircraft types and WT category (SR1.322) and then APP ATCO detects problem and applies DBS without indication for that aircraft (SR 525) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier needs to be enhanced with APP ATCO procedure in order to easily revert back to DBS operations without indicators (SR1.123)	**TB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
			If the Time-based PWS indications are too small but not unreasonably small and error is not timely detected during turn on or quickly after the interception when the follower aircraft	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced at least with APP ATCO procedure as follows:	**TB_Hz#01a:** Inadequate separation management of a spacing conflict following ATC instruction	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
		- late change in the interception arrival sequence	is spaced closely to the indication, then the separation support tool is inducing a Separation Minima Infringement, which can possibly lead to Severe WVE	• APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	during the Final Approach interception	
			Multiple corrupted indications might affect the ability to detect errors during the turn on because it may distract ATCO's attention to other corrupted indications.	➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#01b:** Fail to recover separation following inadequate management of a spacing conflict during the Final Approach interception (following ATC instruction)	**Wake-SC2**
			If the Time-based PWS indications are too large, and detected during turn-on, the Controller shall revert to DBS rule without the support of the separation indication	➢ APP ATCO shall check that the provided Time-based PWS indications look consistent with displayed aircraft types and WT category (SR1.322) and then APP ATCO detects problem and applies DBS without indication for that aircraft (SR 525) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier needs to be enhanced with ATCO procedure in order to check consistency between separation provided by the indication and aircraft types/WT category (SR1.322)	**TB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
			If the Time-based PWS indications are too large, not detected and followed, there is no negative effect on safety (only a capacity impact)	Not safety related		
			If there is a sudden jump in Time-based PWS indications leading to suddenly represent a smaller indication, the Controller might detect this error because the spacing between the time-	➢ APP ATCO detects problem and applies DBS (without indication) for the aircraft (SR 525) ➢ Separation establishment and management t during the final approach interception on Final	**TB_Hz#01:** Spacing conflict following ATC instruction during the	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
			based PWS indications and the follower aircraft would suddenly abnormally increase	App (B5). This barrier needs to be enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR1.123)	final approach interception	
	Time-based PWS indications provided behind an incorrect aircraft	- Aircraft ID swap - late change in the interception arrival sequence -AMAN failure	If the provided Time-based PWS indication is incorrect because it is associated to an incorrect lead aircraft, and if the provided indications are actually too small but such that the error is not timely detected during turn-on when the follower aircraft is spaced closely to the separation indicator, then the separation delivery tool can induce a Separation Minima Infringement, and possibly a WVE	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced at least with APP ATCO procedure as follows: • APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) • The aircraft arrival sequence (AMAN) shall be updated by the controller when a late change in the sequence is accepted (SR 065) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**TB_Hz#01a:** Inadequate separation management of a spacing conflict following ATC instruction during the Final Approach interception	**Wake-SC3b**
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#01b:** Fail to recover separation following inadequate management of a spacing conflict during the Final Approach interception (following ATC instruction)	**Wake-SC2**
	Controller turns the “wrong” aircraft onto the displayed Time-based PWS indication	- ATCO aircraft sequence (the one he/she decided considering the traffic) not in accordance with AMAN sequence - ATCO late decision to turn on another aircraft compared to AMAN order	If the controller turns an aircraft for the approach interception with a time-based PWS indication not computed for this aircraft and if the provided indications are actually too small considering the traffic pair, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by APP ATCO procedure and supporting functions as follows: • APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) • A visual alert shall be provided to APP ATCO when the aircraft instructed to turn-on is	**TB_Hz#01a:** Inadequate separation management of a spacing conflict following ATC instruction during the Final Approach interception	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
		- Inadequate currency with the use of Time-based PWS indication - Inadequate competency with the use of Time-based PWS separation indications - ATCO confusion between separation and spacing		not the one as planned in the arrival sequence (SR1.310) • The aircraft arrival sequence (AMAN) shall be updated by the controller when a late change in the sequence is accepted (SR 065) • Aircraft/Separation indicator pairing function shall be available for the controller (SR1.093) • APP ATCO shall be trained on the use and limitation of Time-based PWS indications (SR 059) • APP ATCO shall be able to visually distinguish between separation indications for WT and MRS separation (SR 127) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm		
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#01b:** Fail to recover separation following inadequate management of a spacing conflict during the Final Approach interception (following ATC instruction)	**Wake-SC2**
SO#45: Flight Crew/Aircraft shall follow ATC instructions in order to correctly intercept the final approach path	Flight crew does not respect ATC clearance/instruction for the approach interception in Time-based PWS mode	- Inadequate ATCO transmission of instruction - Misunderstanding between ATCO and pilot - Pilot delay/latency for respecting the clearance -Too early turn/ Too short turn -LOC overshoot for a leader	If the pilot does not respect the heading and speed instructions, the Approach controller might have difficulty to respect the indication target in Time-based PWS mode during the turn on. Two possible outcomes either the aircraft will be in front of the indicator when established on the localizer or behind it. From a safety point of view only the first case is relevant (aircraft in	➢ During the interception: • When aircraft is established on the approach, APP ATCO asks to reduce the speed if she/he thinks that it will solve the problem. If not she/he requests to initiate a missed approach (A030) • Flight Crew should be trained on the importance to respect ATC	**TB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
		-Intercept Glide from above	front of the indicator when established).	instruction/clearances during interception in Time-based PWS mode (SR 147) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier is considered sufficient because indicator is not corrupted or lost and based on this indications APP ATCO will decide if speed reduction will be efficient to solve the problem or if go-around instruction is necessary (A030).		
		-Pilot error/ misunderstanding -Pilot pick up instruction from another aircraft (heading, speed, altitude)	Despite the APP controller has not instructed the aircraft, she/he detects though radar monitoring that the interception of the final approach is not conducted in accordance with her/his intention for this aircraft.	➢ During the interception: • APP ATCO asks to correct the aircraft trajectory (heading, speed or altitude) during the interception if she/he thinks that it will solve the problem. If not she/he requests to initiate a missed approach or to follow an alternative procedure (A020) ➢ Separation management of Aircraft/Flight-crew-induced spacing conflicts (without ATC instructions) during final approach (B5). This barrier is considered sufficient because ATCO will decide if correction of the aircraft trajectory is sufficient to solve the problem or if go-around instruction is necessary (A020).	**TB_Hz#02:** Spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given	**Wake-SC4**
			The APP controller does not detect that the interception of the final approach is not conducted in accordance with her/his intention for this aircraft, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by at least APP ATCO procedure as follows: • APP ATCO shall monitor all traffic merging to the final approach to detect any deviation from instructed profile (A025) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**TB_Hz#02a:** Inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#02b:** Failure to recover separation following inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given	**Wake-SC2**
Execution Phase-Interception in DBS mode with indications						
SO#35: In advanced DBS operations, ATC shall sequence and instruct aircraft to intercept the final approach path such as to establish applicable separation minima on approach based on DBS indicators SO#40: The DBS indicators shall represent the applicable separation minima (surveillance and wake turbulence) on approach	Distance-based indications for one aircraft not (timely) available on turn-on	- Arrival traffic not in planned Arrivals list - Planned Arrivals list input failure into the separation supporting tool - Missing or unrecognised WV category	An aircraft on turn-on will not have DBS indications associated for spacing reference with the preceding lead aircraft. When the Controller will look after the DBS indications to support the turn-on decision for creating spacing, the spacing would look excessively large from preceding aircraft, and the Controller will probably detect the missing indication. This may create extra workload to manage this situation but is expected to be managed within safety margins. However, if not detected (e.g. case of two aircraft which are both at similar spacing from the preceding aircraft), that might lead to associating the DBS indication to a wrong aircraft (worst case: with a lighter WT category) This is addressed below as a separate failure mode: controller turns the “wrong” aircraft onto the displayed DBS indication.	➢ APP ATCO detects problem and applies DBS without indication for that aircraft (SR 525). If the aircraft is not in the arrival list and if the situation can be handled by the controller, the Approach Controller shall provide appropriate additional spacing between the aircraft in the list to establish a correct spacing ahead and behind the aircraft not in the list so that the separation indicator can still be used as the separation/spacing reference for the follower aircraft in the arrival list. Alternatively, the Approach controller could request the inhibiting of the display of the separation indicator behind the lead aircraft in the arrival list and for both the aircraft not in the arrival list and the follower aircraft in the arrival list to be merged on to final approach. In such case controller shall observe DBS constraints without the associated support of a separation indicator (SR1.309) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier is considered sufficient because currently DBS is applied without indication however ATCO must continue to be trained on DBS minima for a safe reversion (SR1.123).	**DB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
	Distance-based indications for several aircraft not (timely) available on turn-on	- Separation delivery tool failure - AMAN failure	If the missing indication is affecting several aircraft, it is easily detected by ATCO.	➢ APP ATCO easily detects problem and applies DBS (without indication) for all aircraft (SR1.123) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier is considered sufficient because currently DBS is applied without indication however ATCO must continue to be trained on DBS minima for a safe reversion (SR 525).		
	Incorrect DBS indications provided behind the lead aircraft (too small, too large)	- WT category error in flight plan -A/C Type error in Flight plan - Planned Arrivals list input corruption - Arrival sequence not updated - Arrival aircraft in wrong position in the arrival sequence list - late change in the interception arrival sequence	If the DBS indications are too small but error is detected during turn-on, the Controller shall revert to DBS rule without the support of the separation indication. Multiple corrupted indications might affect the ability to detect errors during the turn on because it may distract ATCO's attention to other corrupted indications.	➢ APP ATCO shall check that the provided DBS indications look consistent with displayed aircraft types and WT category (SR1.322) and then APP ATCO detects problem and applies DBS without indication for that aircraft (SR 525) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier is considered sufficient because currently DBS is applied without indication however ATCO must continue to be trained on DBS minima for a safe reversion (SR1.123).	**DB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
			If the DBS indications are too small but not unreasonably small and error is not timely detected during turn on or quickly after the interception when the follower aircraft is spaced closely to the indication, then the separation support tool is inducing a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during approach (B3a). This barrier needs to be enhanced at least with APP ATCO procedure as follows: • APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**DB_Hz#01a:** Inadequate separation management of a spacing conflict following ATC instruction during the Final Approach interception	**Wake-SC3b**
			Multiple corrupted indications might affect the ability to detect errors during the turn on because it may	➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and	**DB_Hz#01b:** Fail to recover separation following inadequate	**Wake-SC2**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
			distract ATCO's attention to other corrupted indications.	recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	management of a spacing conflict during the Final Approach interception (following ATC instruction)	
			If the DBS indications are too large, and detected during turn-on, the Controller shall revert to DBS rule without the support of the separation indication	➢ APP ATCO shall check that the provided DBS indications look consistent with displayed aircraft types and WT category (SR1.322) and then APP ATCO detects problem and applies DBS without indication for that aircraft (SR 525) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier needs to be enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR 525)	**DB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
			If the DBS indications are too large, not detected and followed, there is no negative effect on safety (only a capacity impact)	Not safety related		
			If there is a sudden jump in DBS indications leading to suddenly represent a smaller indication, the Controller might detect this error because the spacing between the DBS indications and the follower aircraft would suddenly abnormally increase	➢ APP ATCO detects problem and applies DBS (without indication) for the aircraft (SR 525) ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier needs to be enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR 525)	**DB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
	DBS indications provided behind an incorrect aircraft	- Aircraft ID swap	If the provided DBS indication is incorrect because it is associated to an incorrect lead aircraft, and if the provided indications are actually too small but such that the error is not	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced at least with APP ATCO procedure as follows:	**DB_Hz#01a:** Inadequate separation management of a spacing conflict following ATC instruction	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
		- late change in the interception arrival sequence - AMAN failure	timely detected during turn-on when the follower aircraft is spaced closely to the separation indicator, then the separation delivery tool can induce a Separation Minima Infringement, and possibly a WVE (if major, it is likely that the error is such that it will be timely detected).	• APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) • The aircraft arrival sequence (AMAN) shall be updated by the controller when a late change in the sequence is accepted (SR 065) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	during the Final Approach interception	
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) This could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**DB_Hz#01b:** Fail to recover separation following inadequate management of a spacing conflict during the Final Approach interception (following ATC instruction)	**Wake-SC2**
	Controller turns the "wrong" aircraft onto the DBS indication	- The ATCO aircraft sequence (the one he/she decided considering the traffic) not in accordance with AMAN sequence - ATCO late decision to turn on another aircraft compared to AMAN order - Inadequate currency with the use of DBS indication - Inadequate competency with the use of DBS separation indications - ATCO confusion between spacing and separation	If the controller turns an aircraft for the approach interception with a DBS indication not computed for this aircraft and if the provided indications are actually too small considering the traffic pair, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by APP ATCO procedure and supporting functions as follows: • APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) • A visual alert shall be provided to APP ATCO when the aircraft instructed to turn-on is not the one as planned in the arrival sequence (SR1.310) • The aircraft arrival sequence (AMAN) shall be updated by the controller when a late change in the sequence is accepted (SR 065) • Aircraft/Separation indicator pairing function shall be available for the controller (SR1.093)	**DB_Hz#01a:** Inadequate separation management of a spacing conflict following ATC instruction during the Final Approach interception	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				• APP ATCO shall be trained on the use and limitation of DBS indications (SR 059) • APP ATCO shall be able to visually distinguish between separation indications for WT and MRS separation (SR 127) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm		
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**DB_Hz#01b:** Fail to recover separation following inadequate management of a spacing conflict during the Final Approach interception (following ATC instruction)	**Wake-SC2**
SO#45: Flight Crew/Aircraft shall follow ATC instructions in order to correctly intercept the final approach path	Flight crew does not respect ATC clearance/instruction for the approach interception in DBS mode	- Inadequate ATCO transmission of instruction - Misunderstanding between ATCO and pilot - Pilot delay/latency for respecting the clearance -Too early turn/ Too short turn -LOC overshoot for a leader -Intercept Glide from above	The controller might have difficulty to respect the indication target in DBS mode during the turn on. Two possible outcomes either the aircraft will be in front of the indicator when established on the localizer or behind it. From a safety point of view only the first case is relevant (aircraft in front of the indicator when established).	➢ When aircraft is established on the approach, Controller asks to reduce the speed if she/he thinks that it will solve the problem. If not she/he requests to initiate a missed approach (A030). ➢ Separation establishment and management t during the final approach interception on Final App (B5). This barrier is considered sufficient because indicator is not corrupted or lost and based on this indications ATCO will decide if speed reduction will be efficient to solve the problem or if go-around instruction is necessary (A030).	**DB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
		-Pilot error/ misunderstanding -Pilot pick up instruction from another aircraft (heading, speed, altitude)	Despite the APP controller has not instructed the aircraft, she/he detects though radar monitoring that the interception of the final approach is not conducted in accordance with her/his intention for this aircraft.	➢ During the interception, APP or TWR ATCO asks to correct the aircraft trajectory (heading, speed or altitude) if she/he thinks that it will solve the problem. If not she/he requests to	**DB_Hz#02:** Spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				initiate a missed approach or to follow an alternative procedure (A020) ➢ Separation management of spacing conflicts due to A/C deviation during final approach interception (B6). This barrier is considered sufficient because ATCO will decide if trajectory correction is sufficient to solve the problem or if go-around instruction is necessary (A020).		
			The APP controller does not detect that the interception of the final approach is not conducted in accordance with her/his intention for this aircraft, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by at least APP ATCO procedure as follows: • APP ATCO shall monitor all traffic merging to the final approach to detect any deviation from instructed profile (A025) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**DB_Hz#02a:** Inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given	**Wake-SC3b**
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**DB_Hz#02b:** Failure to recover separation following inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given	**Wake-SC2**
Execution Phase-Final Approach						
Execution Phase-Final Approach in Time-based PWS mode with indications						
SO#50 In Time-based PWS operations, ATC shall provide correct	Time-based PWS indications for one or several aircraft are lost	- Separation delivery tool failure	Before indications disappear for one or several aircraft during the approach, it	➢ APP and/or TWR ATCO easily detect the problem:	**TB_Hz#03:** Spacing conflict following ATC	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
spacing minima delivery from final approach path acquisition until landing based on Time-based PWS indicators. SO#30: The Time-based PWS indicators shall be calculated to correctly and accurately represent the Time-based PWS-equivalent distance separation minima (surveillance and wake turbulence) for all traffic pairs, in all normal range of weather and operating conditions	when aircraft are established on final approach	-Special scenario requiring to interrupt use of Time-based PWS indication for several aircraft	is assumed that spacing was correct. If not, the operational effect is addressed in the above section "Execution phase –Interception". Therefore, on a short time basis there is no safety issue but separation delivery by the approach controller or the tower controller will become more difficult to handle if indications are not recovered rapidly. Sudden loss of Time-based PWS indications shall lead to a loss of separation on the basis of the applicable DBS rule (the Time-based PWS rule is not applicable without separation indicator provision). if a sudden loss of Time-based PWS indications occurs in case of a traffic pair with unfavourable speed difference (slow lead and fast follower, within normal approach speed range of types within given WT category), a catch-up could occur and possibly develop into a minor loss of separation, and possible WVE	• APP and/or TWR ATCO re-establish DBS rule spacing as soon as feasible, considering the ground speeds and evolution of both lead and follower aircraft, and at least ensure that possible ongoing catch-up situations are closely monitored and resolved (e.g. ask lead aircraft to fly faster or follower aircraft to fly slower if possible within their speed range). If catch-up situation is not possible to be resolved, Controllers shall require follower aircraft to go-around (SR 525) • APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a "Caution Wake Turbulence" information • APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts on final approach (B3). This barrier needs to be enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR 525)	instruction during the final approach	
	Incorrect Time-based indications during the final approach	- Separation delivery tool failure - Wind profile used for the indication computation different from the actual wind on the glide -Aircraft speed profile different from the speed profile used for the indication computation Note: Following causes are not considered because they will impact the approach interception first and therefore cannot appear only during the final approach: WT category error in flight plan; A/C Type error in Flight	If the time-based PWS indications were correct during the interception (if not please see the operational effect described in the above section "Execution phase –Interception") and if there is a sudden indications jump leading to suddenly represent a smaller indication, the Controller might detect this error because the spacing between the time-based PWS indications and the follower aircraft would suddenly abnormally increase	➢ APP and/or TWR ATCO detect the problem: • APP and/or TWR ATCO apply DBS (without indication) for the aircraft (SR 525, SR1.123) • APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a "Caution Wake Turbulence" information • APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts on final approach (B3). This barrier needs to be	**TB_Hz#03:** Spacing conflict following ATC instruction during the final approach	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
		plan; Planned Arrivals list input corruption; Arrival sequence not updated; - Arrival aircraft in wrong position in the arrival sequence list and late change in the interception arrival sequence		enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR 525)		
			If the provided indications are actually too small but such that the error is not timely detected when the follower aircraft is spaced closely to the separation indicator, then the separation delivery tool can induce a Separation Minima Infringement, and possibly a WVE. Multiple corrupted indications might affect the ability to detect errors because it may distract ATCO's attention to other corrupted indications.	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by at least APP and TWR ATCO procedure as follows: • APP and TWR ATCO shall check that the provided Time-based PWS indications look consistent with displayed aircraft types and WT category (SR1.322) • APP and TWR ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**TB_Hz#03a:** Inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC3b**
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#03b:** Fail to recover separation following inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC2**
	Controller does not respect the correctly displayed Time-based PWS indication	- Inadequate currency with the use of Time-based PWS indication - Inadequate competency with the use of Time-based PWS separation indications	If the Approach or Tower controller does not respect the time-based PWS indication and if the aircraft is ahead of the indications, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during approach (B3a). This barrier needs to be enhanced by APP and TWR ATCO procedure and supporting functions as follows: • APP and TWR ATCO are informed about the infringement by a Catch-up warning alerting function (SR 530)	**TB_Hz#03a:** Inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
		- ATCO confusion between separation and spacing	If the Approach or Tower controller feels pressure to position aircraft on the separation indications (considering the indication as a target and not as a reference) with inadequate consideration of speed reduction and variation on final, this might result in an under-spacing / separation infringement	• APP and TWR ATCO shall be trained on the use and limitation of Time-based PWS indications (SR 059) • APP and TWR ATCO shall be able to visually distinguish between separation indications for WT and MRS separation (SR 127) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm		
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#03b:** Fail to recover separation following inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC2**
SO#60: Flight Crew/Aircraft shall follow ATC instructions during the final approach in order to ensure adequate separation with preceding and following aircraft	Flight crew does not respect the instructed speed restrictions on the final approach in Time-based PWS mode	- Inadequate ATCO transmission of instruction - Misunderstanding between ATCO and pilot - Pilot delay/latency for respecting the clearance	The approach or Tower Controller detects that the aircraft is not respecting the speed restriction she/he gives which lead to an inaccurate displayed Time-based PWS indication. Controllers apply a separation buffer to the displayed indications to recover the safety margins. The worst case is when the aircraft flies a speed higher than the speed profile used for the Time-based PWS which lead to an indication too small.	➢ During the approach, • APP and/or TWR ATCO applies a separation buffer to the displayed indication to prevent separation infringement when she/he detects that the speed restriction is not applied (SR 335, SR 336). • APP and/or TWR ATCO ask to reduce the aircraft speed if she/he thinks that it will solve the problem. If not she/he requests flight crew to initiate a missed approach (A030) • APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a “Caution Wake Turbulence” information	**TB_Hz#03:** Spacing conflict following ATC instruction during the final approach	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				• APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) • Flight Crew should be trained on the importance to respect ATC instruction/clearances during approach in Time-based PWS mode. All speed restrictions shall be flown as accurately as possible (SR 148) ➢ Separation management of spacing conflicts on final approach (B3). This barrier is considered sufficient because ATCO will decide if speed reduction is efficient to solve the problem or if go-around instruction is necessary.		
			The Approach or the Tower controller does not detect that the aircraft is not respecting the ATC speed instructions, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by APP or TWR ATCO procedure and supporting functions as follows: • APP and TWR ATCO are informed about the infringement by a Catch-up warning alerting function (SR 530) • APP and TWR ATCO shall be trained on the use and limitation of Time-based PWS indications (SR 059) • APP and TWR ATCO shall be able to visually distinguish between separation indications for WT and MRS separation (SR 127) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**TB_Hz#03a:** Inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC3b**
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE.	**TB_Hz#03b:** Fail to recover separation following inadequate separation management of a spacing conflict	**Wake-SC2**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	following ATC instruction during the final approach	
SO#65: Flight Crew/Aircraft shall fly the final approach path whilst respecting the aircraft speed profile (unless instructed otherwise by ATC or airborne needs to initiate go around)	Aircraft does not respect the speed profile during the approach in Time-based PWS mode (without any specific ATC instructions)	-Airspeed computer problem -A/C flap configuration -Wrong VAPP computation -Pilot error/misunderstanding -A/C deviates from the glide	Despite the controller has not instructed the aircraft, she/he detects that the aircraft is not respecting the speed profile on the glideslope which lead to an inaccurate displayed Time-based PWS indication. When detected, controllers apply a separation buffer to the displayed indications to recover the safety margins. The worst case is when the aircraft flies a speed higher than the speed profile used for the Time-based PWS computation which leads to an indication too small.	➢ During the approach: • APP and/or TWR ATCO applies a separation buffer to the displayed indication to prevent separation infringement when she/he detects that the speed restriction is not flown (SR 335, SR 336). • APP and/or TWR ATCO asks to reduce the aircraft speed if she/he thinks that it will solve the problem. If not she/he requests to initiate a missed approach. (A030) • Flight Crew should advise APP or TWR ATCO if circumstances necessitate a change of speed for aircraft performance reasons (SR 180) • APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a “Caution Wake Turbulence” information • APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts due to A/C deviation on final approach (B4). This barrier is considered sufficient because ATCO will decide if speed reduction is efficient to solve the problem or if go-around instruction is necessary.	**TB_Hz#04:** Spacing conflict due to aircraft deviation from final approach profile without ATC instruction given	**Wake-SC4**
			The APP or TWR controller does not detect that the aircraft is not respecting the speed profile on the glideslope which lead to an inaccurate display of the Time-based PWS	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by at least APP ATCO and Pilot procedures as follows:	**TB_Hz#04a:** Inadequate separation management of a spacing conflict due to aircraft deviation from final approach	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
			indication. The worst case is when the aircraft flies a speed (before and/or after the deceleration point) higher than the speed profile used for the Time-based PWS computation which leads to an indication too small. In such case when the follower aircraft is spaced closely to the separation indicator, then it might induce a Separation Minima Infringement, and possibly a WVE.	• APP and TWR ATCO shall be trained on the use and limitation of Time-based PWS indications (SR 059) • Flight Crew should advise APP or TWR ATCO if circumstances necessitate a change of speed for aircraft performance reasons (SR 180) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	profile without ATC instruction given	
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**TB_Hz#04b:** Fail to recover separation following inadequate separation management of a spacing conflict due to aircraft deviation from final approach profile without ATC instruction given	**Wake-SC2**
Execution Phase-Final Approach in DBS mode with indications						
SO#55: In advanced DBS operations, ATC shall provide correct spacing delivery from final approach path acquisition until landing based on DBS indicators.	DBS indications for one or several aircraft are lost when aircraft are established on final approach	- Separation delivery tool failure -Special scenario requiring to interrupt use of DBS indication for several aircraft	Sudden loss of DBS indications do not lead to an immediate loss of separation and the current separation between aircraft shall be maintained without the indications.	➢ APP and/or TWR ATCO detects the loss of indications and applies DBS (without indication) for the aircraft (SR1.123) ➢ Separation management of spacing conflicts on final approach (B3). This barrier is considered sufficient because currently DBS is applied without indication however ATCO must continue to be trained on DBS minima for a safe reversion (SR1.123).	**DB_Hz#03:** Spacing conflict following ATC instruction during the final approach	**Wake-SC4**
SO#40: The DBS indicators shall represent the applicable separation minima (surveillance and wake	Incorrect DBS indications during the final approach	- Separation delivery tool failure Note: Following causes are not considered because they will impact the approach interception first and therefore cannot appear only during	If the DBS indications were correct during the interception (if not please see the operational effect described in the above section "Execution phase – Interception") and if there is a sudden indications jump leading to suddenly	➢ APP and/or TWR ATCO detect the problem: • APP and/or TWR ATCO applies DBS (without indication) for the aircraft (SR1.123)	**DB_Hz#03:** Spacing conflict following ATC instruction during the final approach	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
turbulence) on approach		the final approach: WT category error in flight plan; A/C Type error in Flight plan; Planned Arrivals list input corruption; Arrival sequence not updated; Arrival aircraft in wrong position in the arrival sequence list and late change in the interception arrival sequence	represent a smaller indication, the Controller might detect this error because the spacing between the DBS indications and the follower aircraft would suddenly abnormally increase	• APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a “Caution Wake Turbulence” information • APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts on final approach (B3). This barrier is considered sufficient because currently DBS is applied without indication however ATCO must continue to be trained on DBS minima for a safe reversion (SR1.123).		
			If the provided indications are actually too small but such that the error is not timely detected when the follower aircraft is spaced closely to the separation indicator, then the separation delivery tool can induce a Separation Minima Infringement, and possibly a WVE. Multiple corrupted indications might affect the ability to detect errors because it may distract ATCO's attention to other corrupted indications.	➢ Management of imminent infringement during approach (B3a). This barrier needs to be enhanced by at least APP ATCO procedure as follows: • APP and TWR ATCO shall check that the provided DBS indications look consistent with displayed aircraft types and WT category (SR1.322) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	**DB_Hz#03a:** Inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC3b**
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**DB_Hz#03b:** Fail to recover separation following inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC2**
			If the Approach or Tower controller does not respect the DBS indication	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by APP ATCO	**DB_Hz#03a:** Inadequate separation management of a spacing conflict	**Wake-SC3b**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
	Controller does not respect the correctly displayed DBS indication	- Inadequate currency with the use of DBS indication - Inadequate competency with the use of DBS indications - ATCO confusion between separation and spacing	and if the aircraft is ahead of the indications, this could lead to a Separation Minima Infringement, which can possibly lead to Severe WVE	procedure and supporting functions as follows: • APP and/ or TWR ATCO are informed about the infringement by a Catch-up warning alerting function (SR 530) • APP and TWR ATCO shall be trained on the use and limitation of DBS indications (SR 059) • APP and TWR ATCO shall be able to visually distinguish between separation indications for WT and MRS separation (SR 127) ➢ This ATC recovery Barrier (B3a) prevents significant separation minima infringement e.g. greater than0.5Nm	following ATC instruction during the final approach	
				➢ If the separation minima infringement e.g. greater than 0.5Nm is not detected and recovered by ATC (failure of Barrier B3a) this could lead to severe WVE. ➢ In such case flight crew react and recover from the wake encounter (Barrier B1). This barrier is considered sufficient to recover the situation.	**DB_Hz#03b:** Fail to recover separation following inadequate separation management of a spacing conflict following ATC instruction during the final approach	**Wake-SC2**
SO#60: Flight Crew/Aircraft shall follow ATC instructions during the final approach in order to ensure adequate separation with preceding and following aircraft	Flight crew does not respect the instructed speed restrictions on the final approach in DBS mode	- Inadequate ATCO transmission of instruction - Misunderstanding between ATCO and pilot - Pilot delay/latency for respecting the clearance	The controller might have difficulty to respect the indication target in DBS mode during the approach. Two possible outcomes either the aircraft will be in front of the indicator or behind it. From a safety point of view only the first case is relevant (aircraft in front of the indicator).	➢ During the approach: • APP and/or TWR ATCO ask to reduce the aircraft speed if she/he thinks that it will solve the problem. If not she/he requests flight crew to initiate a missed approach (A030) • APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a “Caution Wake Turbulence” information	**DB_Hz#03:** Spacing conflict following ATC instruction during the final approach	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				• APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts on final approach (B3). This barrier is considered sufficient because ATCO will decide if speed reduction is efficient to solve the problem or if go-around instruction is necessary (A030).		
SO#65: Flight Crew/Aircraft shall fly the final approach path whilst respecting the aircraft speed profile (unless instructed otherwise by ATC or airborne needs to initiate go around)	Aircraft does not respect the speed profile during the approach in DBS mode (without any specific ATC instructions)	-Airspeed computer problem -A/C flap configuration -Wrong VAPP computation -Pilot error/misunderstanding -A/C deviates from the glide	Despite the controller has not instructed the aircraft, she/he detects that the aircraft is not respecting the speed profile on the glideslope. The controller might have difficulty to respect the indication target in DBS mode during the approach.	➢ During the approach: • APP and/or TWR ATCO ask to reduce the aircraft speed if she/he thinks that it will solve the problem. If not she/he requests flight crew to initiate a missed approach. (A030) • APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a "Caution Wake Turbulence" information • APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts due to A/C deviation on final approach (B4). This barrier is considered sufficient because ATCO will decide if speed reduction is efficient to solve the problem or if go-around instruction is necessary (A030).	**DB_Hz#04:** Spacing conflict due to aircraft deviation from final approach profile without ATC instruction given	**Wake-SC4**
			The controller does not detect that the aircraft is not respecting the speed profile on the glideslope, but the controller will have difficulty to respect the indication target in DBS mode during the approach.	➢ During the approach: • APP and/or TWR ATCO ask to reduce the aircraft speed if she/he thinks that it will solve the problem. If not she/he requests flight crew to initiate a missed approach. (A030)	**DB_Hz#04:** Spacing conflict due to aircraft deviation from final approach profile without ATC instruction given	**Wake-SC4**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				• APP and/or TWR ATCO could inform the flight crew of the relevant aircraft about the possibility to encounter a Wake Turbulence by a "Caution Wake Turbulence" information • APP and/or TWR ATCO could delegate the separation to the flight crew if visual separation conditions apply (A035) ➢ Separation management of spacing conflicts due to A/C deviation on final approach (B5). This barrier is considered sufficient because ATCO will decide if speed reduction is efficient to solve the problem or if go-around instruction is necessary (A030).		
Time-based PWS Activation Phase/ Transition Phase						
SO#05: ATC shall apply Time-based PWS minima rule only when the total wind between 0 and 300 ft above the runway threshold and along the glide path is equal or greater than the Time-based PWS wind threshold AND indicates headwind conditions SO#13: The Time-based PWS wind threshold shall be determined to ensure safe Time-based PWS operations and could be defined in a generic manner based	Time-based PWS is applied whereas relevant applicability criteria (weather conditions) are not present It should be noted that in such case DBS should have been applied	-Error in the surface wind measurement - MET data error - APP or TWR Supervisor error in the time-based PWS activation procedure - APP or TWR Supervisor error when considering daily wind prediction - Misunderstanding between Supervisors and ATCO for time-based PWS activation - APP or TWR controller activates the Time-based PWS mode on their controller working position	<u>For aircraft on the interception:</u> Time-based PWS is applied instead of DBS. If the incorrect activation is not timely detected during turn on or quickly after the interception when the follower aircraft is spaced closely to the indication, then the separation support tool is inducing a Separation Minima Infringement, which can possibly lead to Severe WVE.	➢ To prevent the separation minima infringement: • APP SUP shall verify at regular interval that time-based PWS applicability criteria are present or an automatic feature shall detect and inform APP SUP and ATCO when Time-based PWS applicability criteria are no more present (SR 030). • APP ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) • APP ATCO shall not have the possibility to activate the Time-based PWS on his/her controller working position (SR1.312). ➢ In case of WVE, Flight crew react against the wake encounter. The Wake Encounter recovery (B1). This barrier is considered sufficient to recover the situation	**Hz#05:** Separation minima infringement induced by ATC through inadequate selection & management of the separation mode (i.e. (Time-based PWS), DBS with indication, DBS without indication)	**Wake-SC2**

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
on generic conditions (traffic mix, weather…) or locally considering specificities of local traffic and weather conditions			For aircraft on the final approach: Time-based PWS is applied instead of DBS. If the incorrect activation is not timely detected when the follower aircraft is spaced closely to the indication, then the separation support tool is inducing a Separation Minima Infringement, which can possibly lead to Severe WVE	➢ To prevent the separation minima infringement: • APP and TWR SUP shall verify at regular interval that time-based PWS applicability criteria are present or an automatic feature shall detect and inform APP/TWR SUP and ATCO when Time-based PWS applicability criteria are no more present (SR 030). • APP and TWR ATCO shall maintain an awareness of the separation minima to be applied between the WT categories (SR1.123) • TWR ATCO shall monitor regularly surface wind conditions especially when wind is unstable or is decreasing to verify if time-based PWS could still be applied. If not she/he must inform the TWR Supervisor as soon as possible (replaced with SR 030 in the final safety assessment) ➢ In case of WVE, Flight crew react against the wake encounter. The Wake Encounter recovery (B1). This barrier is considered sufficient to recover the situation	**Hz#05:** Separation minima infringement induced by ATC through inadequate selection & management of the separation mode (i.e. (Time-based PWS), DBS with indication, DBS without indication)	**Wake-SC2**
SO#15: ATC shall apply DBS minima rule when the total wind between 0 and 300 ft above the runway threshold and along the glide path: * is less than the Time-based PWS wind threshold OR * indicates tailwind conditions	DBS is applied whereas relevant applicability criteria (weather conditions) authorises Time-based PWS	-Error in the surface wind measurement -MET data error - APP or TWR Supervisor error in the DBS activation -Misunderstanding between Supervisors and ATCO for DBS activation	For aircraft on the interception: DBS is applied instead of Time-based PWS. This leads to a loss in capacity, but this does not lead to any safety issue.	No safety impact		
			For aircraft on the final approach: DBS is applied instead of Time-based PWS. This leads to a loss in capacity, but this does not lead to any safety issue.	No safety impact		

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
SO#20: Considering the current wind conditions and the Time-based PWS wind threshold, ATC shall transition from Time-based PWS to DBS mode or from DBS to Time-based PWS mode	Time-based PWS is applied whereas DBS must be applied	Same as results provided above for SO#05 and SO#13				
	DBS is applied whereas Time-based PWS should be applied	Same as results provided above for SO#15				

As in the current safety assessment some Safety Objectives (SO) and Operational Hazards (OH) have either evolved (due to the scope extension for incorporating S-PWS and WDS concepts) or just have been renumbered, the following traceability table is provided, in order to allow the reader to easily interpret a OHA/HAZID information coming from the previous safety assessment report (SAR, limited to TBS and DBS modes- see above table) within the context of the current safety assessment report.

Safety Objective or Operational Hazard as per TB PWS SAR		**Traceability to the corresponding Safety Objective or Operational Hazard as per current SAR**	
ID	**Description**	**ID**	**Description**
SO#05	ATC shall apply Time-based PWS minima rule only when the total wind at the aerodrome runway surface for the given runway-end is equal or greater than the Time-based PWS wind threshold.	SO#12	In case of conditional application of Time-based (TB) modes, ATC shall apply the correspondent WT separation minima only when the predefined activation criteria for the considered TB-mode are met i.e. specified wind parameter(s) measured against pre-determined wind threshold(s).
SO#13	The Time-based PWS wind threshold shall be determined to ensure safe Time-based PWS operations and could be defined in a generic manner based on generic conditions (e.g. traffic mix, weather) or locally considering specificities of local traffic and weather conditions.	SO#13	In case of conditional application of TB-modes the wind threshold(s) for the activation criteria specific to each TB-mode shall be determined to mitigate the risk of wake vortex encounter due to the uncertainties on the wind profile prediction data and on the aircraft adherence to the generic airspeed profile.
SO#15	ATC shall apply DBS minima rule when the total wind at the aerodrome runway surface for the given runway-end is less than the Time-based PWS wind threshold.	SO#15	In case of conditional application of Time-based (TB) modes, ATC shall apply the corresponding distance-based WT separation mode (DBS or respectively DB-PWS-A) when the activation criteria for TBS, TB-WDS modes or respectively TB-PWS-A, A-TB-WD-PWS modes are not met anymore.
SO#20	Considering the current and forecast wind conditions and the Time-based PWS wind threshold, ATC shall transition from Time-based PWS to DBS mode or from DBS to Time-based PWS mode.	SO#11	ATC shall be able to apply consistent and accurate DBS, TBS, PWS-A or WDS-A wake turbulence radar separation rules on final approach (encompassing interception) and landing, through operating under Distance-based modes (DBS, DB-PWS-A) and Time-based modes (TBS, TB-PWS-A, A-TB-WDS-Tw and A-TB-WDS-Xw), with the possibility to safely switch between a TB-mode and the corresponding DB-mode.

Safety Objective or Operational Hazard as per TB PWS SAR		Traceability to the corresponding Safety Objective or Operational Hazard as per current SAR	
ID	**Description**	**ID**	**Description**
SO#25	In Time-based PWS operations, ATC shall sequence and instruct aircraft to intercept the final approach path such as to establish and maintain applicable separation minima rule based on Time-based PWS indicators.	SO#25	In a given WT separation mode, ATC shall sequence and instruct aircraft to intercept the final approach path such as to establish and maintain applicable separation minima on final approach segment based on the displayed Target Distance Indicators corresponding to that separation mode.
SO#30	The Time-based PWS indicators shall be calculated to correctly and accurately represent the Time-based PWS -equivalent distance separation minima (surveillance and wake turbulence) for all traffic pairs, in all normal range of weather and operating conditions.	SO#30	The Target Distance Indicators shall be calculated and displayed to correctly and accurately represent the greatest constraint out of wake separation minima of the mode under consideration (for all traffic pairs and in the full range of weather and operating conditions pertinent for that mode), the MRS, the runway spacing or other spacing constraint.
SO#35	In advanced DBS operations (with indicator), ATC shall sequence and instruct aircraft to intercept the final approach path such as to establish and maintain applicable separation minima on approach based on DBS indicators.	SO#25	See last but one above.
SO#40	The DBS indicators shall represent the applicable separation minima (surveillance and wake turbulence) on approach.	SO#30	See last but one above.
SO#45	Flight Crew/Aircraft shall follow ATC instructions in order to correctly intercept the final approach path in Time-based PWS or in DBS mode.	SO#45	The design of the Separation Delivery Tool and associated operating procedures and practises shall not negatively impact Flight Crew/Aircraft who shall be able to follow ATC instructions in order to correctly intercept the final approach path in the mode under consideration.
SO#50	In Time-based PWS operations, ATC shall provide correct spacing minima delivery from final approach	SO#50	In a given WT separation mode, ATC shall provide correct spacing minima delivery from final approach path acquisition until landing based on separation indicators correctly computed for that separation mode.

Safety Objective or Operational Hazard as per TB PWS SAR		Traceability to the corresponding Safety Objective or Operational Hazard as per current SAR	
ID	**Description**	**ID**	**Description**
	path acquisition until landing based on Time-based PWS indicators.		
SO#55	In advanced DBS operations (with indicator), ATC shall provide correct spacing delivery from final approach path acquisition until landing based on DBS indicators.	SO#50	See above.
SO#60	Flight Crew/Aircraft shall follow ATC instructions during the final approach in order to ensure adequate separation with preceding and following aircraft in Time-based PWS or in DBS mode.	SO#60	ATC and Flight Crew/Aircraft shall ensure that the final approach path is flown whilst respecting the aircraft speed profile (unless instructed otherwise by ATC or airborne conditions require to initiate go around) in order to ensure correctness of the separation indicators.
New		SO#65	The runway spacing, or other spacing constraint shall be input to and accounted for the Separation Delivery Tool (in support of SO#30).
SO#70	ATC shall be alerted when the actual wind conditions on the approach Glide Slope differ significantly from the wind conditions used for the Time-based PWS computation.	SO#70	ATC shall be alerted when the actual wind conditions differ significantly from the wind conditions used for the TDIs computation (wind conditions monitoring alert): for the FTD -glideslope Headwind in TBS and TB-PWS-A modes, reference Total wind in A-TB-WDS-Tw and A-TB-WD-PWS-Tw modes, reference Crosswind in A-TB-WDS-Xw and A-TB-WD-PWS-Xw modes; for the ITD - Headwind in all modes.
SO#75	ATC shall be alerted when the aircraft speed varies significantly from the procedural airspeed and/or the stabilized approach speed used for the Time-based PWS computation.	SO#75	ATC shall be alerted when the aircraft speed varies significantly from the procedural airspeed and/or the stabilized approach speed used for the TDIs computation (speed conformance alert) in order to manage compression manually and, if in a TB-mode, apply distance-based WTC separation minima, for the affected aircraft.
SO#80	ATC shall maintain an updated arrival sequence order for Time-based PWS operation following a late change of lead aircraft in the sequence or a late change of aircraft runway intent or a go-around.	SO#80	ATC shall maintain an updated arrival sequence order following a late change of aircraft runway intent or a go-around.

Safety Objective or Operational Hazard as per TB PWS SAR		Traceability to the corresponding Safety Objective or Operational Hazard as per current SAR	
ID	**Description**	**ID**	**Description**
New		SO#81	ATC shall take into account, for the merging on to final approach, the notified approach procedural airspeed non-conformance issues and any notified employment of a slow or fast landing stabilisation speed to determine the additional spacing that is required to be set up behind the ITD indication.
SO#85	The applicable Time-based PWS separation shall be correctly updated in case of late change of landing runway.	SO#85	The Target Distance Indicators shall be correctly updated in case of late (not planned) change of landing runway.
TB_Hz#01 DB_Hz#01	Spacing conflict following ATC instruction during the final Approach interception.	Removed	Merged within Hz#01a below.
TB_Hz#01a DB_Hz#01a	Inadequate separation management of a spacing conflict following ATC instruction during the final Approach interception.	Hz#01a	Inadequate separation management of a pair of aircraft instructed by ATC to merge on the Final Approach interception.
TB_Hz#01b DB_Hz#01b	Fail to recover separation following inadequate separation management of a spacing conflict during the final Approach interception (following ATC instruction).	Hz#01b	Separation not being recovered following imminent infringement of A/C pair instructed by ATC to merge on the Final Approach interception.
TB_Hz#02 DB_Hz#02	Spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given.	Removed	Merged within Hz#02a below.
TB_Hz#02a DB_Hz#02a	Inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given.	Hz#02a	Inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach interception profile without ATC instruction given.

Safety Objective or Operational Hazard as per TB PWS SAR		Traceability to the corresponding Safety Objective or Operational Hazard as per current SAR	
ID	**Description**	**ID**	**Description**
TB_Hz#02b DB_Hz#02b	Fail to recover separation following inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given.	Hz#02b	Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach interception profile without ATC instruction given.
TB_Hz#03 DB_Hz#03	Spacing conflict following ATC instruction during the final approach.	Removed	Merged within Hz#03a below.
TB_Hz#03a DB_Hz#03a	Inadequate separation management of a spacing conflict following ATC instruction during the final approach.	Hz#03a	Inadequate separation management of an aircraft pair naturally catching-up as instructed by ATC on the Final Approach.
TB_Hz#03b DB_Hz#03b	Fail to recover separation following inadequate separation management of a spacing conflict following ATC instruction during the final approach.	Hz#03b	Separation not being recovered following imminent infringement by an aircraft pair instructed by ATC on the Final Approach.
TB_Hz#04 DB_Hz#04	Spacing conflict due to aircraft deviation from final approach profile without ATC instruction given.	Removed	Merged within Hz#04a below.
TB_Hz#04a DB_Hz#04a	Inadequate separation management of a spacing conflict due to aircraft deviation from final approach profile without ATC instruction given.	Hz#04a	Inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach profile without ATC instruction given.
TB_Hz#04b DB_Hz#04b	Fail to recover separation following inadequate separation management of a spacing conflict due to aircraft deviation from final approach profile without ATC instruction given.	Hz#04b	Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach profile without ATC instruction given.
New		Hz#05	One or multiple separation minima infringements due to undetected corruption of separation indicator.

Safety Objective or Operational Hazard as per TB PWS SAR		Traceability to the corresponding Safety Objective or Operational Hazard as per current SAR	
ID	**Description**	**ID**	**Description**
New		Hz#06	One or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft.
Hz#05	Separation minima infringement induced by ATC through inadequate selection & management of the separation mode (Time-based PWS, DBS with indication, DBS without indication).	Hz#07	One or multiple separation minima infringements induced by ATC through inadequate selection & management of a time-based separation mode (TBS, TB-PWS-A, TB-WDS-A or A-TB-WD-PWS).

Appendix F PJ.02.01 / PJ.02.02 / PJ.02.03 Pilots and ATCOs Workshop

A workshop with pilots from Air France and CDG ATCOs has taken place on the 28th of January 2019 on the Air France premises at CDG airport. The workshop was facilitated by SAF and HP experts from EUROCONTROL and it included APP and TWR ATCOs from DSNA, pilots from Air France, together with safety, human performance and concept experts from EUROCONTROL. The workshop helped clarifying remaining SAF/HP and concept questions for projects PJ.02.01, PJ.02.02 and PJ.02.03. Note only the results from PJ.02.01 and PJ.02.03 were kept in this appendix.

PJ	QUESTION	RATIONALE	COMMENTS:
PJ.02-01 PJ.02-03	1. Pilots do not conform to ATC clearances as they may not be comfortable with the reduced separations, e.g. pilots may reduce speed to ensure they have what they consider to be a safe spacing between themselves and the a/c ahead.	Clarify responsibilities between ATCOs and pilots for conformance to speed instructions. Would information campaigns ensure higher acceptability of procedures/ reduced separations?	Depends on confidence pilot vs ATCO. E.g. ATC London is perceived to be more precise than CdG (note that TBS tool-based is already implemented in London) In London the Pilot feels safer when the landing clearance is given only when RWY is safe (and not landing clearance anticipately instructed as in CdG)- according to the Pilots this seems to be the procedure in most airports but not in CdG. As a result, the pilots consider that information campaigns are paramount in order to gain trust and confidence in new procedures and related ATC instructions. Difficult for Heavy to maintain high speed till 4NM (risk for not able to adequately decelerate) –e.g. case of high headwind

			Difference between instructed speed (based on ground speed as perceived by ATCO) and the IAS ECTL: Note the ORD tool accounts for variability of speed profile for various a/c type via a computation buffer. The time to fly accounts for the wind conditions Regarding awareness of separation applicable on Final App, Pilots follow the ATC instructions (not possible to be familiar with the different separation minima applicable on airports around the world) and they consider that especially because of the complexity/diversity of new procedures it should remain the case (pilots shall trust and follow ATC instructions). The ATCOs present in the meeting agree with this approach.
PJ.02-01	2. What information would you require in case an airport is applying under certain conditions reduced wake separations, in addition to the AIP (no indication about actual WDS or DBS mode of operations)?	Flight crew are unaware of the transition or mode of operations DBS and WDS operation. They may ignore ATCOs instructions if they feel that the spacing is not appropriate given the mode of operation.	Pilots do not need much information on frequency Everything that is static becomes standard and should be published in AIP : MRS 2NM, S-PWS (e.g. RECAT) Need of information on ATIS regarding the differences from standard: reduced separation on Fin App WDS (conditional application) Note in CdG the Pilots may sometimes deviate from instructed speed (e.g. reduce speed below

			the instructed one) or published altitude restrictions (e.g. on STAR) That highlights the importance of information campaigns and change management with the introduction of new separation minima (in addition to AIP publication) For more awareness, in case the condition is active, this could be "highlighted" in the ATIS. Currently they do not have this info (e.g. London), but Pilots consider it would be an added value.
PJ.02-01 PJ.02-03	3. Do you require additional info. from the ATCOs, as compared to today`s operations, in order to continue to monitor and conform to safe separations? (e.g. a/c type in front etc.).	Identify info. requirements for pilots to allow them to accurately monitor WDS on approach and to request/take appropriate action in the event that they were concerned that wake separation is lost.	Not enough time/resources (e.g. R/T already busy enough) to perform such check, even in case a cockpit tool would be available.
PJ.02-01 PJ.02-03	4. Would you need a cockpit tool that indicates the applicable separation minima?	Pilots might not adhere to speed instructions and procedures on the FIN APP resulting in separation infringements.	No See above (that would increase Pilot workload) ATC would be in a better position to initiate & manage a Go around Meanwhile, such tool might be useful in case of high wind (involving significant difference of IAS vs ground speed)

PJ.02-01 PJ.02-03	5. Do you consider the need to double check separation values with ATCOs would increase, when applying reduced MRS/conditional separations?	Could WDS negatively impact the amount of R/T usage between pilots & ATCOs. → Validation activities show an acceptable level of R/T for ATCOs during hypothetical normal operating conditions (i.e. no questioning by Pilots)	Pilot will not perform such check (see points 1 and 3 above)
PJ.02-01 PJ.02-03	6. Is the responsibility of the pilots remaining unchanged?	In terms of monitoring and task requirements.	No changes identified.
PJ.02-01 PJ.02-03	7. Can the flight crew detect inappropriate ATC instructions?	Only gross WT separation error can be detected by Pilots in WDS; more efficient detection in PWS, as Pilots might be able to roughly appreciate WT separation of the their aircraft type behind the Leader→ **Weak mitigation** According to the ATCOs this is not the responsibility of the pilots, therefore they do not consider this as a solid and effective mitigation.	Pilots share the same view as the one described in the ATC workshop, i.e. they confirm that checking applicable separation minima is not their responsibility and they have neither the means nor the workload resources to ensure that The pilots. They consider ATCOs should have enough information to correctly instruct them, referring again to the importance of trust between the 2 actors. (see points 1 and 3 above)
PJ.02-01 PJ.02-03	8. Is there a possibility for the pilot/aircraft to accelerate at interception or on the final approach path without ATCO instruction? (due to a pilot error or aircraft malfunction)	Wake FAP: WE11.2 MAC FAP: MB9.2	Not relevant. Sometimes the aircraft might increase speed (e.g. increased speed due to the high weight) but Pilot monitors and corrects

PJ.02-01 PJ.02-03	9. Is there a need to revise phraseology?	E.g. the phraseology is clear for communicating between ATCOs and pilots in regard to their position in relation to the a/c ahead on final approach (confirm to follower a/c their position with respect to the a/c ahead on final approach). How to inform the reduced MRS? Slow reaction times for 2nm MRS due to pilot reluctance require any change in phraseology needed for a fast input? RTS results: The ATCOs consider the phraseology is clear. ➔ a/c type to be specified upon first contact with ATC? (as a mitigation to an erroneous a/c type in PLN)	Again Pilots recall their recommendation for removing the early landing clearance at CdG, in order to improve Pilots confidence. This is a requirement in order to enable the implementation of the reduced separations, in order to increase the Pilots confidence in ATC instructions (that is misleading for the Pilots, they have the wrong feeling that responsibility for RWY separation is somehow delegated to them) Additionally, the early landing clearance is not on the safe side because in case of frequency occupancy or interference or radio failure, the a/c will proceed on landing whilst the RWY is not clear of traffic. In the USA they use as well “clear to land behind” in case the runway was not vacated yet. The current ATC procedures (in CdG) will need to be changed, besides the early landing clearance, also for phraseology: no more need to inform about ahead aircraft type and distance – that is no more feasible and useful with the complex new PWS and WDS separation minima. RRSM (RWY Reduced Separation Minima) – require a second TWR ATCO dedicated to monitoring & instructing Go around (in case the

			2400 m wrt to the Leader are not met by the time the Follower attempts landing). Pilots need to listen to both TWR frequencies (applies in certain US airports, both single RWY and CSPR) Pilots feel there would not be additional workload if they are required to declare the a/c type at first radio contact (instead of the currently "super" or "Heavy") On ATCO side: to analyse whether at INI or ITM first contact (in order to minimize the length of that message). Nonetheless, both pilots and ATCOs mentioned that the exchange with the INI is already quite heavy. The FPL inconsistency might be 1 – 2 per year at CdG (to check with the CdG Safety manager & data collection) In London the a/c reporting became mandatory with the application of TBS (**Question to NATS**: how is this a/c type provided: full name or not – significant for certain PWS pairs e.g. B777 /200 with 60m wing span and /300ER with 64m wing span – the former called B777/2 , the latter B777/W). Alternatively, the PWS table might be simplified (conservatively group the B777/2 under the B777/W). That would be justified due to the ROT as well. ***ANSWER***

			NATS: *The a/c type is provided in detail by Heathrow (e.g. B77W) – beside the fact that different a/c types are separated differently in terms of wake, it is important to state the type because different types also have different stabilisation speeds.* In the US, in certain airports a 2nd frequency with a different ATCO needs to be monitored by pilots on final approach, in case a go-around is required. This applies for very complex environments. Ideally, the introduction of the Mode-S datalink would resolve this issue in the future.
PJ.02-01 PJ.02-03	10. TCAS TA nuisance?	Identify parameters under which aircrew would become sufficiently concerned at a perceived loss of separation that they take unilateral action?	To check whether the reduced separations would involve TCAS nuisance alerts Pilots will give priority to ATCO on Final Approach Pilot suggestion: To arrange the ORD such as to avoid TCAS nuisance alerts, but not change the current TCAS settings (in order to preserve the Pilot confidence in TCAS; note TCAS is very useful at certain airports in order to e.g. at Nice to secure separation against intruding helicopters. Note TA received till ground. RA inhibited below 1000ft. (PJ.02-03 is currently

			checking via FTS that RA are not triggered with 2NM MRS; on CSPR there might be a issue)
PJ.02-01	11. In case of strong crosswind the wake separations could be completely removed. This means that MRS or ROT will apply with a final spacing of about 2.5/3.0 NM behind very heavy aircraft. Provided that enough briefing and concept awareness is provided to Pilots, Airlines other AU, would they accept these separations (e.g. fly with an A320 at 3.0 NM behind an A388, with 13knots crosswind)?	Already RECAT-EU had 2NM reductions for A388-Upper Medium and Lower Heavy-Upper Medium pairs compared to ICAO. However, with RECAT-EU A388-A320 the wake separation was still 5 NM. With WDS-XW we could have 3.0 NM for the same pair, so even with no wake risk there is the ''perception'' from the cockpit of being very close to the leader aircraft and with challenging wind conditions due to the strong crosswind.	Covered above (see points 1 and 3)
PJ.02-01 Depart.	12. How often do Pilots question the time of the take-off instruction wrt WT considerations?	Departures	Current Pilot procedure (AF SOPS compliant with ICAO): Pilot shall check the time separation with previous take-off, in complement to the ATC instruction for take-off (prior to that Pilot requests to ATCO the previous aircraft type, if necessary). For the time being the regulation requires them to double-check. That needs adaptation when D-PWS and D-WDS will be introduced (safety question: the safety barrier represented by Pilot crosscheck will disappear; note that unlike for Arrivals, the aircraft might face wake encounter as soon as it rotates after take-off i.e. no room for ATCO to monitor/recover WT separation)

PJ.02-01 Depart.	13. Prior to push-back (or at the latest before line up) the pilot is either instructed the SID by Ground ATCO or ask confirmation of Ground ATCO for the SID value that has been automatically entered by AO FPL system → always asking/ crosschecking?	Do pilots always ask confirmation for the automatically entered SID? Is this within the required responsibilities? Are you aware of any occurrences of SID mismatch between the ATC expected and the FMS SID?	Pilots do debriefing and check SID that is input in FMS. If they do not receive any SID info with the clearance, they consider the info in the FMS is correct- they do not double check. Sometimes there is a last minute change of the SID between off-block and take-off time (not frequent, because safety critical and time consuming; new SID involves additional onboard checking & computation). The same for RWY entry point
PJ.02-01 Depart	14. Does the pilot switch on the auto-pilot in the stable climb phase before the first SID turn? (flown manually over the take-off roll, rotation, the unstable climb phase and the transition to the stable climb phase)	Question related to the Departures WDS Crosswind concept concerning the navigation performance (which links to a certain deviation from the initial common departure path).	Switch on the auto-pilot at minimum 100ft and at least 5 sec after lift-off (in general it might be as early as e.g. 400ft or as late as e.g. 10000ft) Lateral deviation is not significantly different between whether on Manual (Flight Director) or Autopilot mode Only some slight pitch deviation The climb profile depends on weight, noise abatement procedures (e.g. NADP1 climb first 1300ft then retract flaps at 3000ft). But same procedure applicable to all aircraft departing from same RWY Lateral deviation might arise due to engine failure, strong crosswind, Pilot experience (young)

PJ.02-01 PJ.02-03	15. What other possible impact of reduced separations is envisaged by pilots in terms regarding workload; situational awareness, task performance and task distribution?	Identify impact of any such changes to flight deck procedures on pilot cognitive and physical demand. e.g. do you envisage an increase in workload due to the decreased buffer (go-around procedures, speed adjustment etc)	TCAS TA might trigger also during initial departure. Risk for reducing too close to the minimum speed (stall). There are three phases, each of them with specific rate of climb In case of separation on level (need to stop the climb to prevent MRS separation infringement- mainly following a take-off clearance given too soon), potential risk for aircraft because that would involve need for thrust reduction. Not more frequent need for stopping the climb in case of the application of reduced WT separation. Instructing lateral deviation to prevent separation infringement is rare. Normally not allowed below MSA, however that rule might be infringed in critical situations, at airports with low terrain/no major obstacles.

Appendix G Risk Classification Schemes for relevant accident-incident types

Appendix H covers the following Concepts Solutions:

- Accident-incident types for Arrivals and Departures Concepts Solutions in Section G.1
- Accident-incident types for Departures Concepts Solutions in Section G.2

G.1 Accident-Incident Types for Arrivals and Departures Concepts Solutions

Severity Class	Hazardous situation	Operational Effect	MTFoO [per movt.]
RWY-SC1	A situation where an aircraft has come into physical contact with another object on the runway	Accident - Runway Collision (RF3)	1e-8
RWY-SC2a	A situation where an imminent runway collision was not mitigated by pilot/driver or aircraft system collision avoidance but for which geometry has prevented physical contact.	Near Runway Collision (RF3a)	1e-7
RWY-SC2b	A situation where pilot/driver runway collision avoidance prevents a near runway collision	Imminent runway collision (RP1)	1e-6
RWY-SC3	A situation where an encounter between a/c, vehicle or person on the runway and one a/c approaching occurs but ATC runway Collision avoidance prevents it to become an Imminent Runway Collision.	Runway Conflict (RP2)	1e-5
RWY-SC4	A situation where a runway incursion due to unauthorized entry/exit is concurrent with another aircraft awaiting clearance to use the runway but ATC runway conflict prevention prevents this situation to become a runway conflict	Runway incursion (RP3)	1e-4
RWY-SC5	A situation where runway monitoring prevents a runway incursion	Imminent Runway incursion (RP4)	1e-2

Table 17: Risk Classification Scheme for Runway Collision for the PJ.02.01 Arrivals and Departures Concepts Solutions

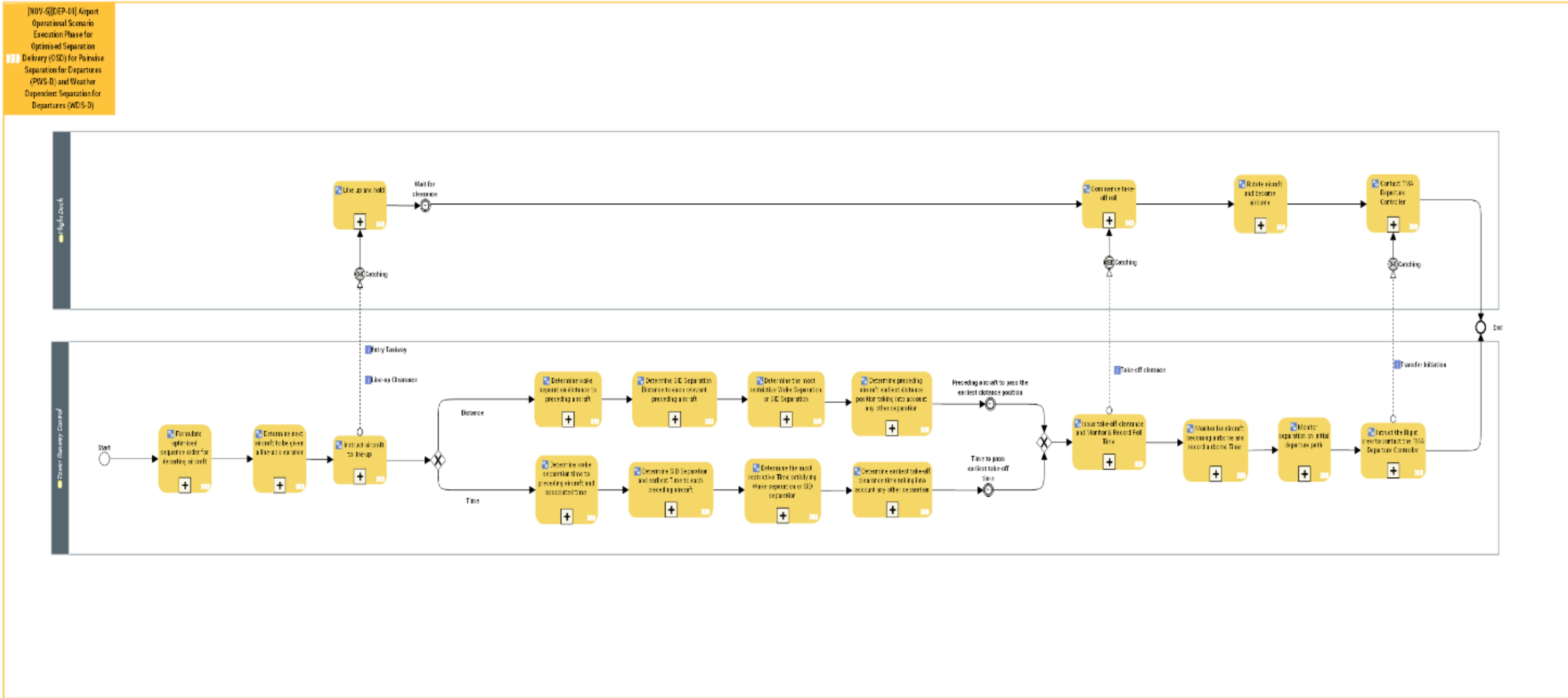
G.2 Accident-Incident Types for Departures Concepts Solutions

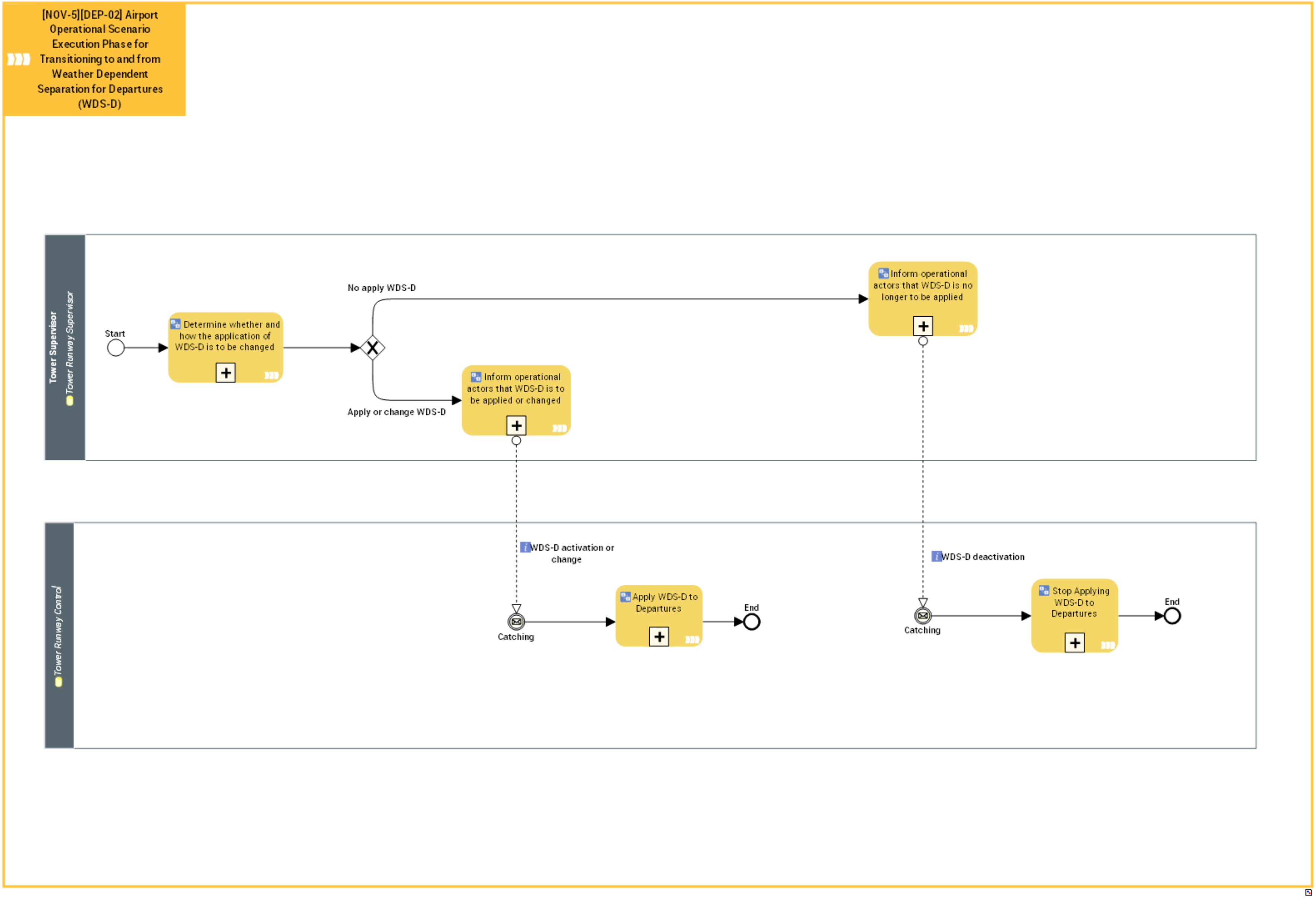
Wake AIM to be inserted here when finalised by ECTL

Appendix H EATMA Models for arrivals and departures

H.1 NOV-5

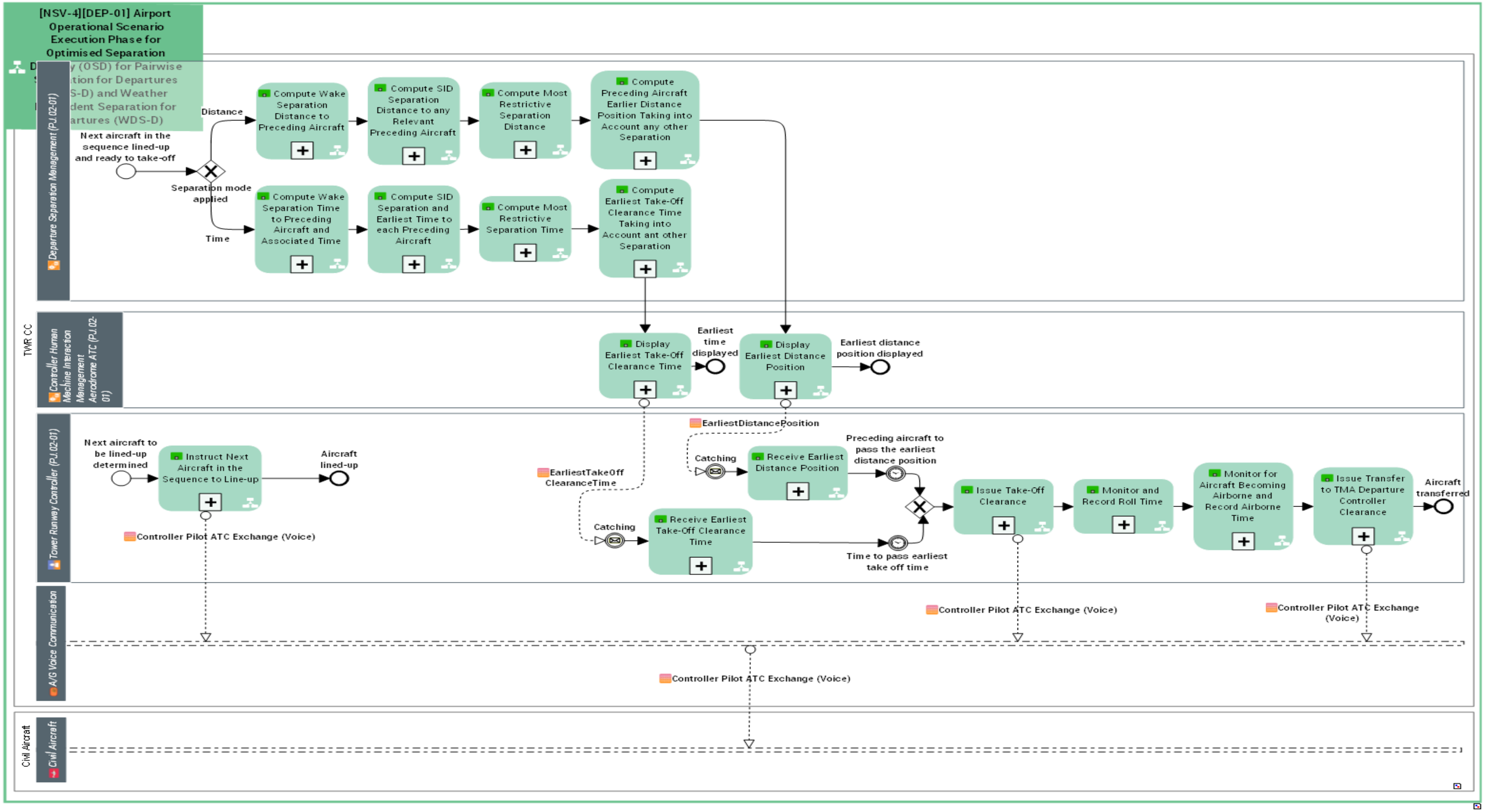
H.1.1 Departures

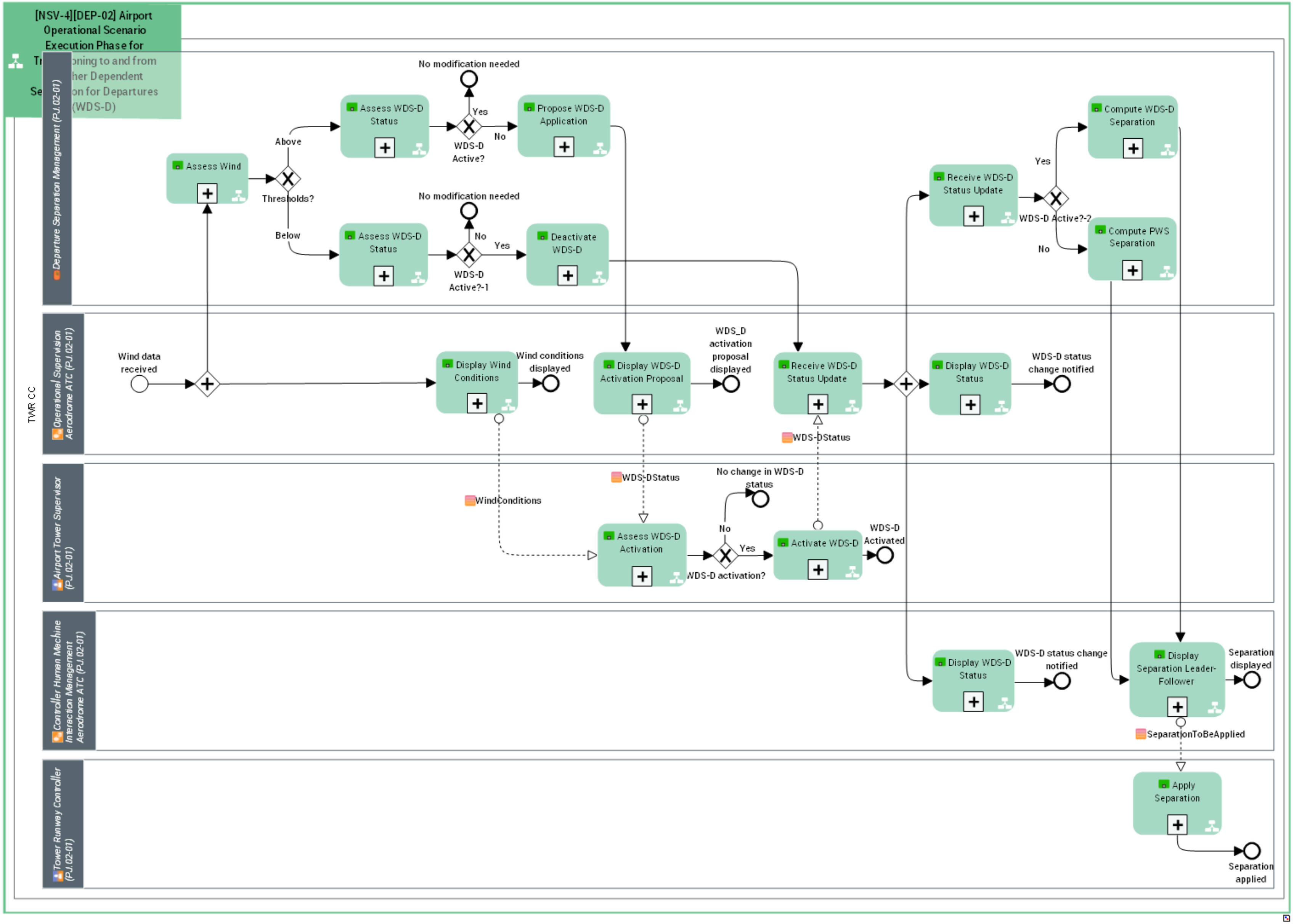



[NOV-5][DEP-02] Airport Operational Scenario Execution Phase for Transitioning to and from Weather Dependent Separation for Departures (WDS-D)
Tower Supervisor
Tower Runway Supervisor
Start
Determine whether and how the application of WDS-D is to be changed
No apply WDS-D
Apply or change WDS-D
Inform operational actors that WDS-D is no longer to be applied
Inform operational actors that WDS-D is to be applied or changed
Tower Runway Control
WDS-D activation or change
WDS-D deactivation
Catching
Apply WDS-D to Departures
End
Catching
Stop Applying WDS-D to Departures
End

H.2 NSV-4

H.2.1 Departures




[NSV-4][DEP-02] Airport Operational Scenario Execution Phase for Transitioning to and from Weather Dependent Separation for Departures (WDS-D)
TWR CC
Departure Separation Management (PJ.02-01)
Operational Supervision Aerodrome ATC (PJ.02-01)
Airport Tower Supervisor (PJ.02-01)
Controller Human Machine Interaction Management Aerodrome ATC (PJ.02-01)
Tower Runway Controller (PJ.02-01)
Wind data received
Assess Wind
Thresholds?
Above
Below
Assess WDS-D Status
WDS-D Active?
No modification needed
Yes
No
Propose WDS-D Application
WDS-D Active?-1
Deactivate WDS-D
Display Wind Conditions
Wind conditions displayed
WindConditions
Display WDS-D Activation Proposal
WDS_D activation proposal displayed
WDS-DStatus
Assess WDS-D Activation
WDS-D activation?
No change in WDS-D status
Activate WDS-D
WDS-D Activated
Receive WDS-D Status Update
WDS-D Active?-2
Compute WDS-D Separation
Compute PWS Separation
Display WDS-D Status
WDS-D status change notified
Display Separation Leader-Follower
Separation displayed
SeparationToBeApplied
Apply Separation
Separation applied

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